Introductory Biology 152 Independent Project (IP) Information

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Mentors:
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Overview:

Plants are an integral part of the earth's biosphere. Through photosynthesis, they fix carbon into biomass, forming the base of all terrestrial ecosystems globally. Plant leaves, the primary organ for photosynthesis and carbon gain, exhibit considerable morphological, physiological, and chemical variation within and among species. Often this variability occurs along gradients in plant resources, like light, water, and nutrients, in observable and meaningful ways. Determining the drivers of this variability in leaf form and function is thus key for understanding global ecosystem processes and providing important insight into plant adaptation and evolution.

Beginning with Alexander von Humboldt at the turn of the 19th century (Figure 1), scientists have long been fascinated by regular, repeated elevational shifts in plant form and function on mountains. In the northeastern United States, complex topography contributes to considerable variability in plant communities with elevation. Temperate broadleaf deciduous forests dominated by sugar maple and American beech at low elevations transition to boreal evergreen forests dominated by red spruce and balsam at high elevations, with alpine tundra communities of low shrubs, grasses, and forbs persisting on exposed mountain tops. **We look to explore the causes of these shifts in plant communities and plant form and function along a steep environmental gradient on Mt. Washington, the tallest peak in northeastern North America.**

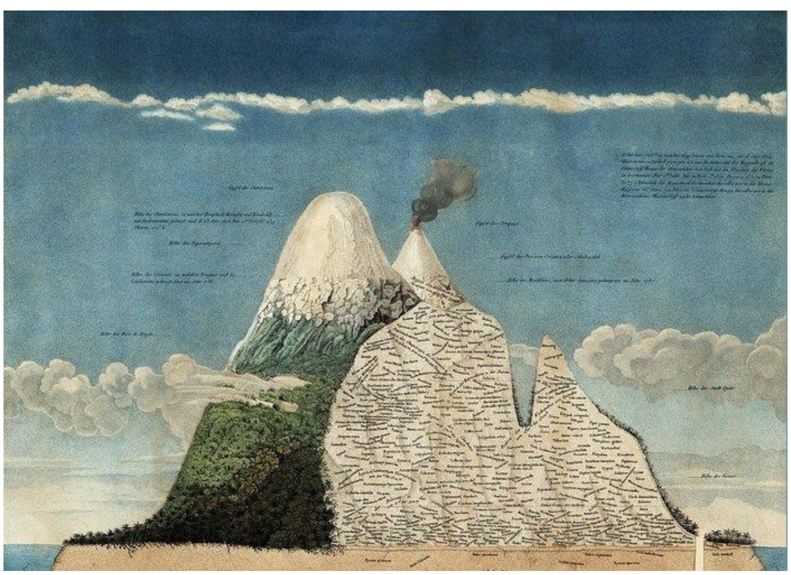

Figure 1. Drawing by Alexander von Humboldt of Chimborazo, a dormant stratovolcano in South American he visited in 1802, with a detailed accounting of the distribution of dominant place species across the mountain.

This semester, we will process leaves collected from hundreds of individuals across 27 species of woody plants along this elevational gradient in summer 2023. In particular, we will: (1) measure the weight and area of individual leaves to determine variability in these traits within and among species across elevation; and (2) grind leaf tissue for subsequent analyses on variability in leaf chemistry across elevation. This research is timely and will improve our understanding of plant biology, plant community ecology, and whole ecosystem functioning along major environmental gradients.

Expectations:
Time commitment: 10 hrs/week including a routine schedule of ~6 hrs/week working in the lab is expected. As the semester progresses, the balance between leaf weighing, photo processing, reading relevant primary literature, data analyses, and writing will shift as you prepare your project, but 10 hrs/week is still expected. A general description of each component of this research project is outlined below.

- *Leaf weighing and photo processing:* You will work closely with Nathan at the beginning of the semester to familiarize yourself with protocols for leaf weighing and photo processing. Leaf weighing will be conducted on a micro-balance in the Damschen research lab (Birge 445). You will be provided with the key code to access the lab and coordinate use of the lab space with other researchers. After leaf weighing gets underway, you will begin to incorporate leaf image processing in ImageJ to the weekly data collection routine. As with weighing, you will work with an established protocol that you will become familiar with early in the semester.
- *Reading literature*: Reading and understanding scientific literature is among the more challenging but important activities in science. At the beginning of the semester, Nathan will work with you on best practices for reading for understanding. Required and recommended papers have been provided at the end of this document to use as a starting point for engaging with the literature you will become familiar with this semester.
- *Data analyses:* After leaf weighing and photo processing, data will be analyzed using Microsoft Excel and the programming language R. You are not expected to have prior familiarity with R but will gain basic proficiency in coding and data analysis through this project. NOTE: you are part of a larger research team conducting similar data collection and analyses. As a result, the analyses you conduct for your independent project *may* be on species for which you did not process samples. We will coordinate early in the semester among researchers who will oversee which species!
- *Writing:* Like reading scientific literature, writing scientific literature is a continual process of improvement that takes time and effort. Biology 152 provides deadlines for writing throughout the semester, with each being an opportunity for Nathan and an assigned Independent Project reviewer to provide feedback.
- *Regular meetings*: You will meet periodically with Nathan throughout the semester to provide updates on progress and discuss whatever is most timely (e.g., data processing, analyses, writing, etc.). We will tentatively schedule these for a 30-minute time slot every week but will be flexible with scheduling as needed.

Readings

Starred (*) readings are required and should be read at the beginning of the project. The remainder are meant to introduce you to the literature you will likely need for writing your final paper. Be sure to utilize them not only for content but also for finding more papers worth reading! The references section of each paper is an excellent place to find relevant literature. Many of these papers are accessible through [UW-Madison libraries] or [Google Scholar].

