

From Tarweed to Silversword

Hawaiian plants with California roots challenge botanical dogma

By WENDY GIBBONS

Looming lush and fertile amongst the gentle climes of the mid-Pacific, Hawaii's volcanic islands flaunt their solitary existence thousands of miles from the nearest continental landmass.

Because of this isolation, "anything that gets [to Hawaii] had to get there from somewhere else originally," explains plant systematist Donald W. Kyhos of the University of California, Davis. Deciphering the origins of the islands' diverse flora and fauna has fascinated biologists since the time of Darwin.

Now, by applying molecular biology to the study of evolution, taxonomic sleuths have identified two California cousins of the Hawaiian silversword "alliance," a grouping of 28 closely related plants. The findings also furnish genetic clues suggesting that all existing silversword species may have evolved from a single seed. Plant evolutionist Bruce G. Baldwin suspects the genealogic evidence he has collected may even inspire new thinking

about how plants worldwide "came to be where they are."

"I really jumped out of my chair when I read that article," recalls G. Ledyard Stebbins, an evolutionary biologist who specializes in the study of plants at the University of California, Davis. The "remarkable" new study is the first to identify species that probably are closely related to a now extinct continental ancestor of a cluster of island species such as the silverswords, he says.

Plants now indigenous to Hawaii first arrived millions of years ago, says Baldwin, of the University of Arizona in Tucson. Transported by wind, birds or water, these plants could have "hopped" between the many islands — some of which no longer exist — dotting the South Pacific.

Most of the plants probably originated in southeast Asia and Australia. However, because of their resemblances to plants

now growing in North and South America, about 20 percent of Hawaii's native plants probably emigrated west across the open ocean separating the island chain from the American continents — a daunting 2,400 miles. Proof of such ancestry, however, has evolved slowly.

With silverswords, it was not for lack of trying, say study coauthors Kyhos and Gerald D. Carr, a plant geneticist at the University of Hawaii in Honolulu. The California tarweeds, 99 species of scrubby plants that Kyhos says most people "probably would walk right by" without noticing, resemble Hawaii's silverswords in several important ways. The similarities led botanists to suspect the plants might be related.

As a litmus test for close genetic ties, researchers traditionally cross two potentially related plants to see if they can produce hybrids. But Kyhos and Carr's attempts to cross numerous different tarweeds to silversword plants proved fruitless. "I began to despair that there were any close ancestors" that had not gone extinct, Kyhos says.

These efforts nevertheless laid the groundwork for research that Baldwin and his colleagues describe in the March 1 PROCEEDINGS of the NATIONAL ACADEMY of SCIENCES. Baldwin examined DNA from the chloroplasts — cellular compartments where photosynthesis occurs — of tarweeds and plants in the silversword alliance, looking for genetic mutations shared more commonly among these species than among less closely related plants. The technique allowed Baldwin to screen for genetic ties much more simply and quickly than setting up crosses between hundreds of species. The analyses pinpointed two California tarweeds with sets of mutations closely resembling those of the Hawaiian plants.

To confirm the apparent kinship, the researchers crossed a Hawaiian silversword specimen with each of the two California species. "We could hardly believe our eyes when the results came in," Kyhos says. The matings produced healthy hybrid plants.

How did the tarweeds cross the open Pacific? "To explain going from California to Hawaii requires a bird," Kyhos asserts. Sticky appendages on tarweed fruit may have allowed the plant to hitch a ride with a winged traveler.

The researchers speculate that a single tarweed progenitor established itself on one Hawaiian island. Subsequent generations from that single plant probably evolved into the diverse group of silverswords now endemic to Hawaii. The exotic family includes trees, shrubs, cushion plants and a vine. Various species have colonized such dramatically different ecosystems as the peak of Mt. Waialeale on the island of Kauai — the wettest spot on Earth — and the extreme desert-like conditions of Mt. Haleakala, an extinct volcano on the island of Maui.



Baldwin

Top: One of the Hawaiian silverswords' tarweed cousins, Raillardiospis muirii, grows almost exclusively in the southern Sierra Nevada of California. Its preferred habitats consist of granite outcrops and sandy areas along rivers. Bottom left: Dubautia laevigata, a member of the silversword alliance, lives in wet forests on the Hawaiian island of Kauai. Bottom right: When researchers crossed R. muirii with D. laevigata, they produced a "trans-oceanic" hybrid.

