Understanding how molecules and ecosystems interact

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Millions of different organic compounds are found in the soil and in bodies of water. New methods are making it possible to analyse these molecules more accurately than ever before – and to decipher their role in the functioning of ecosystems and species communities. In a scientific journal, a research team from Eawag and University of Zurich therefore calls for a new "ecology of molecules".

Meadows, forests, lakes or moorlands: ecosystems are complex networks of relationships. Plants, animals and other living organisms influence each other, but they also depend on the properties of the non-living environment. For example, nutrient-rich soils support a completely different range of species communities than do nutrient-poor soils.

Such relationships have been known for a long time. Nevertheless, research has so far only scratched the surface, says Erika C. Freeman, a postdoctoral researcher in the research group of Professor Florian Altermatt at the aquatic research institute Eawag and the University of Zurich. "There are millions of different organic compounds in the soil, water and air. Little research has been done into how they interact with each other and influence ecological processes."

In an article just published in the scientific journal "Trends in Ecology & Evolution", lead author Erika C. Freeman and her research team call for this research gap to be closed. The prerequisites for this are in place, says Freeman. "The development of high-resolution mass spectrometry, growing molecular databases and the marked increase in computing capacity are enabling us for the first time to systematically capture the complexity of ecosystems at the molecular level. At the same time, our understanding of metabolic processes has made enormous strides not only in animals and plants, but

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also in microbes, thanks to new sequencing technologies." The time is therefore ripe for an "ecology of molecules", in which the interactions between individual organic molecules and the organisms in ecosystems are researched.

A bromine molecule kills sea eagles

Individual studies of this kind already exist. A few years ago, scientists were able to prove that a molecule containing bromine was the cause of a mysterious death in bald eagles in the USA. Cyanobacteria living on an invasive aquatic plant produced this toxin, which then accumulated through the food chain and was ingested by the sea eagles along with their prey, such as water birds. In another study, a research team showed that a compound called "6PPD" from tyre abrasion in US rivers was responsible for the death of silver salmon.

Such spectacular individual examples are just the tip of the iceberg. According to the researchers, it is known, for example, that in forests, tannins – plant tanning agents – slow down the decomposition of leaves and thus influence the nutrient cycle. Bark beetles, in turn, use volatile molecules known as pheromones to coordinate mass attacks on weakened coniferous trees, which they infest and cause to die. These pheromones thus play a major role in the beetles' reproduction cycles, in the health of the trees and, ultimately, in the distribution of nutrients in the forest through the decomposition of wood.

Erika C. Freeman has been fascinated by such interdependencies since completing her studies in Canada and the UK. In her doctoral thesis, she examined how carbon compounds are washed out of soils into rivers and lakes as dissolved substances. She was able to show how these compounds are broken down by microbes on their way, how the composition of the molecules changes and what effects this has on the carbon storage capacity of the water bodies.

A new research field with many questions

"There are many exciting and important questions about how chemistry and life interact in ecosystems," says Erika C. Freeman. For example, are there key molecules that are particularly important for certain ecosystem functions? Are there chemical compounds that act as a kind of fingerprint, providing information on the state of waterbodies? How do the many chemicals that humans introduce into drinking water reservoirs interact, and how does this affect their toxicity? Or: is the diversity of molecules in the tropics comparable to the biological diversity, which is particularly high? And if so: how do chemical and biological diversity influence each other in the evolutionary process?

The publication aims to encourage the ecosystem research community to address such questions. "Our study sets the framework for a new research field," says Erika C. Freeman. "This framework is important so that we can move forward together in a more organised and focused way."

Chemistry and biology join forces

The article outlines how questions in the "ecology of molecules" can be addressed. Identifying and analysing individual molecules in a sample and determining their frequency is a basic requirement. Analyses of molecular characteristics are also important, however, such as functional chemical groups or water solubility. Last but not least, it is essential to analyse how the molecules interact with each other and with the organisms in the ecosystem. Such investigations are only possible through interdisciplinary collaboration.

But Florian Altermatt is convinced that the close collaboration between chemistry and biology is worthwhile. This is because the importance of molecular ecology goes far beyond basic research. "In an age of rapid environmental change, this knowledge is not only scientifically interesting, but important for our society," he says. "Understanding how molecules and organisms interact in ecosystems helps us to predict the effects of climate change, ensure the quality of our drinking water and maintain the productivity of our agriculture."

Cover picture: The time is ripe for an "ecology of molecules", in which the interactions between individual organic molecules and the organisms in ecosystems are researched (Photo: Adobe Stock).

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