From Woese to *Wired*

The unexpected payoffs of basic research

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Fundamental observations about nature sometimes take a circuitous and utterly unpredictable course from bright idea to demonstrably practical impact. The tale of how Carl Woese’s basic insights about microbial diversity eventually contributed to the emergence of a new field of science with numerous potential applications is just such a story.

In a scientific and political climate where deliverables, return-on-investment, and translation are all too often promoted as the best metrics of good science, it is important and instructive to highlight examples of the circuitous and utterly unpredictable course often traced between bright idea and demonstrably practical impact. Such stories are important—for scientists who believe passionately in the value of basic research, for scientist volunteers who are called upon to frame policy issues, for policymakers whose decisions influence allocation of funds, for funding agencies who judge the relative merit of research proposals, and for the public who will win or lose depending on how wisely research funds are allocated. And so, the story of how the work of Carl Woese gained acceptance and, eventually, practical application, in ways that could never have been anticipated is a story worth telling.

In 1977, Woese demonstrated that the 16S rRNA gene could be used to illuminate the evolutionary relationships among bacteria. His critical insight led to a remarkable discovery: the identification of Archaea as an evolutionarily distinct kingdom. Even in the microbiology world, Woese’s conclusions were not immediately accepted. Certainly by no definition, did these stunning discoveries about the diversity of microbial life, or even the discovery of a previously unrecognized biological domain, jump out as “practical,” “clinically relevant,” or potentially “translatable.” Gradually, however, Woese’s tree gained increasing acceptance and the gene it was based on began to be used not only for evolutionary studies, but also as a probe for the composition of complex microbial communities—in other words, to take a census of “who’s there.” This would eventually have significant practical implications.

PCR-based surveys of the 16S rRNA gene in mixed microbial communities revealed staggering diversity in virtually all environments. It was soon recognized, however, that surveys alone would not reveal what microbial communities could do or how they assembled, persisted, and changed over time. A collection of approaches that came to be called “metagenomics” aimed to tackle these more complicated questions. Metagenomic studies were emerging from disconnected branches of the research world—marine biology, medicine, soil science, ecology, and evolutionary biology, to name a few, and these early studies were revealing complex, distinct mixtures of microbes in every environment sampled, including the soil, ocean, toxic waste sites, termite guts, inside the human mouth, and more. Could, and should, these significant yet fragmented efforts be made into a coherent new science?

Enter Jim Tiedje, a microbial ecologist from Michigan State University, who in 2005 was serving on the Board on Life Sciences of the National Research Council (NRC), the operating arm of the National Academy of Sciences (NAS). The NAS was established in 1863 by President Abraham Lincoln, with a mandate to “investigate, examine, experiment, and report upon any subject of science or art whenever called upon to do so by any department of the government.” NRC boards convene top scientists, engineers, and other experts to digest vast amounts of primary information, and prepare consensus reports that explain how current scientific understanding underpins their recommendations. These reports are the gold standard for policy guidance and can have substantial political and budgetary significance. Tiedje, along with Jo Handelsman (then at the University of Wisconsin, Madison, now at Yale), convinced the National Science Foundation that an NRC report might help delineate the field, explain its potential, and suggest what it would need to thrive. The Department of Energy and five institutes of the National Institutes of Health joined NSF in sponsoring the report and the NRC’s Board on Life Sciences convened a committee to write it. Handelsman and Tiedje co-chaired the committee of 12 scientists tasked with laying out a roadmap for this new field.

The report: “The New Science of Metagenomics: Revealing the Secrets of Our Microbial Planet” pays appropriate homage to Woese, presenting early in the first chapter the iconic tree that encapsulated his work and that of his colleagues and trainees, and suggesting that its implications could prove as transformative as the invention of the microscope. The authors explained that Woese’s work had revealed the microbiological world to be vastly
more diverse than previously recognized, expanding the known biological world by at least an order of magnitude. If properly supported, the report argued, metagenomics approaches would render accessible this newly visible, and highly important, microbiological world.

Since the report’s publication, the NIH—through the Human Microbiome Project, the NSF—through the Terragenome project, and the DOE—through its poplar biomass and cow rumen metagenomics projects, have invested significant resources in metagenomics research, supporting research at all scales, from individual investigators to international consortia. The results of these investments are beginning to reach even the popular media, with the human microbiome project inspiring articles in The Economist, the New York Times, and Wired magazines, and a comprehensive series on National Public Radio. From health, to agriculture, to environmental remediation, to sustainable energy, microbial communities are coming to be seen as critical players—and potential intervention points—in many biological systems. If the leap from fundamental understanding to commercial products and treatments is still in its earliest stages, there is no longer much doubt that significant applications in human health and beyond are not far off.

Woese was fiercely dedicated to fundamental discovery, his work undeniably basic, arguably even arcane. In time, however, his basic insights were adopted and applied in new contexts by scientists who subsequently recognized and recommended support for a new discipline and research endeavor. Policymakers and funding agencies responded, nurturing the emergence of the new field of metagenomics. As basic research faces escalating constraints, it is worth telling the story of how one scientist’s fundamental insights contributed so profoundly to creating a field that is now capturing the public imagination, contributing to stunning advances in fundamental understanding, and yielding practical applications in agriculture, bioenergy, and human health.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.