**Carl Woese’s Discovery**

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 Photo by Steve Kagan

Carl Woese, a biophysicist and evolutionary microbiologist, in his laboratory in 1996 at the University of Illinois, Urbana.

IT'S clear to me that if you wiped all multicellular life forms off the face of the earth, microbial life might shift a tiny bit,'' said Dr. Carl R. Woese, an evolutionary microbiologist who has devoted his life to convincing people, including other scientists, that microorganisms are in charge of nearly everything. ''If microbial life were to disappear, that would be it -- instant death for the planet.''

Sitting in his cluttered office at the University of Illinois in Urbana, Dr. Woese (pronounced ''woes'') put his feet up on his desk and tried to explain the nature of his devotion to the proposition that microorganisms dominate the globe.

Dr. Woese, 68, single-handedly discovered a third branch of life called Archaea, a microbial form that is turning up in great quantities around the globe. He rewrote the tree of life, paring it from five kingdoms to three domains, with the human species sitting at the tip of one. And he pioneered the application of Darwinian thought to microbiology -- a marriage of disciplines that is revolutionizing the way scientists view the world and how humans fit in.



At first Dr. Woese's division of life was controversial, but it gradually gained wide acceptance. When the complete genome of an archaeon organism was decoded for the first time, a landmark scientific step, Dr. Craig Venter, who decoded the genome, argued that the work put beyond doubt the question of whether the Archaea were a separate domain.

The problem with appreciating microbes is that they are invisible, Dr. Woese said. But they make up at least 80 percent or perhaps even 90 percent of the biomass. In terms of living protoplasm, he said, microbes outweigh all plants, insects and animals.

''If you took all the fish and whales out of the ocean, it would not make a dent in the amount of living matter in the oceans,'' Dr. Woese said.

Human beings like to think that biodiversity is represented by the rain forest, in the insects, plant life and larger animals that people can see and understand, Dr. Woese said.

But he argues that true biodiversity is found in microbes, which have been evolving for at least 3.5 billion years. On this time scale, plants and animals are not far apart on the evolutionary tree. Humans and fungi are practically on the same branch. The microbial world established the biosphere and sustains it.

Dr. Woese said bacteria were responsible for all the oxygen on the planet, via chloroplasts, which were once free-living bacteria and now reside in plants. They recycle carbon with infinite variation, regulate gases in the atmosphere and oversee mineral deposition. They invented biochemistry. Humans are merely jerry-built embodiments of microbial engineering, Dr. Woese said.

But that is not all. Dr. Woese leaned forward and described his quest of the last 30 years. The microbial world contains a detailed record of human evolutionary history, he said. The story of how life arose from a pre-biotic soup to the complex webs of life today is written in the genomic sequences of microbes. Sequences are the ancient texts. Humans just have to learn how to read them.

To decipher them, Dr. Woese has applied modern evolutionary biology, a fusion of Darwinian theory and molecular genetics, to the study of microbes. Dr. Woese says it has been a solitary task, since most microbiologists are not interested in evolution and most evolutionary biologists care little about microbes. ''I've been pretty much ignored,'' he said.

Actually, Dr. Woese has not been ignored by mainstream biologists, although some, like the eminent Harvard zoologist Ernst Mayr, feel that he has gone too far in his reclassification of life and emphasis on microbes. ''Woese would put dinosaurs and birds together,'' Dr. Mayr said in a telephone interview. ''While birds derived from something like dinosaurs, they have become so different that they should be recognized as different taxa in their own right.''

Others are in awe. ''If you pick up any biology textbook and look at the people who have been remembered in the past 100 years, you will see names like Darwin and Mendel,'' said Dr. Mitchell Sogin, an evolutionary microbiologist at the Woods Hole Marine Biological Laboratory on Cape Cod. ''Tomorrow's biology textbooks will have names like Watson and Crick and Carl Woese. He works on the big picture instead of the little details.''

Educated at Amherst College and Yale University, Dr. Woese studied biophysics. This, he said, kept him from being indoctrinated by the reigning paradigm of microbiology in the early 1960's. At the time, he said, most microbiologists thought that sequencing microbial genes was impossible, even though there was a robust evolving technology for sequencing proteins and DNA from the mid-1950's on. Compared with today's techniques, it was primitive and laborious but it laid the groundwork for modern biotechnology.

A deeper problem was that even the microbiologists and bacteriologists who studied microbes for a living tended to be deceived by their morphology, or shape, Dr. Woese said. Most microbes really do look alike. There are big rods, little rods, big spheres, little spheres, spirals and a few other shapes. But the deep diversity of microorganisms is not evident on the surface.

