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Adaptive molecular convergence more common than previously thought

A new study has found that adaptive molecular convergence — the process by which distantly or unrelated species evolve the same genomic changes — is not as rare as previously thought. Reconstructing and studying sections of jellyfish genomes to the deep past, researchers found evidence of identical genetic changes in multiple lineages separated by even more than 600 million years.

The work was conducted by researchers at UC Santa Barbara, University of Kansas, Texas A&M University and the University of Nebraska.

“We’re studying molecular evolution here — to what extent similar genetic changes occur in different organisms,” said Cory Berger, a postdoctoral researcher in the lab of UCSB biologist Todd Oakley. “And that in particular is something we don’t know much about.”

Importantly, according to the paper, these identical genetic changes were largely unassociated with the jellyfishes’ phenotypic convergence, or the evolution of similar physical traits in distantly related species, suggesting a complex relationship between genetic and phenotypic convergence.

The research is published in the Proceedings of the National Academy of Sciences.

Natural selection in action

How repeatable is evolution and under what time scales and circumstances is evolution repeatable? This was the core question of the research, said Oakley, the paper's senior author . Answering this question would provide insight into the predictability of evolution, he added, which could potentially lead to being able to predict evolutionary outcomes, including how genes underlie physical traits.

To investigate, the researchers turned to Medusozoa, an ancient and diverse lineage that includes jellyfish and their relatives. Emerging about 650 million years ago, different members of this clade have undergone convergent and repeated phenotypic evolutions, including multiple origins of eyes and repeated losses of the free-swimming medusa stage.

"We're studying this particularly old group of animals that has some interesting convergent phenotypes that we already know about," Berger said. The idea was to associate patterns of molecular convergence found in the jellyfish genomes with the convergent phenotypes. "Maybe it's just the case that organisms that have phenotypic convergence who look similar to one another have convergent molecular changes."

But first, the researchers needed to reconstruct Medusozoa evolutionary history. With fossil and molecular data, they created an evolutionary tree, using a method called ancestral state reconstruction, to infer the convergent emergence of certain traits like eyes. It's one of the most comprehensive jellyfish phylogenetic trees to date.

The researchers then examined the genetic data.

"We sequenced all the genes that in these different jellyfish, all the genes that are expressed, at least in theory," said Oakley. "And then we looked at the patterns of change across those genes. If the same specific change has happened in distantly related species, then we're calling that convergence." They found an "unexpectedly high" number of repeated molecular evolutions, represented by specific genetic changes across different species, some separated by more than 600 million years.

Interestingly and somewhat counterintuitively, however, the genetic convergences did not predictably relate to the physical convergences. According to the

researchers, while natural selection can promote the same genetic change to disparate species, molecular convergence is the result of a more complex process that reflects interactions of organisms with their environments.

“The amount of genetic similarity indicates that at the genetic level, evolution may be more repeatable and maybe therefore more predictable than we expected,” Oakley said. “But it also means that we still have a huge amount to learn about how the genes function, how that plays out on the whole-organism scale.”

Research in this paper was also conducted by Marina I. Stoilova and Paulyn Cartwright at the University of Kansas, Rebecca M. Varney at the University of Nebraska, Maria Pia Miglietta at Texas A&M University and Sam C. Abrams at UCSB.

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