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COMMENTARY: REFLECTIONS ON 40 YEARS

From Insect Communication to Bacterial Communication

Stefan Schulz

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One of the driving forces in the early stages of the ISCE and the *Journal of Chemical Ecology* was the aim to unravel the chemistry and biology of insect communication. Since then, a remarkable number of insect pheromones have been identified, probably for about 1,000 species, and the mysteries of their formation and perception elucidated, in some cases in great detail. We now have a pretty good picture how the chemical message is triggered, produced, released, perceived, processed, and transformed into behavior. A driving force for this was the potential application of many of these insect pheromones.

During this time period, the analytical techniques became much more sensitive, new ideas popped-up, and the genomic area arrived. Bacteria were not much on the radar of chemical ecologists 40 years ago, but this changed and nowadays we have become much more interested in the role bacteria play in shaping our environment. Bacteria may influence the production and formation of insect pheromones when thriving on a host, but they also can communicate with each other. A typical phenomenon observed is "quorum-sensing", a trait found in many bacteria. A physiological change in a bacterial population is performed when the pheromone concentration is above a certain threshold level. The concentration of this autoinducer is enlarged by a positive feedback loop.

One would think that the sensitive modern techniques and the genomic information at hand would allow easy elucidation of many bacterial semiochemicals, but surprisingly this is not the case. If one looks at the known structures of bacterial pheromones, autoinducers, or quorum-sensing compounds, not much more than two handfuls of structural types are described. Nevertheless, similar to insect pheromones for which agricultural application is a driving force, potential pharmaceutical and life science applications stimulate research in bacterial communication, e.g., in biofilm inhibition or antibiotics research.

The most explored compounds used in bacterial communication systems are *N*-acylhomoserine lactones (AHLs) used by Gram-negative bacteria (Dickschat 2010). The AHL-dependent information transfer is the best and most investigated bacterial communication system, and its understanding in all its variants complements that of insect pheromone systems, covering aspects from biosynthesis, perception, degradation, and evoked physiological effects. One reason might be the ease of how genetic information is nowadays at hand. Research on bacterial communication often starts on a genetic level, using homology approaches. By this method, one easily finds similar systems in other bacteria, but not entirely new systems with potential different structures. The major question is whether this predominance of AHLs is indeed a true picture of the reality. Or, are there many more signaling systems working with different compounds, maybe with similar importance to the AHLs? Probably the answer is yes. An example is the recent identification of photopyrones produced by the insect pathogenic proteobacterium *Photorhabdus luminescens* (Brachmann et al. 2013). These medium-sized lactones invoke a clumping behavior of the bacterial cells. The identification was possible only by the combination of genetic and chemical approaches. The photopyrones constitute a new type of bacterial signaling compounds.

Obviously there is much room for development to understand better chemical communication in bacteria and in a much broader sense. What do we have to do? Genetic information today is the easiest to obtain, at least in bacteria. This would be a good starting point, but additionally we have to look for new gene functions. Chemical characterization of bacterial exometabolites also is key. Only with the compounds in hand can we do various assays, gene expression analysis, etc. The focus of the chemical side should be not only on new structures, but more on the assessment of all metabolites released by bacteria under certain conditions. This work currently is in progress in many laboratories especially for small, volatile compounds, and probably will lead finally to a range of compounds typically associated with bacteria. Finally, we have to start from the other end, the phenotype, and work backwards by phenotype observation to the communication compounds and the genes involved. The combination of all these approaches certainly will improve our understanding of bacterial communication and their interaction with other organisms.

In essence, the overall approach stays the same, even after 40 years: A close cooperation between biologists and chemists is key for success.

References

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S. Schulz (✉)
Institute of Organic Chemistry, TU Braunschweig,
Braunschweig, Germany
e-mail: stefan.schulz@tu-bs.de