Evolution written in lianas

Botanists use climbing plants to understand the origin of Brazilian forests | **Ricardo Zorzetto** | PUBLISHED IN OCTOBER 2012

No challenge appears to be too intimidating for botanist Lúcia Garcez Lohmann, a specialist in plant systematics at the University of São Paulo. Upon completing her studies in biology in 1995 at the age of 22, she took on a task that would strike fear into the heart of any experienced researcher. She decided to seek a definitive answer to a question that had occupied botanists for two centuries: understanding the kinship and the evolutionary and biogeographic history of the 382 species of lianas that are scattered across a vast swath of the Americas, from southern Mexico to northern Argentina and Chile, and that help make tropical forests so different from temperate forests.

After visiting museum collections around the world and spending months collecting new specimens in Central and South American forests, Lohmann set up a classification system based on the kinship relationship between the species using the genetic and morphological characteristics of these plants. Now, as she is beginning to understand when, where and how these lianas—species representing nearly half of the Bignoniaceae, a family of plants with bell-shaped flowers that includes trees such as *ipês* and rosewoods—developed such variety, Lohmann is ready to begin an even more ambitious project. She now wants to understand what led the Amazon forest to host the world's largest variety of plants and animals—in other words, how the Amazon became the Amazon.

Over the next five years, in collaboration with Joel Cracraft, a U.S. ornithologist, Lohmann will coordinate approximately 30 researchers—half in Brazil and half in the United States—who will analyze data on plants, animals and the environment as they seek an explanation for the biodiversity of the world's largest tropical forest. The project, approved in September, is the result of a collaboration between FAPESP and the U.S. National Science Foundation. Through the Biota-FAPESP and Dimensions of Biodiversity programs, the two foundations will devote US$ 2 million to this research. "I know of no other project that proposes to produce such a comprehensive, integrated view of the Amazon," Lohmann says. "The idea is to do a synthesis of everything we know about the region and build a theoretical model to better explain the origin of its biodiversity."

Approximately 40 years ago, the emergence of the abundant variety of plants and animals in the Amazon was viewed in the light of the refuge theory, which was proposed in the late 1960s by German geologist Jürgen Haffer and was tested by zoologist Paulo Vanzolini. According to this model, climate change left the region dryer than in the past, and the forest shrank down to narrow, isolated areas. These areas, known as refuges, were thought to have

FÁBIO COLOMBINI

Lianas in the Atlantic Forest in Itatiaia, State of Rio de Janeiro: Lianas of the group Bignonieae can help determine the evolutionary history of several ecosystems

enabled the survival of many species and promoted the emergence of others that later spread out when the climate again became humid and the forest expanded. Having been put to the test a number of times, the refuge theory no longer seems sufficient to explain the biodiversity of the Amazon.

One reason for the debate is the idea that refuges, as centers of species diversity, may be the result of a distortion, because in many cases, the refuges coincide with the areas where the most specimens of plants and animals have been collected. Therefore, more species may have been found in the refuges because more searches have been conducted in those areas and not because these areas necessarily have a richer variety of species. "People who study biodiversity test the refuge theory because no other alternatives exist," Lohmann comments.

With this new project, Lohmann and Cracraft hope to create a more comprehensive theoretical model to explain Amazonian biodiversity. "By the end of the five years, we hope to understand in detail the patterns of biodiversity that occur in the Amazon and to be able to resolve some controversies about the environmental history of the region," says Cracraft, who conducts his research at the American Museum of Natural History in New York. He, Lohmann and other researchers began planning this study nearly four years ago. "We had a scientific interest in the Amazon, and many of us had already published papers on the region," Cracraft notes. "But understanding the biotic and environmental history of the Amazon is too big and complex an undertaking to be resolved by a few researchers, so it made sense to think about a larger-scale project."

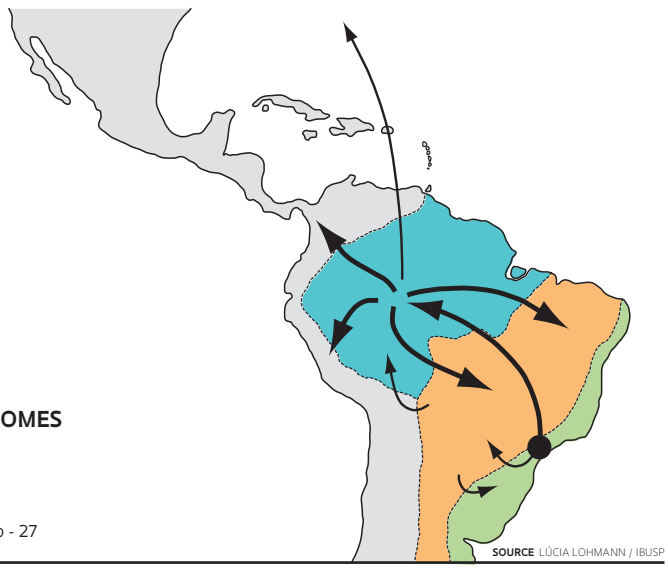
"We want to reconstruct what happened in the Amazon in the last 20 million years," Lohmann says

The first step will be to gather all the available information about certain groups of Amazon flora and fauna. Using these data, the researchers hope to identify the location where the greatest number of species is concentrated and whether that concentration is associated with some environmental characteristic, whether geological or climatic. Then, the researchers plan to uncover the evolutionary history of all the species of plants, butterflies, birds and mammals they have been able to sample. Using genetic information and fossil dating, they want to identify the principal events that gave rise to species diversification and where each group's ancestors were. They also plan to investigate whether the diversification events were associated with geological or climatic phenomena or with other past environmental characteristics, such as variations in the availability of carbon and nitrogen. "We want to reconstruct what happened in the last 20 million years, since that is when many of the species living there are thought to have emerged," Lohmann says.

