MILLER INSTITUTE NEWSLETTER

Spring 2007

Miller Fellow Focus: Jarmila Pittermann

THE EVOLUTIONARY ECO-PHYSIOLOGY OF THE REDWOOD FAMILY

Few plants can match the impressive stature of California's endemic Coast Redwood and Giant Sequoia trees. Given their substantial height and girth, they are some of the world's most compelling organisms and their appeal lures considerable amounts of tourists to California each year. It is unfortunate however that the redwood relatives, species such as Bald Cypress and Dawn Redwood rarely conjure such collective adulation despite being charismatic in their own right. This is probably because most people don't realize that the redwoods, as well as their 11 nearest relatives comprise a unique group of conifers called the 'Taxodiaceae', which were once a dominant element of Cretaceous to Eocene (120-50 m.y.a.) forests and most certainly co-existed with some of the dinosaur fauna of that time. Given the unique role of the Taxodiaceae in the development of the faunal and floristic components of the Northern Hemisphere, it is surprising that so little is known about the biology of these unique gymnosperms. What are the physiological features that allowed this intriguing group of conifers to effectively exploit their ancient habitat, and how have those features impacted their evolutionary trajectories and current distributions? As a Miller Fellow working with Todd Dawson and Bruce Baldwin in the Department of Integrative Biology, Jarmila hopes to provide insight into the evolutionary structure-function trends of the Taxodiaceae by integrating the physiology, phylogeny and fossil record of this intriguing group of conifers.

THE 'TAXODIACEAOUS' CONIFERS WERE ONCE WIDESPREAD

The fossil record indicates that Taxodiaceous taxa such as Coast Redwoods, Bald Cypress and Dawn Redwoods once dominated the northern hemisphere forests and their range extended as far as the Arctic. In fact, some of the most abundant Taxodiaceous fossil finds are from the Eocene (45 m.y.a.) deposits at Axel Heiberg Island in Nunavut, Canada where petrified as well as mummified trees and leaf litter are all that remains of once temperate forests and swamps rich in Dawn Redwood and Bald Cypress-like trees. Climate modelers tell us that the mean global temperature characteristic of the Cretaceous to Eocene epochs was on average 6 to 14ºC warmer than it is today, a phenomenon that may be attributed to atmospheric CO_2 levels of at least 800 ppm. The nature of the taxa at other fossil deposits at high latitudes, such as in Greenland and Siberia are consistent with geological evidence that from the Cretaceous through to the Eocene epochs, it was truly a greenhouse world.

By contrast, today's Taxodiaceous taxa are restricted to small, relictual populations sprinkled mostly across California, Louisiana and Asia. Modern-day species generally inhabit a variety of temperature and moisture regimes but for the most part, they prefer temperate climates with high water availability. Interestingly, the fossil record indicates that the abundance of Taxodiaceous taxa declines precipitously during the Miocene epoch (15 m.y.a.). What

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Announcement: Call for Nominations

Miller Fellow nominations are due on
Thursday, September 13, 2007

Miller Professor applications are due on
Thursday, September 20, 2007

Visiting Miller Professsor departmental nominations are due on
Monday, September 24, 2007

Please see the enclosed insert for details on making nominations for the Miller Fellowship program. For complete information on all our programs, visit: http://millerinstitute.berkeley.edu

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caused the post-Eocene global reductions in Taxodiaceous conifers, and can we formulate some testable hypotheses that link climate to species' physiology?

