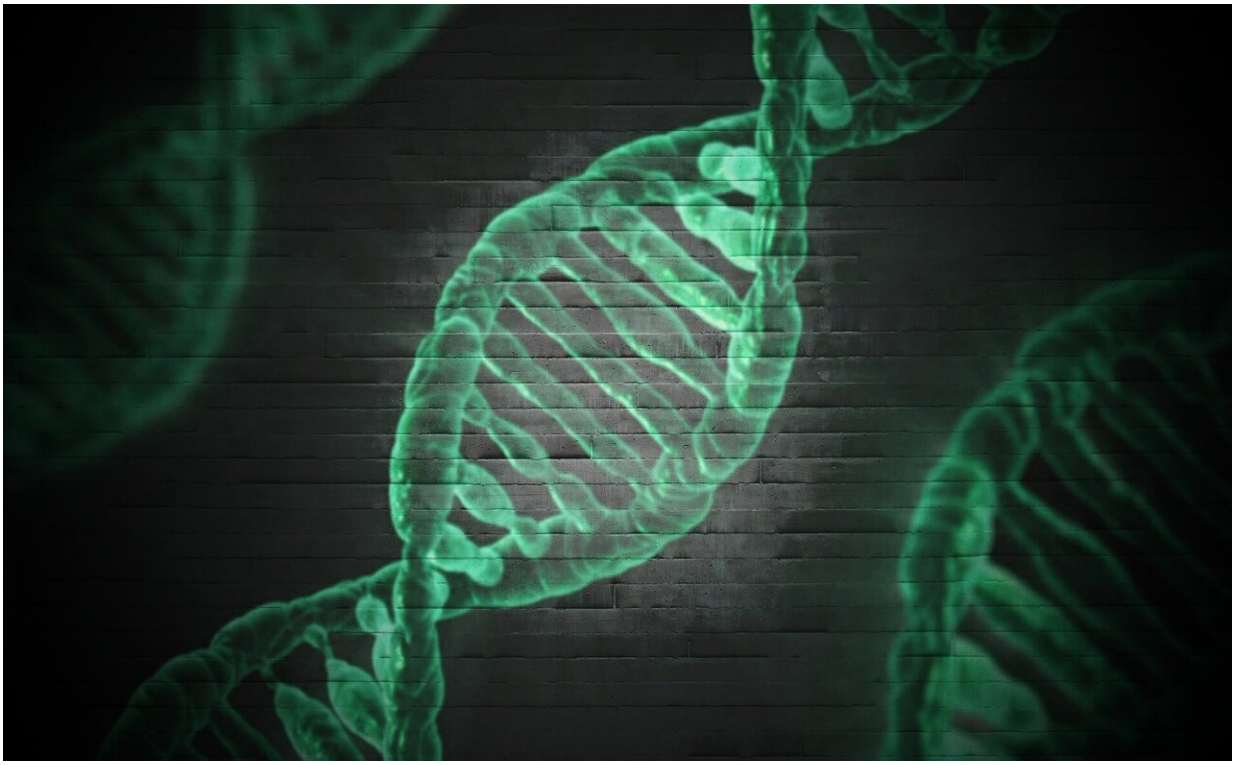
Evolution can reconfigure gene networks to deal with environmental change

November 13 2019



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Scientists at the University of Birmingham have unravelled the genetic mechanisms behind tiny waterfleas' ability to adapt to increased levels of phosphorus pollution in lakes.

By mapping networks of genes to the physiological responses of ancient and modern waterfleas (Daphnia), the researchers, based in the University's School of Biosciences, were able to show that a cluster of over 800 genes, many of them involved in metabolic processes, evolved to become "plastic", or flexible.

This allows the modern Daphnia to adjust its gene expression according to the amount of phosphorus present in the environment. This is particularly fascinating as their 700-year-old ancestors were incapable of such a plastic response.

Understanding the adaptive capabilities will help scientists to better predict the capacity of these creatures to help us mitigate against the threat posed by phosphorus pollution.

Strikingly, the team was only able to make these discoveries by comparing the responses of modern Daphnia with their 700-year-old ancestors. Both the modern and the ancient samples studied came from the same lake in Minnesota where eutrophication—a process that causes devastating algal blooms with high phosphorus content—first started at the beginning of the 20th century.

Modern-day industrialised agriculture with its extensive use of phosphorus-based fertilizers is adding to the many stresses on wildlife. The phosphorus eventually ends up in our freshwater systems resulting in eutrophication. Daphnia can help to reduce these blooms, but must cope with the increased phosphorus levels which can cause problems to its health.

Dr. Dagmar Frisch, Dr. Dörthe Becker and Dr. Marcin Wojewodzic, all three of them awardees of prestigious EU Marie Sklodowska-Curie fellowships, joined their expertise to develop new concepts in evolutionary ecology that enabled this analysis to take place.

"We used existing data and state-of-the-art analytical methods to connect patterns of gene expression with the physiological responses that allow these animals to deal with increased environmental phosphorus" says Dr. Dagmar Frisch, an expert in environmental paleogenomics. "This allowed us to identify which part of the gene network was accountable for the newly evolved response".

While this work helps us to better understand how animals adapt to new environments in general, Dr. Dörthe Becker who is now at the University of Sheffield, points out: "Because Daphnia is such a central species in aquatic ecosystems, our study ultimately improves our understanding of how aquatic ecosystems can mitigate some of the effects of eutrophication, one of the major global threats to freshwater environments".

By reviving eggs that lie dormant in the sediment of lakes, a method called resurrection ecology, the authors were able to compare the gene responses of centuries-old revived waterfleas with modern day descendants in a novel way.

"We used network analysis methods to find out which genes 'communicate' with others or form clusters (called modules), and how this gene communication has changed in a keystone species over the last 700 years. In addition, we were able to connect these modules with particular observed traits, which was achieved for the first time in resurrection ecology"—says Dr. Marcin Wojewodzic, now a researcher at the Cancer Registry of Norway.

"Our study emphasizes that evolution is a result of molecular fine-tuning that happens on different layers, ranging from basic cellular responses to complex physiological traits" says Dr. Becker.

Dr. Frisch adds: "Our approach allows a more holistic view of how

animals can and do respond to environmental change, and by that improve our understanding of organisms as integrated units of biological organisation".

"After applying the recently developed network analyses, the logical next step is to explore how other molecular mechanisms including epigenetics plays a role in evolutionary processes. We have already begun this investigation" says Dr. Wojewodzic.

This work is published today in *Molecular Biology and Evolution*.

Provided by University of Birmingham