Take a stroll through the Arboretum during the growing season and you may come to appreciate the diversity of form, color, and fragrance represented by the flowers you encounter. In a similar vein, you also may be struck by the many types of pollinators you see, from moths and butterflies to flies and bees and even hummingbirds. Through natural selection, plants have evolved traits and floral structures that favor interactions with specific pollinators, which in turn have evolved to reinforce these symbiotic relationships. Studying these associations from a number of evolutionary and genetic perspectives is Robin Hopkins, PhD, Assistant Professor of Organismic and Evolutionary Biology (OEB), and one of three Harvard faculty—along with Director William (Ned) Friedman and Assistant Professor of OEB Elizabeth Wolковich—holding joint appointments with the Arnold Arboretum.

As an undergraduate in biology at Brown University, Robin studied adaptation and diversity across natural ranges in plants, topics that ignited her interest in the dynamic interplay between plant populations and the environments they inhabit. Her specialization on these issues developed further during her graduate studies at Duke University, where her PhD work centered on how plant species form—from investigating the traits that are important in distinguishing individual species to revealing the factors that keep different species from hybridizing. Her published findings in this arena have received much favorable attention, and her research is credited with being the first to use a natural system to identify the genetic basis of reinforcement—the process by which natural selection increases reproductive isolation. Since her arrival as a faculty researcher at the Arboretum in January, Robin has pursued a growing focus on the role that natural selection plays in causing diverging plant populations to become distinct species, through field experiments, molecular studies, population genetic analyses, and pollinator behavior trials.

Q. How did you become interested in plants and the science of speciation?
A. I was raised in rural Vermont and began gardening with my Mom before I could walk, so I suppose that I’ve always loved plants and flowers. From a very young age I was also drawn to science, and for a long time I resisted the idea of becoming a plant biologist because I was worried that I would love plants less if I had to work with them every day! Happily, I came around to realizing that it is possible to love what you do. My interests as a researcher grew directly out of the laboratory experiences that engaged me as an undergraduate at Brown and subsequently in my PhD studies at Duke. While many aspects of plants sparked my interest, it was the question of how plant species form—what traits are important in distinguishing individual species, and the factors that keep different species from reproducing with each other—that I kept returning to again and again. This area of study led directly to my interest in how morphological or formal characteristics of flowers—like color, shape, and scent—can manipulate the behavior of the pollinators that facilitate plant reproduction.
Q. What about this area of study captured your imagination?
A. The direction of my work in science has always been aimed at understanding biodiversity. One of the big unknowns that has daunted evolutionary biologists is how individual species form. So the questions I’m pursuing are important because it’s only when species lose the ability to reproduce with other species that they begin to evolve very distinct differences. It’s the barriers between species that help us to understand the remarkable diversity we see around us, so I am incredibly fascinated by studying the traits that contribute to that process. Since these questions revolve around reproduction, much of it comes down to the flowers—the pollinators they attract, the means flowers employ to attract those pollinators, and when they do so.

Q. Your studies focus primarily on Phlox, a perennial woodland and prairie flower. Why this model system for your research?
A. One of the things that really interests me about this work is delving into the genetic basis of these traits; mutations cause trait differences and natural selection works to either favor or disfavor those differences from being passed on. For this type of work, it’s advantageous to use an annual, herbaceous species that is short-lived and easy to grow and manipulate. Phlox has been extensively studied for over 50 years, so there’s a great deal of literature available on many aspects of its ecology and evolutionary history. This body of work provides background and perspective to my own research. My current investigations focus on flower color, and Phlox exhibits interesting differences in flower color that are involved in this process of species formation. When I was at Duke, I did field work in Texas where there are native populations of Phlox, and I continued this research there as a Post Doc.