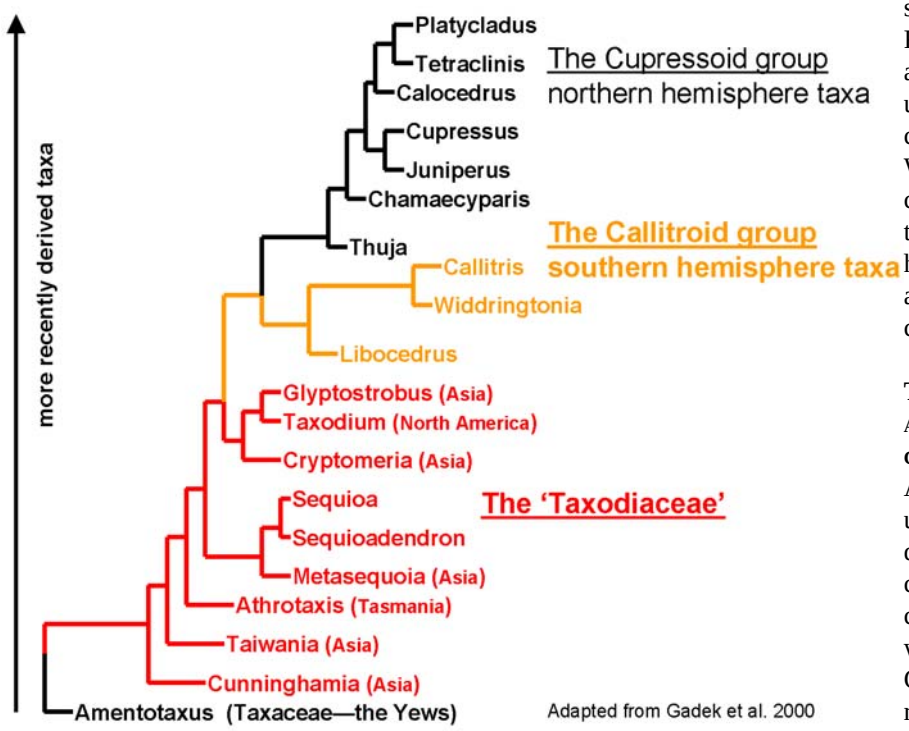
The post-Miocene climates may have contributed to reductions in redwood distributions

The Miocene was a unique period in the earth's climate. Phenomena such as continental chemical weathering in combination with increased marine organic carbon burial are thought to have acted to reduce atmospheric CO_2 to levels as low as 180 ppm. Such low CO_2 levels may have 'primed' the climate for the reductions in temperature, increased continental aridity and greater frequency of glacial periods that characterize this epoch. How would the shift from an Eocene greenhouse world to one that is drier, more temperate and relatively deficient in atmospheric CO_2 impact the physiology of Taxodiaceous conifers? Jarmila suspects that this combination of abiotic factors may have compromised the physiology, and thereby the reproductive fitness of the Taxodiaceae to the point where they became less competitive with other taxa, conifer and otherwise.

To test the effect of varying atmospheric CO_2 levels on Taxodiaceae physiology, Jarmila is growing selected Taxodiaceous conifers and their closest ecological equivalents from the Pine family (8 species in total) in growth cabinets under conditions of both elevated Eocene-like (800 ppm) and sub-ambient Miocene-like CO_2 (280 ppm) levels. She is hypothesizing that relative to the Pinaceae, the Taxodiaceous species will exhibit reduced photosynthetic rates when grown at sub-ambient CO_2 levels. This hypothesis is based on what is known about the Taxodiaceous ancestry which extends back to the moist, high CO_2 Cretaceous epoch, and the continued overall preference of modern taxa for environments with reliable water inputs. Alternatively, the Taxodiaceae may outperform the Pinaceae at the elevated CO_2 levels that are consistent with the strong presence of the Taxodiaceae in the earth's flora during the Eocene. Although we cannot make the assumption that extant species are equivalent representatives of their possibly extinct ancestors, it does appear that in large part, the physiology of the Taxodiaceae may have been conserved. Some components of this project will be performed in collaboration with Dr. Lenny Kouwenberg, a paleobotanist at the Field Museum at the University of Chicago.

Redwoods on campus at UC Berkeley.

Unlike CO_2 studies, evaluating the effect of increased aridity on Taxodiaceous and Pinaceous ecological analogues is technically simple because a reduction in water input is all that is required. In other words, Jarmila will cease to water her trees for a period of time during which she will measure plant water status, photosynthesis and transpiration. This data will be coupled to leaf-level hydraulic measurements because the leaves exert either short- and/or long-term control over plant performance under drought conditions, and the response is species-specific. Interestingly, Coast Redwood transpires water nocturnally, a phenomenon that challenges our understanding of the general water conservation strategies of plants. Whether or not other Taxodiaceaous conifers lose water nocturnally remains to be seen, but one can easily imagine how a climatic shift toward increased aridity would render water loss without carbon fixation a maladaptive process.



A combined molecular and morphological phylogeny of the Cupressaceae with the Taxodiaceous grade highlighted in red. Members of the Taxodiaceae are endemic to both the northern and southern hemispheres.

