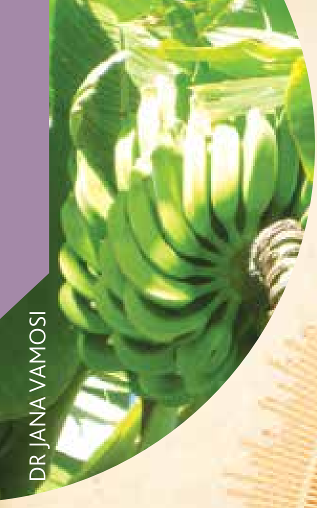


Flowers and phylogenetics

Dr Jana Vamosi clarifies how her research into pollination and selection pressures has contributed to further understanding the incredible biodiversity that exists among flowering plants

By way of an introduction, can you outline how you became interested in the field of plant evolutionary biology? What experiences have helped shape your career so far?

I began graduate school studying the evolution of sex in yeast. While completing my coursework, I stumbled upon claims that little was known about the consequences of separate sexes in flowering plants in terms of speciation and extinction. I couldn't stop working on this as a side project and it eventually became my new PhD thesis. I was alarmed by the rate of extinction of plant species and my research has progressed toward determining the consequences of extinction to ecosystems.

Could you describe the main objectives of your research into the drivers of flower diversity – otherwise known as Darwin's 'abominable mystery'?

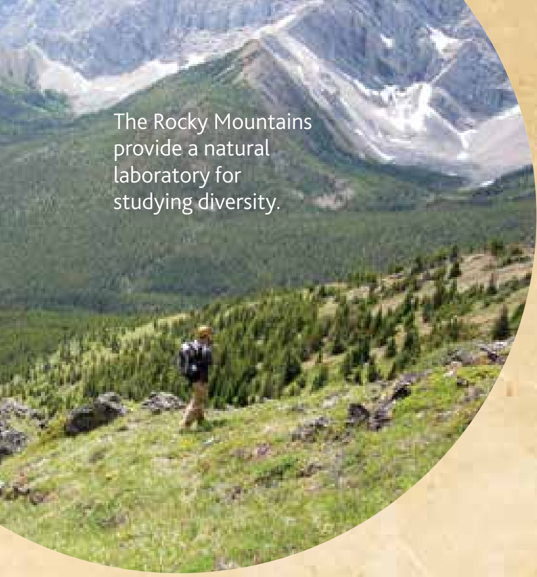
One objective is to uncover how the association with pollinators influences diversity in flowering plants. Spatially separated populations of plants are often faced with a different contingent of pollinators, as well as a different community of competing plants for these pollinators. My research aims to tease apart these sources of complexity as a driving force producing divergent selection pressures and, consequently, diversity.

What methods are you using to study the underlying forces that spur diversity?

My investigations explore the idea that every plant survives, reproduces or dies, in part due to the genetic legacy inherited from its ancestors as well as its neighbours and pollinators. When dealing with a community of plants, it can be useful to summarise the strength of this legacy with the techniques of comparative phylogenetics. This can entail depicting the relationships between all the members of a community with a phylogeny, and investigating whether, for instance, a greater number of close relatives and similar plants coexist at a site than one would expect through random chance.

How close are you to resolving this mystery? At what stage is your research currently?

Darwin's 'mystery' specifically refers to the contrast in diversity between angiosperms (flowering plants) and gymnosperms (seed-producing plants), their sister lineage. I don't work at that level of comparison but it seems that the relationship between flowering plants and their pollinators is one major force driving differences in rates of speciation between these two major groups. However, similar mysteries abound when diversity between lineages of flowering plants are contrasted. My findings currently indicate that geographical aspects of a plant lineage matter as much or more than plant traits in determining evolutionary success. Now the challenge becomes understanding what determines whether a plant species becomes widespread or remains rare and restricted to a small area –



The Rocky Mountains provide a natural laboratory for studying diversity.

is it traits relating to pollination and dispersal or just sheer luck?

What challenges have emerged with this work and how have they been overcome?

