Evolutionary game of rock-paper-scissors may lead to new species

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Side-blotched lizards have three color morphs with different mating strategies, but in some populations only one morph occurs. This male lizard is from an all-orange population. Photo by Ammon Corl.

(PhysOrg.com) -- New research on lizards supports an old idea about how species can originate. Morphologically distinct types are often found within species, and biologists have speculated that these "morphs" could be the raw material for speciation. What were once different types of individuals within the same population could eventually evolve into separate species.

A new study conducted by researchers at the University of California, Santa Cruz, supports this idea. The study documents the disappearance of certain morphs of the side-blotched lizard in some populations. The researchers reported their findings in a paper published this week in the online early edition of Proceedings of the National Academy of Sciences (*PNAS*).

The side-blotched lizard, Uta stansburiana, has three morphs differing in color and mating behavior. Barry Sinervo, a professor of ecology and evolutionary biology at UCSC, has studied a population of side-blotched lizards near Los Baños, Calif., for over 20 years. Ammon Corl, now a postdoctoral researcher at Uppsala University in Sweden, led the new study as a graduate student at UCSC and is first author of the paper.

Previous work by Sinervo and his colleagues showed that competition among male side-blotched lizards takes the form of a rock-paper-scissors game in which each mating strategy beats and is beaten by one other strategy. Males with orange throats can take territory from blue-throated males because they have more testosterone and body mass. As a result, orange males control large territories containing many females. Blue-throated males cooperate with each other to defend territories and closely guard females, so they are able to beat the sneaking strategy of yellow-throated males. Yellow-throated males are not territorial, but mimic female behavior and coloration to sneak onto the large territories of orange males to mate with females.

"My goal when starting my Ph.D. thesis research was to understand how this fascinating mating system evolved," Corl said. "We studied lizard populations from California to Texas and from Washington State down to Baja California Sur in Mexico."

Corl found the three color morphs in many places, but not everywhere. Some populations were missing some of the color morphs. For example, populations in the northwest only have orange-throated lizards, while only orange- and blue-throated morphs are found on Anacapa Island in the Channel Islands. In the field, the researchers captured lizards to collect tissue samples for DNA analysis and then released them back into the wild. In the lab, they used the tissue samples to get DNA sequences from all of the lizard populations in the study.

"Based on these sequences, we reconstructed the 'family tree' of the lizard populations and figured out which populations were more closely related to one another. This let us figure out how the mating strategies evolved," Corl said.

The results showed that all three color morphs existed millions of years ago and have persisted since then in many populations. Over time, however, some branches of the lizard family tree lost some of the color types.

"What was particularly interesting was the pattern in how color morphs were lost," Corl said. "Any time there was a loss, the yellow type--the sneaky males that mimic females--was the first to go. Thus, the rock-paper-scissors game can break down on an evolutionary timescale. Something about the game must change so that, for instance, both the rock and scissors strategies are able to beat paper."

Sinervo has documented the cycling of the rock-paper-scissors game at his main study site for 22 years, with the dominant morph in the population changing every four to five years. "It's like an evolutionary clock ticking between rock, paper, scissors then back to rock," he said. "Ammon's research indicates that the game has been cycling for millions of years at some sites, and yet at other sites it collapses on one or two strategies and begins to create new species. It is simply mind-boggling to think about deep time and these evolutionary cycles."

Many aspects of the evolutionary history of these lizards are consistent with the theory that morphs can be involved in speciation, Corl said. Evolutionary theory predicts that new species could arise from particular morphs originally found in a population containing multiple morphs. Side-blotched lizards started off with three color morphs. If just one or two types occur in a population, they look just like the original morphs.

The theory was also supported by patterns in the formation of subspecies, which are the precursors to new species. Two subspecies of side-blotched lizard that originated from populations with three morphs now have only a single color morph. Thus, populations that lose morphs are not transitory, but can persist and eventually become a different species.

The study also found evidence to support the hypothesis that rapid evolutionary change occurs when particular morphs are lost from the system. "Imagine the three lizard morphs playing rock-paper-scissors," Corl explained. "They have very specific adaptations for fighting one another. Now imagine that some morphs are lost, leaving a population of all rock morphs. Their adaptations for fighting the paper and scissors morphs are no longer useful. Therefore, rapid evolutionary change is expected in a population of rock morphs as they adapt to a new game in which they only fight other rock morphs."

The study showed clear evidence of very rapid evolution of body size when morphs are lost from a population. "Such rapid evolution could eventually cause populations to evolve into distinct species. We are the first group to provide a statistical test of this hypothesis," Corl said.

The idea of morphs being involved in speciation is an old one. Charles Darwin conducted experiments with different reproductive morphs in flowers to try to gain insight into the process of speciation. However, the new paper by Corl and colleagues is one of the first studies to use modern techniques to tackle the problem of morphs and speciation.

"My hope is that the paper will inspire other researchers to consider a role for morphs in the evolution of the species that they study," said Corl. "For most species, the speciation process is thought to begin only after populations are geographically separated. Our study shows that the distinctive morphs that build up within populations are important for understanding speciation. Thus, the first stages of new species may occur within and not between populations. This idea could fuel lots of interesting research for many years to come."

Provided by University of California - Santa Cruz

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