The Taxodiaceae are thought to be ancestral members of the Cupressaceae

A useful method that allows us to understand the evolutionary directionality of the Taxodiaceous conifers' physiology is to examine certain key, functional traits broadly within the cypress family that is the Cupressaceae. Although many researchers continue to recognize the Taxodiaceae as a unique group of

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Miller Research Fellowship Awards 2007-2010

The Miller Institute is pleased to announce the 2007-2010 Miller Research Fellows. Each year, the Miller Institute seeks to discover individuals of outstanding talent and to bring to Berkeley young scholars of great promise. Candidates are nominated for these awards and are selected on the basis of their academic achievement and the potential of their scientific research. They will be working with Berkeley faculty for a three-year term beginning in the 2007 academic year.

Theodor Agapie

Ph.D. California Institute of Technology
Berkeley Department: Chemistry
Faculty Sponsor: Michael Marletta

Dr. Agapie is interested in the mechanism of biosynthetic and signaling pathways and, broadly defined, the role of metals in these contexts. His research will focus on fundamental processes involved in the biological formation and regulation of nitric oxide.

Tessa Burch-Smith

Ph.D. Yale University
Berkeley Dept: Plant & Microbial Biology
Faculty Sponsor: Patricia Zambryski

Despite having rigid cell walls, plant cells do not exist in isolation but rather, communicate with each other through channels known as plasmodesmata (PD). The sizes of PD can be modified to facilitate, or limit, the transit of signaling molecules including nucleic acids and proteins, which are crucial for plant development and defense. Dr. Burch-Smith will study how PD aperture is regulated to control the movement of endogenous signaling molecules.

Tanja Cuk

Ph.D. Stanford University
Berkeley Department: Physics
Faculty Sponsor: Joseph Orenstein

Dr. Cuk's area of research is experimental condensed matter physics. Her PhD investigated the high-Tc superconductors using optical spectroscopies and high pressures. At Berkeley, she will be looking at the dynamics of structural and electronic properties of materials using time-resolved optical spectroscopies and x-ray diffraction

Christopher Douglas

Ph.D. Massachusetts Institute of Technology
Berkeley Department: Mathematics
Faculty Sponsor: Peter Teichner

Dr. Douglas is interested in algebraic topology and its application to problems in geometry and mathematical physics. His research focuses on developing algebraic invariants for studying the topology of infinite-dimensional manifolds.
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Thomas Hunt

Ph.D. Harvard University
Berkeley Depts: Bioengineering / Chemistry
Faculty Sponsors: Daniel Fletcher (Bioengineering) & Richard Mathies (Chemistry)

Tom combines microfluidics and microelectronics to build fast, sensitive detectors and manipulation systems. With these tools, we can rapidly examine statistical numbers of individual cells to improve our understanding of complex, stochastic cellular behavior such as motility and cell-cell interaction.

Julius Lucks

Ph.D. Harvard University
Berkeley Department: Bioengineering
Faculty Sponsor: Adam Arkin

Viruses infect almost every known organism on the planet. Even the bacteria that infect our gut are themselves infected by viruses. To achieve such omnipresence, viruses must be more abundant and diverse than all animals, plants and unicellular organisms combined. Using viruses that infect bacteria as a model system, Mr. Lucks has studied viral evolution through comparative genomics techniques that have revealed non-trivial patterns in viral

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genomes that reflect the necessity of the viral host for the virus' replication. His research as a Miller Fellow will expand methods developed for this study to viruses of eukaryotes, with the aim of furthering our understanding of these parasites in order to better understand their hosts.

Frederik Matsen

Ph.D. Harvard University
Berkeley Department: Statistics
Faculty Sponsor: Steven Evans

I develop mathematical techniques and computer algorithms to improve our understanding of evolution. Currently, my main focus is on phylogenetic reconstruction, which is the inference of evolutionary history from present-day genetic material. I am also interested in ways of quantifying the "shape" or overall structure of tree diagrams representing evolutionary history.

Maryam Modjaz

Ph.D. Harvard University
Berkeley Department: Astronomy
Faculty Sponsor: Alex Filippenko

Massive stars die violently. Dr. Modjaz is interested in understanding explosions of very massive stars that either die as Supernovae or as Gamma-Ray Bursts. In particular, she will use an array of ground-based and space-borne telescopes to study their temporal behavior as well as their immediate galactic environments, including their chemical abundances.

Corrie Saux Moreau

Ph.D. Harvard University
Berkeley Depts: Integrative Biology / Environmental Science, Policy & Management
Faculty Sponsors: Craig Moritz (IB) & George Roderick (ESPM)

I am interested in the origin and evolution of species, and in particular, how geographic events can influence patterns of diversification. I propose to investigate the population structure and ecology of ants with widespread distributions in the lowlands of the Australian Wet Tropics. A phylogeographic analysis of species whose distributions span this region will allow me to test the hypothesis that historical climatic barriers have been major obstacles to gene flow, and to estimate the time frames involved.