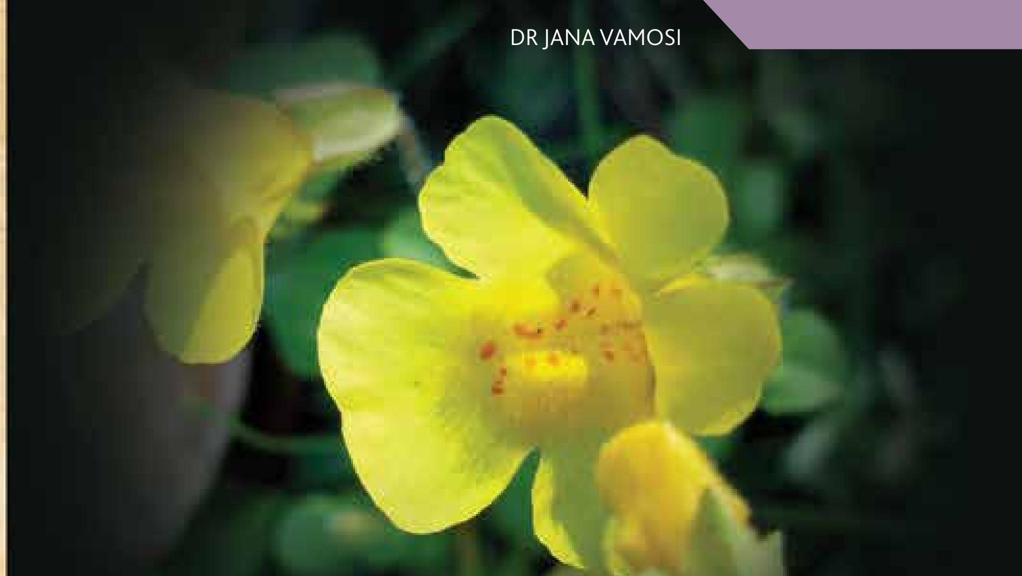
Research is constantly plagued with challenges but half the fun is overcoming them. One challenge for my research is obtaining reliable phylogenies for the groups I wish to study. For plants, disparate lineages can often hybridise and double their genomes, making this process difficult. Possibly the biggest challenge, however, is studying the community of pollinators. There are very few people with the advanced expertise to identify bees and other insects to species level. One of the main objectives of the Canadian Pollination Initiative (CANPOLIN) was to train the next generation of insect taxonomists and provide the keys necessary so that botanists like me can better understand how plant mutualists are changing over biogeographical gradients.

How important is collaboration to the advancement of your research?

Collaboration is critical. I like to employ innovative approaches that borrow techniques from many different fields. Because my research can be wide-ranging in the threads we're trying to weave together, I often need the help and expertise of the individuals with specialised knowledge.

What are your expectations for the future of your research?

We're now exploring how landscape influences the selection pressures on a plant population. Mountainous areas seem to be hotspots of speciation and one can see how a series of isolated peaks produces a landscape much like an island archipelago. We are investigating whether the heterogeneity of pollinators to plant populations on isolated peaks, combined with the climate niche limitations on dispersal, is enough to produce high rates of speciation.



Revealing relationships

The Department of Biological Sciences at the University of Calgary, Canada, is home to a laboratory exploring speciation and extinction rates in plants through the lens of evolutionary analysis

PLANTS ARE THE foundation of most life on Earth and an essential resource for human health and wellbeing. Maintaining plant biodiversity is hugely important, not least because plants provide oxygen, form the backbone of ecosystems and are a source for innovative new medicines. While plant biodiversity ensures ecosystem resilience, plant extinctions herald significant negative impacts on the humans and wildlife that depend on them. Alarmingly, of approximately 350,000 species of plants in the world, it has been estimated that over 10 per cent are struggling to survive.

Dr Jana Vamosi, an associate professor in Evolutionary Biology at the University of Calgary, Canada, uses a combination of experimental and phylogenetic approaches to explore how pollination and sexual systems influence speciation and extinction rates in plants. Vamosi aims to determine how the evolutionary relationships among species can lead to increased or decreased diversity within angiosperms – flowering plants. She employs innovative evolutionary applications, using plant and pollinator phylogenies as tools to gain insight into which aspects of biodiversity impact ecosystems and, consequently, human welfare.

UNDERSTANDING BIODIVERSITY

Vamosi has made important steps towards explaining what drives flowering plant diversity. In a joint study with Dr Steven Vamosi, a population biologist at the University of Calgary, the researchers found that the size of the geographical area is the most important contributing factor to plant biodiversity, suggesting that available area places limits on species richness: "The number of species in a lineage is most keenly determined by the size of the continent – or continents – that it occupies," Dr Jana Vamosi explains.

The study has examined the effects of age, ecoregion area and four ecological traits on diversification in 409 angiosperm families. The results show a low phylogenetic signal of diversification and support the idea that ecological limits play a major role in setting the carrying capacity for a lineage. However, within the wider context of available area, traits associated with biotic pollination (zygomorphy) were consistently found to contribute to increased species richness.

The next challenge in understanding plant diversification involves characterising ecological limits and determining whether biotic interactions influence the carrying capacity of angiosperm clades within a given area. While the results of the study mostly help to explain what drives diversity, they may also comment on what produces extinction patterns if it can be established that patterns of extinction risk mirror those observed for diversification.

