WHEN DID BACTERIA APPEAR?

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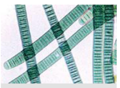
Changing age like a fading starlet

The bacteria family tree may be facing some changes due to the recent work of an evolutionary biologist at Washington University in St. Louis. And that may change our understanding of when bacteria and oxygen first appeared on earth. Carrine Blank, Ph.D., assistant professor of earth and planetary sciences in Arts & Sciences, has found that the currently accepted dates for the appearance of oxygen-producing bacteria and sulfur-producing bacteria on the early earth are not correct. She believes that these bacteria appeared on earth much later than is now believed. "It sets up a new framework of new hypotheses to be tested," she says of the new findings.

Blank's findings appear in the February 2004 issue of *Geobiology*.



Cyanobacteria (above) became the first microbes to produce oxygen by photosynthesis.
Credit: UC Berkeley

As an evolutionary biologist, Blank said she is, "really interested in the view of the earth and microorganisms and how they come together." She uses elements of biology and geology to understand how the earth and its inhabitants co-evolved.

It is known that earth's earliest organisms were thermophilic, or able to dwell in hot environments. These organisms engaged in chemotropic metabolism — they converted inorganic substances, such as sulfur and carbon, into energy to live. This process is similar to how we use food, water, and oxygen to generate energy.

The predecessors of modern bacteria differ in much more than age. The Archean era, which records the first billion years of Earth's geologic history, ended 2.5 billion years ago. It was at this point that the earth's biosphere must have changed and the atmospheric temperature reached 72 degrees Celsius. This is the maximum temperature at which photosynthesis can take place. Near the end of this era, about 2.7 to 2.9 billion years ago, according to Blank, stromatolites, organisms of the group Bacteria that use photosynthesis to create energy without producing oxygen, first appeared.

Microbial mat producing oxygen through photosynthesis.
Credit: UTA Department of Geology

Blank's approach is to understand organisms by determining what materials they metabolized. Using genetic analysis, she looked at the early rock record to determine when the first substantial amounts of oxygen and sulfur appeared on earth. While she mapped the evolution of several bacteria, Blank believes the dating of the emergence of cyanobacteria – bacteria that use light, water, and carbon dioxide to produce oxygen and biomass – is most crucial.

Blank explains that the precise dating of the emergence of cyanobacteria is so important because, "once you have oxygen, you have a whole new biosphere."

Cyanobacteria are the only bacteria that produce oxygen as a byproduct of their metabolism. It was not until these creatures appeared on earth that oxygen was found in the earth's atmosphere. "No other photosynthetic microbe is as efficient," said Blank.

Scientists initially believed that cyanobacteria were present on earth as early as 2.7 billion years ago. Blank has challenged this view by presenting dates she feels give a more accurate chronology of the evolution of cyanobacteria and other bacteria lineages in general. With this data, she was also able to better pinpoint the emergence of other organisms. She has determined that cyanobacteria can only be dated to as far back as 2.3 billion years ago.

Genetic Analysis

Blank, an assistant professor of geomicrobiology in the Department of Earth & Planetary Sciences at Washington University in St. Louis, used an evolutionary analysis technique pioneered by Carl Woese, Ph.D., professor emeritus of microbiology at the University of Illinois, to construct evolutionary trees of the bacteria.

A 3D structure of RNA.
Credit: SpaceDaily

Woese pioneered the technique of using ribosomal RNA genes to make the first family trees of microbes. He was also the first person to distinguish between the two domains of microbial life – Bacteria and Archaea. These Archaea are not related to the Archaan era mentioned previously.

Using many genes that are common to all these creatures, Blank was able to construct evolutionary trees with better chronological accuracy than those produced previously, which used fewer genes. Based on the extent of the changes, Blank could determine how distant the organism was from the last common ancestor.

Blank obtained her gene sequences from whole genome sequences that are available in GenBank, a public database hosted by the National Institutes of Health. This provided large amounts of data to enhance the evolutionary trees.

From this data, Blank's diagrams show how different types of metabolism evolved. For example, her data show that oxygen-producing organisms evolved from organisms that metabolize sulfur. Her diagrams are based on the idea that evolution is a branching process in which a common ancestor's descendants slowly diverged into a few organisms, each of which diverged into a few more, and so on until the multitude of the organisms we see today developed.

The "molecular clock" method assumes that changes in DNA accumulate at approximately constant rates over time.
Credit: www.lbl.gov

These family trees also show which organism's genes are least like the last common ancestor's genes. These organisms will be more toward the tips of the lines, while those with genes that closely resemble the genes of the last common ancestor will be closer to the center of the tree. "The tips of the tree use oxygen, so they first originated the use of oxygen," explained Blank.

Opening New Areas of Study

While Blank sites evidence in the geologic record as the reason her findings are more accurate than previous ones, she does acknowledge that there is one piece of evidence that may disprove her proposed chronology.

Lipid markers, similar to fossils in the rocks in that they provide evidence of species' presence in the past, in the rock record indicate that cyanobacteria may have been present as early as 2.7 billion years ago. But, because ancient lipid research just started in 1999, this evidence is still being examined.

Blank's research also brings up the question of how nuclei functioned for a billion years before mitochondria appeared. Mitochondria are the powerhouse of the cell; they process resources and convert them into cellular energy. While mapping genomes for her research, Blank noticed that prior to 2.2 billion years ago, mitochondria were not present in eukaryotic cells – more highly developed cells that contain mitochondria and other organelles in a membrane. "This is an intriguing insight into eukaryote evolution," said Blank.

• ***based on Washington University, St. Louis report***

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