David Shelly

Ph.D. Stanford University
Berkeley Dept: Earth & Planetary Science
Faculty Sponsor: Roland Bürgmann

Dr. Shelly's research focuses on the deformation occurring on the deep extension of active earthquake-generating faults. Recently, a weak, extended-duration seismic signal, known as non-volcanic tremor, has been observed accompanying deformation transients on some major faults. At UC-Berkeley, Dr. Shelly aims to use non-volcanic tremor to examine this process and its implications for the shallower earthquake-prone portion of the fault.

Birth Announcements

Congratulations to **Elena Mantovan** (Miller Fellow 2002 - 2005) and Tom Graber on the birth of Ludovico Pietro Graber on October 6, 2006.

Congratulations to **Sheila Patek** (Miller Fellow 2001 - 2004) and her husband Charlie Nunn on the birth of their daughter, Sylvia Janet Patek Nunn. Sylvia was born on February 19, 2007 in Leipzig, Germany.

Congratulaions to **Joshua Shaevitz** (Miller Fellow, 2004 - 2007) and Sarita Shaevitz on the birth of their new baby boy, Rishi Sudhir Shaevitz, born on born on April 2, 2007, in Berkeley, California.

Obituaries

Frederick Mosteller (Visiting Miller Professor Fall 1974 - Spring 1975) who founded Harvard University's Statistics department and used mathematical theories to explain everyday concerns, from health care to the World Series, died July 23, 2006 at the age of 89.

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plants, there is convincing evidence and a consensus among the vast majority of plant scientists, that the Taxodiaceae are in fact inseparable from the Cupressaceae. That said, all phylogenetic 'trees' (ie: 'family tree' type descriptions of relationships among different taxa) of the Cupressaceae place the Taxodiaceous genera at the bottom of the tree as an ancestral 'grade' of the more derived Cupressaceae. Jarmila can use these phylogenies to examine the hypothesis that the radiation of the Cupressaceae was associated with an overall shift towards increased drought tolerance, which was concurrent with drier, post-Cretaceous climates. She is currently measuring important functional traits such as drought resistance, wood anatomical features and isotopic markers of leaf-level water-use efficiency of key Cupressaceous taxa growing at the Strybing Arboretum in Golden Gate Park and the U.C. Botanical Garden.

The fossil record can reveal information about the physiology of ancient plants

Another goal of Jarmila's research will be to examine the morphological features of Taxodiaceous and Cupressaceous fossil material, much of which can be found at the Berkeley Natural History Museum on campus. Features such as leaf surface anatomy can provide clues about paleo-climates, while continually improving methods in stable isotope approaches may allow us to obtain information from fossils regarding the physiology of species under widely differing climatic conditions. This work will be done in collaboration with colleagues here at U.C. Berkeley as well as with Dr. Sergei Vikulin, a paleobotanist from the Komarov Botanical Institute in St. Petersburg.

This is an interdisciplinary project of broad scope that would not have been possible without the support of the Miller Institute. Jarmila is grateful to the Institute as well as her advisors and collaborators for the opportunity to carry out this research.

About Jarmila

Jarmila obtained her PhD at the University of Utah where her research examined the structure and function of conifer wood with respect to water transport efficiency versus protection against environmental stress. Some of her hobbies include mountain biking and skiing, but she'll probably trade her downhill skis for a surfboard when she starts her professorship at UC Santa Cruz next fall.

Awards & Honors

Alex Filippenko (Miller Fellow 1984-86, Miller Professor Spring 1996 and Spring 2005) was awarded the prestigious Richtmyer Memorial Award of the American Association of Physics Teachers (AAPT) at their annual meeting in Seattle.

Stephen Smale (Miller Professor 1967-68, 1979-80, 1990-91), who has contributed to a broad range of mathematical fields, has been named a recipient of the 2007 Wolf Foundation Prize in Mathematics, one of an array of prestigious prizes awarded yearly by the Israeli foundation.

John Spence (Visiting Miller Professor Fall 2007) was honored with the 2006 Distinguished Scientist Award by The Microscopy Society of America.

The Miller Institute is "dedicated to the encouragement of creative thought and the conduct of research and investigation in the field of pure science and investigation in the field of applied science in so far as such research and investigation are deemed by the Advisory Board to offer a promising approach to fundamental problems."