POLLEN LIMITATION PATTERNS

Vamosi has also conducted extensive research into pollen limitation in biodiversity hotspots, such as tropical rainforests. Published in January 2006, one central study involved a meta-analysis of over 1,000 studies from around the world, revealing a strong positive correlation between regional species richness and the magnitude of pollen limitation. This finding is consistent with the hypothesis that competition among co-flowering species for pollinators reduces plant reproductive success.

Vamosi points out that this pattern may arise for a number of reasons: "Pollinators are more often in short supply in biodiversity hotspots, and plants suffer greater fitness consequences when pollinators deliver pollen from closely-related species in the area. Biodiversity hotspots

INTELLIGENCE

PLANT BIODIVERSITY LAB

OBJECTIVES

Research in the Vamosi Plant Biodiversity Lab investigates:

- The role of evolutionary history and diversity on key ecosystem functions, such as pollination
- The effects of loss of phylogenetic diversity on ecosystems
- How changes to the environment affect plant-insect interactions

KEY COLLABORATORS

Professor Jeremy T Kerr, Canadian Facility for Ecoinformatics Research, University of Ottawa, Canada

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JANA VAMOSI is an Associate Professor at the University of Calgary, Canada. Her research in plant and pollinator biodiversity spans a wide spectrum of subdisciplines, scaling from characterising the ecosystem services provided by diversity to understanding how climate affects global patterns of seed and fruit production. The research is innovative in incorporating evolutionary history to better understand the benefits of biodiversity.

Vamosi employs innovative evolutionary applications to gain insight into which aspects of biodiversity impact the ecosystem and, consequently, human welfare

are more closely packed with close relatives, meaning these plant species suffer from low-quality pollen delivery".

CONSERVATION IMPLICATIONS

The positive correlation between pollen limitation and high diversity environments could be the result of recent changes to these areas, such as increased habitat destruction, climate change and the introduction of alien species. In this case, pollen limitation may lead to increased extinction risk, thereby threatening the maintenance of global plant biodiversity and, as a result, ecosystems at large. This could have serious consequences for human welfare because fruit or seed production from 76 per cent of the 115 leading global food crops is dependent on animal pollination.

It is posited that this correlation may have existed over evolutionary timescales, with pollen limitation and competition for pollinators being a driver of speciation in angiosperms. In other words, the presence of numerous species creates competition for pollinators so that plants then evolve to specialise in particular types of these biotic agents: "There is the intriguing possibility that being in the vicinity of relatives puts strong selection pressures on a plant population, which may in turn precipitate a speciation event," elucidates Vamosi. "Consequently, this may place resulting plant species in the proximity of even more close relatives: in other words, a positive feedback loop arises."

In further research involving both cross-species and comparative phylogenetic meta-analyses, evidence was found to suggest that self-incompatible endemic species from biodiversity hotspots are at greatest risk of pollination failure. This previously unknown aspect has enormous implications for the future development of conservation strategies, suggesting that increased efforts should be devoted to the assessment of consequences for plant fecundity and population demography in high diversity areas.

PHYLOGENETICS AND FOOD SECURITY

Vamosi has also contributed to groundbreaking research into the globalisation and distribution of the human diet. In the first ever study of its kind, she collaborated with a team of scientists from the DST-NRF Centre for Invasion Biology at Stellenbosch University, South Africa, in order to examine the phylogenetic patterns in plants consumed by humans. The results, which showed that the human diet is broad and diverse, yet still phylogenetically patterned, refuted implications in previous studies that a broad human diet is simply indicative of opportunistic feeding.

Assessing the diversity of plants in the human diet from a phylogenetic perspective has important implications for agriculture, dietary science and plant conservation. The research flagged up a 'phylogenetic signal' for plant edibility, reveals Vamosi: "The downstream implication of this finding was that it suggested that there were a number of plant species in the 'edible spectrum' that we do not currently eat but probably could, and this may be relevant for our food security".

The study has opened the way for future comparisons with the diet breadth of other species, which may help to further explain the role that an increase in potential food items had in hominid evolution.

FUTURE DEVELOPMENTS

Although currently exploring more applied avenues for how plant and pollinator diversity affect ecosystem services (eg. crop yields), Vamosi also plans to continue investigating the relationships between different plant traits, pollination, climate change and latitude at a global scale through spatially explicit modelling and comparative analysis.

In addition, she is involved in a new initiative investigating Canada's phylogenetic diversity in a changing world, which has been launched in response to the finding that both range and changing climate alter the evolutionary potential of lineages. Vamosi describes how this working group, recently funded by the Canadian Institute of Ecology and Evolution, will be using species distribution modelling to project how patches of habitat are expected to change over the next 50 years: "Combined with new understanding of how phylogenetic diversity influences the fitness of focal species, we should be able to help predict what lineages are to suffer the highest losses of species, as well as gain insight into whether we are situated to experience acceleration of extinction rates".