Joseph P. Noel

PEERING BACK IN TIME

John Dole

Joseph P. Noel wants to use paleontology to learn how plants endured history's harsh climates—and how to ready crops to face severe conditions in the future. Protecting the world's food supply by borrowing from plants of the past is a natural solution that should appeal to the public, says the HHMI investigator at the Salk Institute for Biological Studies.

Most people are familiar with biodiversity. But "chemodiversity"—the tapestry of natural chemicals found in plants—is just as important for life, the appearance of new species, and the survival of many different ecosystems. More than any other organism, plants produce hundreds of thousands of different kinds of chemicals. They use unique chemical cocktails to protect themselves from the elements, battle infections, and attract pollinators, among many other things.

People have long exploited plant chemicals—as medicines, for example. With modern tools to compare genes and enzymes from diverse organisms, we are now in a position to understand the natural history of plant chemical systems—much like a paleontologist but at a molecular level. Evolution teaches us how plants responded to threats such as climate change in the past and how we can speed up their adaptation today.

The importance of plant chemicals to animals, and ultimately people, goes all the way back to the Cambrian explosion. Approximately 500 million years ago, animal life underwent a large evolutionary expansion. That event was very likely predated by plants moving from water to land. Plants provided food for the newly arriving animals. If plants hadn't migrated onto land, you and I wouldn't be here.

These early land plants needed protection from the sun's damaging UV rays. When ancestors of these early plants lived in water, the water absorbed most of the UV rays. To live on dry land, however, plants needed sunscreens. The sunscreen molecules they likely used looked much like modern plant chemicals called flavonoids. In today's plants, flavonoids play a number of roles: they are very effective at absorbing UV radiation, and they are responsible for the colors of flowers.

Different species of plants make unique, but similar, chemicals using similar enzymes. By comparing the few genetic differences between closely related enzymes, we can envision the "ancestor enzyme" that these cousins evolved from. Studying this "old" enzyme in the lab, we learn what chemicals it likely made. In essence, we reanimate these molecular fossils to peer back in time.

In my lab, we have used this technique to discover that the enzymes that make flavonoids are very similar to the enzymes that make fatty acids in all organisms. Modern plant ancestors, by a fluke of evolution, coopted the enzymes that make fatty acids, changed them incrementally, and began making sunscreens.

Some plants have evolved those enzymes further to make a flavonoid-like molecule called resveratrol. This molecule, found in red wine, has received plenty of positive publicity over its anti-aging and cholesterol-lowering properties in animals. The grapevine makes resveratrol to defend against fungal infections. After generations of breeding for grape quality, however, some modern grapevines have lost the ability to make resveratrol as efficiently as their ancestors. To get the same level of protection that resveratrol could provide, wineries have to use artificial fungicides, which can damage the environment.

To make the grapevines naturally fungus resistant again, growers could try to restore resveratrol biosynthesis through breeding, a slow process. I suggest, instead, that scientists could use genetic engineering to quickly and precisely return the right enzyme to the grapevine. This kind of pinpoint engineering, based on what nature has already explored, would allow scientists to take a shortcut to engineer crop plants.

We could also use this technique to engineer plants to withstand climate change. History repeats itself: in past eras, carbon dioxide concentrations on Earth were 10 times higher than they are now, and most of the planet was a hot, wet environment. With collaborators, I hope to re-create ancestor enzymes from these time periods and discover what kinds of chemicals helped them thrive in high temperatures. We can apply the same genetic changes to speed up plant adaptation to climate change today.

Genetic manipulation of plants remains controversial; people worry about unintended consequences of moving a gene from one organism into another. But that's not what we're doing here. We want to restore an ability—thriving in a warmer, carbon-dioxide-rich climate—that the ancestors of modern plants once had. While the plants would be transgenic, we would use the plants' own genes, not genes borrowed from other organisms. I think the public will likely approve of this more natural approach.

INTERVIEW BY AMBER DANCE. *Joe Noel is the director of the Jack H. Skirball Center for Chemical Biology and Proteomics at the Salk Institute.*