Q. Talk about your work studying flower color and speciation—what are some of the highlights of this research for you?
A. I’m deeply interested in the process of reinforcement—the idea that if two species mate with each other and their offspring are either sterile or maladapted in some way, then selection can favor those traits that prevent hybridization from occurring at all. In Phlox, we have two species, Phlox cuspidata and P. drummondii, that tend to hybridize where they grow together, and their offspring are largely sterile. One of the species—P. drummondii—has evolved a change in flower color, and this change appears to drastically decrease instances of hybridization with P. cuspidata. With less hybridization, the two species can coexist in the same environment and have stable populations. So much of my work before I came to the Arboretum centered on finding the genetic basis for this color difference. From there, it becomes a question of how the flower color change stops hybridization.

So I did many field experiments watching the behavior of Phlox pollinators, which are butterflies. What I found is that the butterflies typically visit flowers that are the same color, so if the flowers of two species are different colors, individual pollinators don’t tend to move between them. Essentially, this is how a selective change in flower color can alter hybridization rates. So my future work will look into this pollinator movement in greater depth, particularly how and why the butterflies show this behavior, how plant adaptation affects this behavior, and if there are other plant traits beyond color differences involved.

Q. You point out that these species tend to hybridize despite the selective forces acting against reproduction. Are the limits of reinforcement another way of looking at speciation?
A. Absolutely. An inherent aspect of reinforcement is that two species are actually hybridizing with each other, which allows for some genes to cross over that genetic barrier.

Assistant Professor Robin Hopkins observes flowering specimens of Phlox drummondii in the Weld Hill Research Building’s greenhouses.
The broad scope and ongoing enhancement of children’s education at the Arboretum has been made possible in large part by the contributions and commitment of a dedicated corps of Field Studies volunteers. Coming from a diversity of backgrounds, our volunteer guides absorb many domains of learning through their training and experience in the program—how to leverage the collections and landscape, how to engage and manage groups of children, and how to teach in flexible ways that resonate with all ages and abilities. Their accumulated experiences and valuable insights are essential evaluative tools that have yielded significant improvements to all of the programs.

Three decades and countless impressions later, the Field Study Programs continue to build on the premise that the Arnold Arboretum and its spectacular collections provide exceptional opportunities for learning at every age. By encouraging the natural curiosity of children and drawing on their love of the outdoors, the Arboretum provides fertile ground for building scientific interest and scientific literacy among students, their teachers, and the community.

As we look to the future—and welcome the expertise and perspective of our new Director of Public Programs, Daphne Minner—it’s clear that a strong foundation exists to continue growing these opportunities in previously unimaginable and exhilarating ways.

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between species. So the genetic piece of my research looks at these plants’ genomes to see which genes are passing over that species boundary, and if we can find evidence of past hybridization and determine how that has affected their evolution. In this case, we know hybridization was detrimental enough that traits evolved to slow or stop this process for these two species. However, we also see examples of Phlox species where hybridization appears to have been a good thing, including some examples in the Midwest where adaptive traits moved across that species barrier and resulted in increased fitness. Much of my future work will be directed at understanding both the good and the bad of hybridization.

Q. Selection of favorable traits plays an important role in horticulture—much of what we’re talking about is applicable to this aspect of the Arnold Arboretum.

A. Yes, horticulture relies heavily on hybridization to create new cultivars with desirable traits, from more abundant flowers or tastier fruits to more expansive hardiness ranges or greater pest tolerance. We depend on hybridization for most of what we eat. Corn for example is a crop that is only available in hybrid form. We count on “hybrid vigor”—the idea that crossing two very distinct organisms can create particularly robust offspring. However, while hybridization can create diversity, it can also hurt diversity, particularly if the offspring produced are sterile so that populations in general dwindle, or if fertile offspring end up out-competing other diverse communities of insects, birds, and other wildlife that depend on them. The diversity of plants and the organisms that pollinate them is critical to maintaining healthy environments, so from an ecological perspective there is so much we can share here to raise awareness about how these things fit together to make a healthy planet. This is particularly important now, as we see more and more plants becoming endangered in their native habitats, as well as threats to pollinators like honeybees and butterflies through pesticides, disease, and compromised habitats.