At molecular level, evolutionary change is unpredictable

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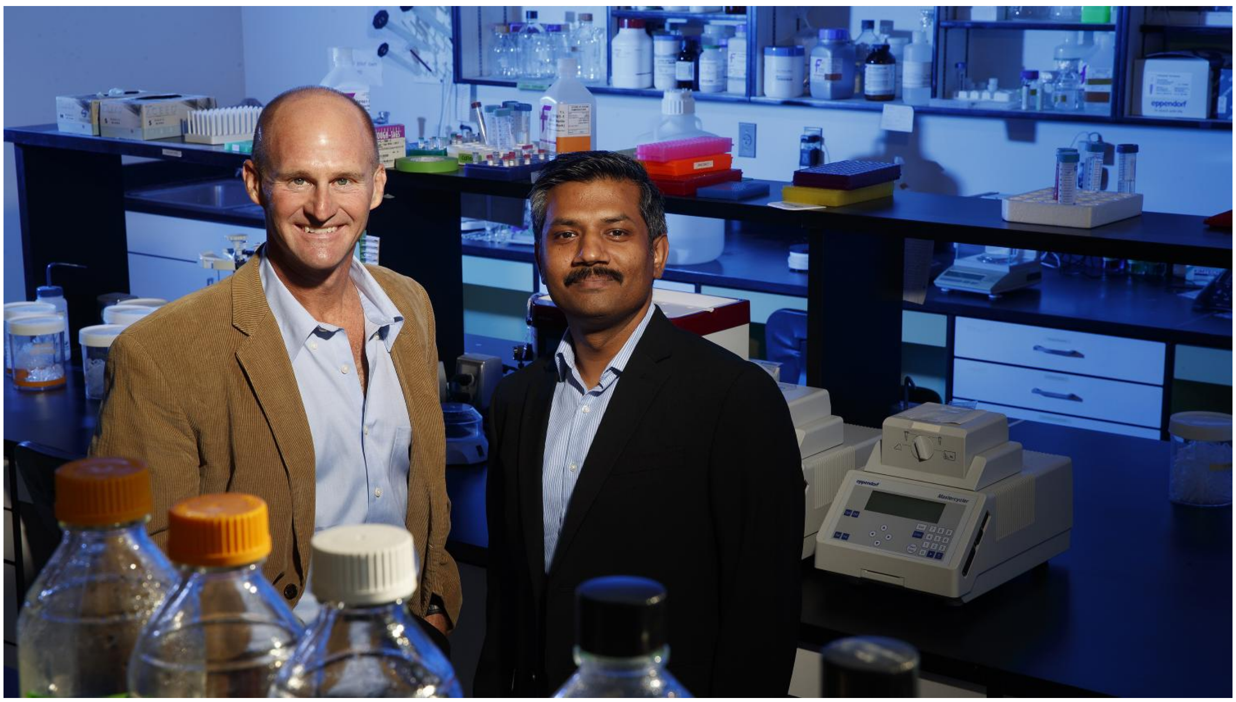

Jay Storz (left), Susan J. Rosowski professor of biological sciences, and Chandrasekhar Natarajan, research assistant professor in biological sciences. Credit: Craig Chandler/University Communication/University of Nebraska-Lincoln

Biologists have been contemplating evolutionary change since Charles Darwin first explained it.

Using modern molecular tools and fieldwork, University of Nebraska-Lincoln biologist Jay Storz and colleagues have demonstrated for the first time that different species can take different genetic paths to develop the same trait. The team's findings appear in the Oct. 21 issue of the journal *Science*.

"There's this really long-standing question in evolutionary genetics about the predictability of genetic change," said Storz, Susan J. Rosowski professor of biological sciences.

In other words, did species with a common, beneficial trait undergo the same genetic changes to evolve that trait? Or did the trait develop through different, and therefore unpredictable, genetic paths?

It turns out that natural selection, a primary evolutionary process, can dependably produce similar, beneficial traits in different species. But at the molecular level, the evolutionary changes tend to be highly idiosyncratic, and are therefore far less predictable.

To find that out, Storz turned to birds living in South America's Andes Mountains. Comparing high-altitude bird species with their lowland counterparts, his team determined that the high-altitude birds had evolved red blood cells with hemoglobin proteins that more readily bind oxygen molecules. This trait benefits species living in low-oxygen settings, such as the mountains.

Storz and his team tested the hemoglobin proteins from numerous high-altitude bird species and identified which differences, or mutations, in the proteins' makeup were responsible for the high-altitude trait. In most cases, the change in protein function among the different species was caused by different mutations.

"What this indicates is that there are many possible mutations that can all produce the same phenotypic effect (trait)," Storz said. "We can't predict which particular mutations are responsible for these changes." One possible reason for this variability is that during evolution, the hemoglobins of different species have each accumulated their own unique set of mutations. Given these distinct genetic backgrounds, a mutation that produces a beneficial effect in one species may produce a detrimental effect in a different species.

To test this theory, Storz's team used genetic engineering tools to reconstruct and resurrect the hemoglobin proteins of several ancestral bird species, including the ancestor common to all birds, which existed more than 100 million years ago. Engineering the high-altitude hemoglobin mutations into the ancient bird proteins resulted in vastly different effects than in contemporary birds.

As evolution advances through time, different mutations accumulate in distinct species and settings. Natural selection applies similar pressures for species to adapt as they move to higher altitudes, for example, but the adaptation must take different genetic paths to get there.

"This is a new phenomenon that our findings have helped reveal," Storz said. His team continues to explore historical influences on genetic adaptation.

More information: C. Natarajan et al, Predictable convergence in hemoglobin function has unpredictable molecular underpinnings, *Science* (2016). DOI: 10.1126/science.aaf9070

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