

Carl Woese (1928–2012)

Carl Richard Woese died due to complications of pancreatic cancer at his residence in Urbana, Illinois on 30 December 2012. He was regarded as a ‘revolutionary’ who overturned the century-old dogma and proposed *Archaea* as the third main branch of the evolutionary tree of life.

Woese was born in Syracuse, New York, USA on 15 July 1928. After earning his Bachelor’s degree from Amherst College in Mathematics and Physics, he obtained PhD in Biophysics from Yale University. Subsequently, he studied medicine at the University of Rochester and after a brief stay as a biophysicist at General Electric Research Laboratory, he joined University of Illinois (UI) as a faculty in microbiology in 1964. He continued to work there till his death.

His introduction with the microbial world came through his postdoctoral work at Yale, where he studied the effect of different physical conditions on spore germination. Amongst these, one of the parameters he studied was nucleic acid metabolism during spore germination. This could be regarded as the starting point of his association with ribosomal RNA and microbial taxonomy. He published his first paper in *Nature* on comparison of ribonucleic acid fractions from microorganisms with different DNA composition. Later on, he published a series of papers on the molecular basis, universality, order, nature and evolution of the genetic code that proved his growing interest in prokaryotic evolution.

In those days, plant and animal phylogenies were derived from the morphological characters, but bacteria were too simple and offered very few morphological characters for such analysis. There were some attempts to use physiological characters for this purpose, but the approach had severe limitations. C. B. Van Niel and Roger Stanier understood this limitation and concluded that a phylogenetic ordering of bacteria is just not possible. Woese, a physicist by training, decided to address this problem using his knowledge of physics and his belief that ‘the world has deep and simple principles’. In a letter written to Francis Crick dated 24 June 1969, he proposed the idea of using the ‘internal fossil record’ of a cell, the primary structure of genes to

understand evolution. He knew that ribosomal RNAs exist in all bacteria in large quantities, are easy to extract and are conserved. All these made them the best recorders of the evolutionary history of life. He used the labour-intensive and cumbersome technique of ‘oligonucleotide cataloguing’ to decipher the relationship between the rRNA sequences. In 1972, he published his first paper on structural homology between 16S rRNA



of *Bacillus megatarium* and *Escherichia coli* by oligonucleotide cataloguing. This was followed by a series of publications on phylogeny of *Aerobacter*, blue-green algae, *Pasterurella (Yersinia) pestis*, photosynthetic bacteria, *Clostridia* and also intracellular organelles like mitochondria and chloroplasts.

Woese was instrumental in changing the view of the living world through his work. In the first of his revolutionary papers in *PNAS* published in October 1977, Woese suggested that methanogens are a ‘coherent phylogenetic group but they are quite distinct from other bacteria as well’. In the November 1977 paper, he made the proposal that living systems represent three lines of decent: (i) eubacteria, comprising all typical bacteria, (ii) archaeobacteria, comprising methanogenic bacteria and (iii) ukaryotes, now represented in the cytoplasmic component of eukaryotic cells. He then published several papers describing and revising phylogeny of all the important groups of bacteria and archaea. However, the scientific community was skeptical about this discovery and found it difficult to believe that archaea are not bacteria. For almost two decades, he was ridiculed for his ideas. In May 1997, the *Science* magazine carried an article terming him a ‘scarred revolutionary’. For his contri-

bution to microbiology, medicine and biology, *Nature* had endorsed Carl Woese for the Nobel Prize, but he could never make it.

Since the last decade of the 20th century, the scientific community began to realize the impact of his contribution. It is now realized that it has consequences that are far beyond proposal of archaea as the third domain of life or revamping of microbial taxonomy. When coupled with PCR and DNA sequencing, the power of 16S rRNA gene as a taxonomic marker yielded a tool to understand the vast majority of bacteria that could not be cultivated in the laboratory, giving us better understanding of ecosystems and their functioning. This includes the human body where microbiome is regarded as an important ‘organ’ and fluctuation in its composition is now believed to be associated with almost every disorder, including obesity, cardiovascular diseases, diabetes, many disorders of the gastrointestinal tract and even behaviour. All the buzz words of modern-day microbiology, genomics, metagenomics and mega projects like HMP, MetaHIT and Terragenome have their roots in the discovery of Carl Woese.

Although his contributions were not favourably regarded by the Nobel Committee, Woese received many other prestigious awards. He was also an elected member of the National Academy of Sciences, USA. He was associated with University of Illinois’s Institute of Genome Biology, of which he was a founding member. Woese was recently awarded a grant from NASA to study origin of life. With his death, not only has UI, but the scientific community has lost one of the most significant biologists. In the words of Nigel Goldenfeld a long-time colleague, ‘wide ranging and practical implications of his work on microbiology, ecology and even medicine are still to be worked out’.

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