Much of what is to be performed in the Amazon is no different from her work with the 382 species of lianas of the group Bignonieae, the largest of the groups or tribes of the family Bignoniaceae. Using the genealogy she constructed, she and her team began to uncover the evolutionary history of these plants, which are the largest group of lianas—climbing plants with a woody stem—in the Americas. These plants have so many variations in shape, are spread over so many environments and are so abundant in tropical forests that, botanists say, they serve as a model for understanding what is happening with other species of flowering plants.

Conquest of a continent

Native to the South American coast, lianas of the group Bignonieae spread to the humid regions of the continental interior before reaching dryer climates and Central and North America



SOURCE LÚCIA LOHMANN / IBUSP

ORIGIN

On the basis of molecular data and the new genealogy, Lohmann can say with more assurance that lianas of the group Bignonieae appeared approximately 50 million years ago in the region that is now the Brazilian coast occupied by the Atlantic Forest, according to an article to be published in the *Botanical Journal of the Linnean Society*. At that time, South America had already separated from Africa. The climate was hot and humid, dinosaurs were extinct, and a large variety of mammals had begun to occupy the planet.

The ancestor of these 382 species of lianas was most likely a tree, not a climbing plant. The flowers of the Bignonieae ancestor had five petals that formed an elongated tube, with internal sexual organs and a nectar-producing region at the bottom. These flowers were similar to the flowers of species of the genus *An-*

PHOTOS 1 AND 3 LÚCIA LOHMANN 2 G. GERLACH

Clockwise from left: *Dolichandra unguis-cati*, *Martinella obovata*, *Pyrostegia venusta*, native lianas of the Amazon found nearly throughout the Americas

emopaegma, which are purple, white or yellow, concluded Lohmann and botanist Suzana Alcantara after analyzing the evolution of 12 anatomical characteristics of Bignonieae flowers. "The flowers of the first Bignonieae were probably purple and pollinated by small bees," Alcantara says.

The external morphology of the flowers, however, appears to be the characteristic most subject to change. Although most of these flowers are pollinated by bees, those with more vivid colors (reds and yellows) and a shape that facilitates pollination by hummingbirds appeared 11 times among the 104 species analyzed by Alcantara and Lohmann. Flowers that were generally white, had a narrow elongated tube, and released an intense perfume attractive to butterflies appeared five additional times. However, what actually appears to have influenced the spread of these plants are environmental characteristics such as the availability of water and light and temperature variations.

NEW FRONTIERS

From the coast, the Bignonieae traversed a long path through the Americas. They arrived in the region that is now the Amazon, home to the world's greatest species diversity, 39 million years ago. From there, they spread to the Andes and to Central and North America. Then, 27 million years ago, they spread into the Cerrado, the Caatinga and the Chaco.

Whenever these plants migrated to these dryer ecosystems, they underwent drastic changes in morphology: climbing plants gave way to shrubs, with a variety of probable adaptations to the new environment where there was greater luminosity and the plants did not need to climb a tree to receive light.

During this migration, these plants lost their tendrils, which are the filaments that spiral up the trunks of trees and enable the plants to reach the forest canopy. At the same time, small nectar-producing structures on the stem and leaves—the extrafloral nectaries—appear to have stopped performing a protective function. In the forest, they exist in greater quantity and attract ants, which in turn drive away herbivorous insects. "At each transition of humid forests to dryer areas, the number of nectaries decreased, altering the interactions of these nectaries with ants and herbivores," explains ecologist Anselmo Nogueira, a member of Lohmann's team. "These morphological transitions opened the door to other environments for the Bignonieae and probably enabled them to diversify so much," he says.

Lohmann and her team are currently compiling data on the timing of the appearance and disappearance of these and other characteristics of the Bignonieae. It is an attempt to understand whether the changes are innovations that enabled these plants to occupy new environments, or whether they occurred after the arrival of new biomes as an adaptation to different environmental conditions. "The evolutionary history of the Bignonieae," Lohmann believes, "can help us explain the origins and evolution of tropical ecosystems in general." ■

Projects

1. Systematics of the tribe Bignonieae (Bignoniaceae) (nº 2011/50859-2); Regular Line of Research Project Award; **Coord.** Lúcia Garcez Lohmann – IB/USP; **Investment** R$721,836.88 (FAPESP)
2. Structure and evolution of the Amazonian biota and its environment: An integrative approach (nº 2012/50260-6); Biota Program – Thematic project; **Coord.** Lúcia Garcez Lohmann – IB/USP; **Investment** R$2,974,606.54 / US$461,132.00 (FAPESP).

Scientific articles

LOHMANN, L. G. *et al.* Pattern and timing of biogeographic history in the neotropical tribe Bignonieae. **Botanical Journal of the Linnean Society**. 2012.