Furthermore, most microorganisms cannot be cultured in the laboratory, Dr. Woese said. They are intrinsically interdependent and refuse to grow in a laboratory dish.

But for microbial ecologists, what could be cultured was the basis of their conception of what existed, he said. ''This is exactly like learning about animals from visiting zoos,'' he said. ''Their natural representation and behaviors are completely distorted.''

Finally, biologists had a dogmatic belief that life falls into five kingdoms (animals, plants, fungi, protozoa and bacteria). The sheer dominance of the microbial world was ignored, even though there were many clues to its existence.

''I knew that to go after the deep evolutionary problems in biology, I had to have a universal phylogeny -- a family tree -- of the microbial world,'' Dr. Woese said. ''I was particularly interested in how nucleic acids talk to amino acids, in how early cells managed to translate this information.

Using a painstaking method for sequencing genetic material, Dr. Woese spent 10 years staring at patterns of microbial nucleic acids. In the beginning, he said, it took a year to do one bacterium.

Dr. Woese pioneered the use of ribosomal RNA, a relatively abundant nucleic acid that is found in all life forms. It is a yardstick for finding out the evolutionary history of cellular organisms. The more alike their ribosomal RNA sequences, the more closely they are related.

''After a time you get a feel for the relationships among these organisms,'' he said. At the time, all organisms were classified under two groups: Prokaryotes and Eukaryotes. Prokaryotes have no nucleus and tend to show one pattern. Eukaryotes (cells with nuclei) have a different pattern.

In June 1976, Dr. Woese encountered a pattern he had never seen before. It was from a microbe that produces methane. ''I was stunned,'' he said.

After looking at a few other microbes that make their living in a similar manner, Dr. Woese realized that he had found a third domain of life. He called it Archaea.

Before Woese’s discovery, these organisms had been grouped together with Bacteria under the “Prokaryotes” because both types of organisms lack nuclei. Looking at the ribosomal RNAs of these organisms, however, revealed that they were very different. Actually, Archaea are now known to be more closely related to Eukaryotes (like humans, plants and fungi) than to Bacteria.

Most scientists now follow Dr. Woese and classify life into three domains: Bacteria, Archaea, and Eukarya. These divisions represent profoundly different lines of evolution that may be rooted in a common ancestor.

An organism that is close to the very first ''cell'' could still be around or it could be extinct, Dr. Woese said. No one knows.

Dr. Woese said he was helped in his continuing exploration of the micro-wilderness by Dr. Norman Pace, a colleague who is now at the University of Colorado in Boulder. Dr. Woese recalled: ''One day Norm said to me, 'Carl, you don't need to culture microorganisms. You can pull out single genes and build evolutionary trees from that information.' ''

The ability to extract millions of genes from a soil sample, apply a probe and pull out the ribosomal RNA allowed for the discovery of new microbial species.

Using Dr. Pace's methods and others developed in the 1980's and in the decades to follow, researchers can identify new microbes in a few days. They went to exotic locales -- hot springs, active volcanoes, deep-sea vents, Antarctic ice packs -- to find ''bugs.''

The microbial tree of life had fewer than 500 species in 1991, Dr. Woese said. It now has more than 5,000 species. And that, Dr. Woese said, is the tip of the iceberg.

People are beginning to pay attention to the microbial world. Surprises turn up every week. Every time an assay is made, new microbes are found. Those thought to live in only extreme environments, like boiling waters in Yellowstone, have relatives found in temperate oceans where they make up 50 percent of the microbial life. No one knows what they are doing there—that is to say, not yet.

**References**

* Article adapted from:
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	+ Yardley, W. (December 2012). Carl Woese Dies at 84; Discovered life’s ‘Third Domain’. *New York Times.* Retrieved from: <http://www.nytimes.com/2013/01/01/science/carl-woese-dies-discovered-lifes-third-domain.html>

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**Reading Guide**

1. Before Woese’s techniques, what problems did microbiologists encounter when classifying microbes?
2. Describe the new method Carl Woese used to determine the phylogeny of microbes.
3. What discovery did his new methods and data lead him to?
4. How was this new finding received by the scientific community? In your explanation, include immediate and long term reactions.
5. Why did the scientific community respond this way?
6. How did Woese’s finding affect the world of microbiology? Provide examples.
7. What role did the advancement of technology play in the progress of microbiology research?
8. According to Carl Woese, as described in this article, why is it important to conduct more research to learn about the diversity of microbes? Provide examples.