The evolution and function of the tiniest bacterial genomes in the context of obligatory symbiosis collapse: a general summary

Many animals form long-term symbiotic associations with microorganisms, most often bacteria, that enable them to survive on foods that would not have been available or sufficient otherwise. Microbial associations of plant sap-sucking insects such as aphids, cicadas, or planthoppers exemplify such symbioses. Within their bodies, these insects usually house bacteria that produce essential nutrients lacking in plant sap, allowing their hosts to thrive on this nutritionally imbalanced food. However, these bacteria are often so specialized that they cannot live outside of insects' organs, since during co-evolution with insect hosts they have lost the large majority of genes and functions that were not necessary for such a lifestyle, resulting in some of the smallest genomes known. Until recently, **scientists thought that these specialized symbiotic bacteria and their insect hosts were a perfect example of a stable partnership**. However, my group's research revealed that in some cases, these supposedly stable partnerships are actually falling apart. **In some planthoppers and cicadas, we discovered insect-symbiotic bacteria with incredibly small genomes, some encoding fewer than ten genes, much less than any other known cellular organism.** These bacteria seem to degenerate further in a variety of ways. But so far, we have only had the first glimpse of these extremely unusual organisms.

This project aims to resolve how these unique bacteria evolve, survive and function with such minimal genetic material, and what their role in insect biology may be. The project team will address these questions using a combination of advanced research techniques. To understand the diversity and evolution of these bacteria, we will sequence and analyze the DNA from diverse insect species representing clades where such degeneration has been observed. To understand the organization of these unusual symbioses, we will fully characterize the genomes of selected bacteria and their host insects, and use microscopy to understand how bacteria are distributed within insects. Finally, to understand the symbiont function, we will assess which bacterial and insect genes are active, and how their products are distributed inside the insect body.

The proposed research will provide extensive information on some of the most extreme biological states ever discovered – but will do much more than just explain a strange case of insect biology. **The project will challenge our fundamental understanding of what defines life itself. By studying these extreme examples of "collapsed" genomes, we hope to shed new light on how organisms evolve, how they integrate with one another, and what a "genome", a "cell", or even a cellular "organelle" really is.** As such, this project is a journey to the very edge of what we thought was possible in biology.