Species distributions along environmental gradients

* Bliss, L. C. 1963. Alpine plant communities of the Presidential Range, New Hampshire. *Ecology* 44(4):678-697 https://doi.org/10.2307/1933014.

Curtis, J. T. and R. P. McIntosh. 1951. An upland forest continuum in the prairie-forest border region in Wisconsin. *Ecology* 32(3):476-496 https://doi.org/10.2307/1931725.

Harmon, M. E., S. P. Bratton, and P. S. White. 1984. Disturbance and vegetation response in relation to environmental gradients in the Great Smokey Mountains. *Vegetatio* 55:129-139 https://doi.org/10.1007/BF00045013.

Maharjan, S. K., F. J. Sterck, N. Raes, and L. Poorter. 2022. Temperature and soils predict the distribution of plant species along the Himalayan elevational gradient. *Journal of Tropical Ecology* 38:58-70 https://doi.org/10.1017/S026646742100050X.

* Sardinero, S. 2000. Classification and ordination of plant communities along an altitudinal gradient on the Presidential Range, New Hampshire, USA. *Plant Ecology* 148:81-103 https://doi.org/10.1023/A:1009853730949.

Whittaker, R. H. 1956. Vegetation of the Great Smoky Mountains. *Ecological Monographs* 26(1):1-80 https://doi.org/10.2307/1943577.

Background on leaf traits, form, and function

Diaz, S., J. Kattge, J. H. C. Cornelissen, I. J. Wright, S. Lavorel, S. Dray, B. Reu, M. Kleyer, C. Wirth, I. C. Prentice, *et al.* 2016. The global spectrum of plant form and function. *Nature* 529:167-171 https://doi.org/10.1038/nature16489.

* Jung, V., C. Violle, C. Mondy, L. Hoffmann, and S. Muller. 2010. Intraspecific variability and trait-based community assembly. *Journal of Ecology* 98:1134-1140 https://doi.org/10.1111/j.1365-2745.2010.01687.x.

* Reich, P. B., M. B. Walters, and D. S. Ellsworth. 1997. From tropics to tundra: global convergence in plant functioning. *Proceedings of the National Academy of Science* 94(25): 13730-13734 https://doi.org/10.1073/pnas.94.25.13730.

Nicotra, A. B., A. Leigh, C. K. Boyce, C. S. Jones, K. J. Niklas, D. L. Royer, and H. Tsukaya. 2011. The evolution and functional significance of leaf shape in the angiosperms. *Functional Plant Biology* 38(7):535-552 https://doi.org/10.1071/FP11057.

* Wright, I. J., P. B. Reich, M. Westoby, D. D. Ackerly, Z. Baruch, F. Bongers, J. Cavender-Bares, T. Chapin, J. H. C. Cornelissen, M. Diemer, *et al.* 2004. The worldwide leaf economics spectrum. *Nature* 428:821-827 https://doi.org/10.1038/nature02403.

Wright, I. J., N. Dong, V. Maire, I. C. Prentice, M. Westoby, S. Diaz, R. V. Gallagher, B. F. Jacobs, R. Kooyman, E. A. Law, *et al.* 2017. Global climatic drivers of leaf size. *Science* 357(6354):917-921 https://doi.org/10.1126/science.aal4760.

Leaf trait variation with elevation

Gordillo, A. L. H., S. V. Mendoza, M. A. N. Being, D. Delgado, and B. Finegan. 2021. Altitude and community traits explain rain forest stand dynamics over a 2370-m altitudinal gradient in Costa Rica. *Ecosphere* 12(12):e03867 https://doi.org/10.1002/ecs2.3867.

Joel, G., G. Aplet, and P. M. Vitousek. 1994. Leaf morphology along environmental gradients in Hawaiian *Metrosideros polymorpha*. *Biotropica* 26(1):17-22 https://doi.org/10.2307/2389106.

Ke, X., H. Kang, and Y. Tang. 2022. Reduction in leaf size at higher altitudes across 39 broad-leaved herbaceous species on the northeastern Qinghai-Tibetan Plateau. *Journal of Plant Ecology* 15(6):1227-1240 https://doi.org/10.1093/jpe/rtac051.

Li, Y., D. Zou, N. Shrestha, X. Xu, Q. Wang, W. Jia, and Z. Wang. 2020. Spatiotemporal variation in leaf size and shape in response to climate. *Journal of Plant Ecology* 13(1):87-96 https://doi.org/10.1093/jpe/rtz053.

* Liu, W., L. Zheng, and D. Qi. 2020. Variation in leaf traits at different altitudes reflects the adaptive strategy of plants to environmental changes. *Ecology and Evolution* 10:8166-8175 https://doi.org/10.1002/ece3.6519.

* Morecroft, M. D., F. I. Woodward, and R. H. Marris. 1992. Altitudinal trends in leaf nutrient contents, leaf size, and $\delta^{13}C$ of *Alchemilla alpina*. *Functional Ecology* 6(6):730-740 https://doi.org/10.2307/2389970.

* Peng, Y., K. J. Bloomfield, and I. C. Prentice. 2020. A theory of plant function helps to explain leaf-trait and productivity responses to elevation. *New Phytologist* 226:1274-1284 https://doi.org/10.1111/nph.16447.

* Read, Q. D., L. C. Moorhead, N. G. Swenson, J. K. Bailey, and N. J. Sanders. 2014. Convergent effects of elevation on functional leaf traits within and among species. *Functional Ecology* 28:37-45 https://doi.org/10.1111/1365-2435.12162.