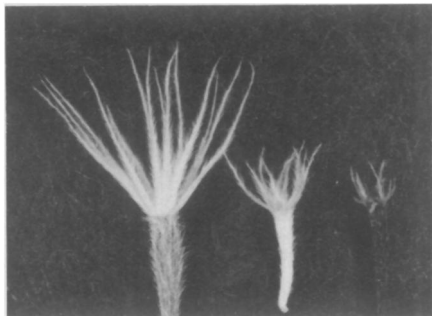


Carr



Jack Kelly Clark

The two California cousins — *Raillardropsis muirii* (left) and *Madia bolanderi* (right) — produce fruit with sticky hairs, as does their cross (center).



Baldwin

"When you see these things, it's hard to believe that they're related," Kyhos says.

How could one ancestral seed give rise to such diversity?

Because of the island chain's isolation, relatively few plants reached Hawaii before the first humans came along about 1,600 years ago. But those botanical squatters that did survive the journey encountered volcanic refuges offering a wealth of ecological opportunities, or "niches," formed by local variations in weather patterns, elevation and the age of the foundation rocks.

"The bottom line is [that] relatively few different kinds of [plant] families were able to establish in Hawaii, which means that the ones that did establish had far greater opportunities," Baldwin says.

The strong new evidence that a tarweed made its way from California to Hawaii also raises questions about the origins of plants outside Hawaii, he adds. Many researchers believe that related plants on different continents that were once adjacent, such as Africa and South America, probably evolved independ-

ently from an ancestral line that populated both continents before they drifted apart. Others have suggested that long after the continental split, seeds might have been carried across the ocean by wind, water currents or migrating birds. These intercontinental voyagers could have seeded each of the landmasses with species picked up from the other. But scientists had no way to test the likelihood that such long-distance travel could occur, leading many to downplay the scenario. "This is a very contentious issue in biogeography," Baldwin says.

The distance between California and Hawaii is 60 percent greater than that between Africa and South America, forming one of the greatest expanses of unbroken ocean in the world, Baldwin says. Therefore, the new study "tests the outer limits of long-distance dispersal," he says.

Though intercontinental travel probably does not explain many instances of apparent relationships between plants on different continents, Baldwin believes the new findings "strongly suggest" that long-distance travel may have more significance than researchers have conceded in the past.

Still unanswered, Stebbins observes, is what it is about Hawaii and California that "caused evolution to go in such different directions." Silverswords and their California kin, he says, may provide researchers with a means to begin solving this puzzle — if they survive.

Many of Hawaii's silversword species are in danger of extinction, Baldwin notes. Once lands of opportunity for these flora, Hawaii's islands now are overrun with more recently introduced species — such as goats, wild pigs and tourists. These intruders are destroying both the plants and the environments that nurtured them. One of the silversword's tarweed ancestors is also considered an endangered species by the California Native Plant Protection Society.

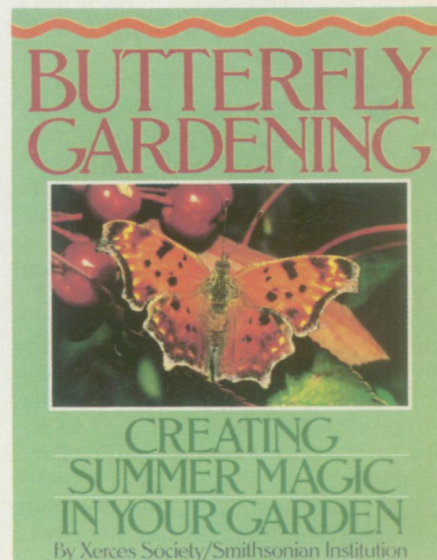
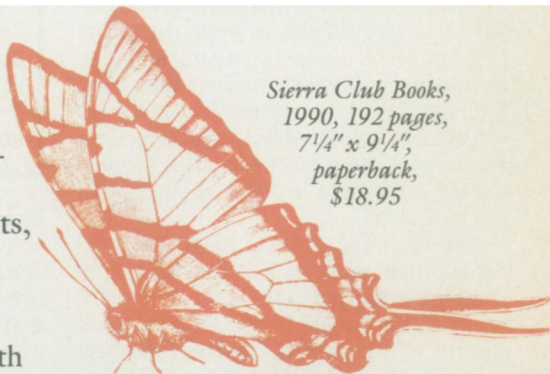
Baldwin says his study emphasizes the importance of preserving endangered species. Moreover, he argues, because the tarweeds' lineage gave rise to such a diverse array of plants in Hawaii, this line of study suggests that threatened species "may not be the evolutionary dead ends that they are thought to be." □

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