New Evidence That Natural Selection Is A General Driving Force Behind The Origin Of Species

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Charles Darwin would undoubtedly be both pleased and chagrined:

Daniel Funk is in the greenhouse where he raises a type of tiny leaf beetle that is in the process of transforming into a new species.

The famous scientist would be pleased because a study published this week finally provides the first clear evidence that natural selection, his favored mechanism of evolution, drives the process of species formation in a wide variety of plants and animals. But he would be chagrined because it has taken nearly 150 years to do so.

What Darwin did in his revolutionary treatise "On the Origin of Species" was to explain how many of the extraordinary biological traits possessed by plants and animals arise from a single process, natural selection. Since then a large number of studies and observations have supported and extended his original work. However, linking natural selection to the origin of the 30 to 100 million different species estimated to inhabit the earth, has proven considerably more elusive.

In the last 20 years, studies of a number of specific species have demonstrated that natural selection can cause sub-populations to adapt to new environments in ways that reduce their ability to interbreed, an essential first step in the formation of a new species. However, biologists have not known whether these cases represent special exceptions or illustrate a general rule.

The new study, published online in the Proceedings of the National Academy of Sciences, provides empirical support for the proposition that natural selection is a general force behind the formation of new species by analyzing the relationship between natural selection and the ability to interbreed in hundreds of different organisms â€“ ranging from plants through insects, fish, frogs and birds â€“ and finding that the overall link between them is positive.

Filling a gap in evolutionary studies

"This helps fill a big gap that has existed in evolutionary studies," says Daniel Funk, assistant professor of biological sciences at Vanderbilt University. He authored the study with Patrik Nosil from Simon Fraser University in British Columbia and William J. Etges from the University of Arkansas. "We have known for some time that when species invade a new environment or ecological niche, a common result is the formation of a great diversity of new species. However, we haven't really understood how or whether the process of adaptation generally drives this pattern of species diversification."

The specific question that Funk and his colleagues set out to answer is whether there is a positive link between the degree of adaptation to different environments by closely related groups (termed ecological divergence) and the extent to which they can interbreed (termed reproductive isolation.)

Funk and his colleagues saw a way to address this question by extending a method pioneered by Jerry A. Coyne, University of Chicago, and H. Allen Orr, University of Rochester in a now classic study of speciation in fruit flies published in 1989.

Coyne and Orr were interested in exploring how the process of species formation develops over time. To measure this process, known as speciation, they developed an index of reproductive isolation. For a measure of time, they used the fact that genetic mutations accumulate over time. So if the percent difference in the genomes of species A and B differs by five percent while the difference between A and C differs by 10 percent, then the time since A and C diverged is about twice that since A and B split apart.

Extending the methodology of a classic, 1989 study

Coyne and Orr's approach provided a number of valuable insights into the speciation process, such as showing that a certain amount of time must pass before reproductive isolation evolves and that it isn't a sudden but a gradual process. Other researchers were impressed with the power of their method and applied it to a number of other groups of creatures. In Coyne and Orr's book, Speciation, published in 2004, the scientists listed eight different studies that applied their approach to flowering plants, birds in general, doves in particular, fruit flies, butterflies, frogs, fish in general, and a specific type of fish called darters. Together, the studies evaluated many hundreds of species.

"I got the idea that we could extend the analysis into a third dimension, ecological divergence," says Funk. He realized that applying this new approach to data from each of the eight studies would have two major advantages:

Freedom from bias. The studies that had been previously subjected to the Coyne and Orr analysis provided the researchers with an unbiased sample. Many of the individual case studies that have found a role for natural selection were picked for study because the investigators detected indications that this was the case and so, as a group, the cases suffer from a pro-natural-selection bias.

Eliminating the time factor. The results of previous speciation studies have been clouded by the effects of time. Regardless of the role that natural selection plays, random mutations are bound to increase the reproductive isolation between two groups over time. In earlier studies, it has been difficult â€“ if not impossible â€“ to disentangle the two effects. With the proposed approach, however, the authors could apply a widely used mathematical procedure, called regression analysis, to factor out time's effects and isolate the impact of natural selection.

"We thought that the idea itself was important, that this is a really powerful approach to a very major question," says Funk, "but we thought that there was no way in the world that we were actually going to get statistically significant results."

Problem posed by lack of uniformity of ecological data

The reason for his doubt was the incompleteness and lack of uniformity of ecological data. "There are all these species out there and so few of them are known in intimate detail, so any kind of ecological characterization, through no fault of ecologists, will be limited in accuracy and precision," Funk says.

Nevertheless, the researchers decided to do the best they could with the information available. Specifically, they collected information from the published literature on three basic ecological variables: habitat, diet and size. They reasoned that evaluating the degree to which a pair of species differed from each other in these variables would provide an idea of to what degree natural selection had caused them to diverge evolutionarily.

Next they used this information to calculate estimates of ecological divergence for each pair of species from each of the eight original studies. For example, if one species of bird eats fruit, insects and nuts and the second species eats fruit, insects and meat, then their estimate of ecological divergence in diet is one third. Similarly, if the

average weight of one species of bird is 4 ounces and that of the other is 5 ounces, then the estimate of ecological divergence in size is 25 percent.

When they compared the ecological divergence estimates with the degree of reproductive isolation for each of hundreds of pairs of species from the original studies, they found that the overall association was positive with a surprisingly high level of confidence: The odds that these findings are simply due to chance are only one in 250, substantially higher than the standard confidence level of one chance in 20 that scientists demand.

"The fact that the association is statistically significant despite the crudeness of our estimates suggests that the true biological association is very strong," Funk says. "Darwin's famous book was called 'On the Origin of Species,' but it was really about natural selection on traits rather than speciation. Since our study suggests that natural selection is a general cause of speciation, it seems that Darwin chose an appropriate title after all."