BRYAN NICHOLAS DANFORTH

ACADEMIC RANK: Professor

CAMPUS ADDRESS: Department of Entomology
Comstock Hall
Cornell University
Ithaca, NY 14853
Tel: (607) 255-3563
FAX: (607) 255-0939

WEB SITE: *http://www.danforthlab.entomology.cornell.edu/*

HOME ADDRESS: P.O. Box 267
Ithaca, NY
14851-0267
Tel: (607) 351-9319

TRAINING:
BS zoology, Duke University, Durham, NC, 1983.
MS entomology, University of Kansas, Lawrence, KS, 1987.
Advisor: C.D. Michener.
PhD entomology, University of Kansas, Lawrence, KS, May, 1991.
Advisor: C.D. Michener.

FIELD OF SPECIALIZATION:

Research/Teaching: Insect phylogeny, social evolution, behavioral ecology, systematics, pollination biology. Specialization: phylogeny, ecology, and social evolution of bees.

PROFESSIONAL EXPERIENCE:

1982	Teaching assistant, Department of Zoology, Duke University, Durham, NC (Animal Diversity)
1985	Teaching assistant, Department of Entomology, University of Kansas, Lawrence, KS (Introductory Biology).
1985-1986	Teaching assistant, Department of Entomology, University of Kansas, Lawrence, KS (Introductory Entomology).
1987-1989	Research assistant, Department of Entomology, University of Kansas, Lawrence, KS. Supervisor: C.D. Michener.
1989-1991	Pre-doctoral Fellow. Department of Entomology, Smithsonian Institution. Supervisor: Ronald J. McGinley.
1991-1992	Research Assistant, Department of Entomology, Smithsonian Institution. Supervisor: Ronald J. McGinley.
1992	Post-doc, Department of Entomology, University of California, Riverside. Advisor: P. Kirk Visscher

1993-1995	Post-doc, Department of Entomology, Cornell University, Ithaca, NY. Advisor: G.C. Eickwort.
1993	Lecturer, Genome Variation Analysis Facility, Cornell University, Ithaca, NY; Analysis of Genomic Variation (Instructor: Bernie May)
1995	Lecturer, Insect Morphology, Cornell University, Ithaca, NY
1996-2002	Assistant Professor, Cornell University, Ithaca, NY
2002-2008	Associate Professor, Cornell University, Ithaca, NY
2008-	Professor, Cornell University, Ithaca, NY

PROFESSIONAL AWARDS

Cum Laude, Duke University, 1983.
Fulbright Scholarship Finalist, 1983.
H.B. Hungerford Award for an outstanding thesis, University of Kansas, 1987.
United States Department of Agriculture, Unit Award for Superior Service, 1993.

PROFESSIONAL ACITIVITIES (1990 to present)

A. Professional societies

American Association for the Advancement of Science
Entomological Society of America
Journal of the Kansas Entomological Society
Pan-Pacific Entomological Society
Society of Systematic Biologists
Society for the Study of Evolution
Society for Molecular Biology and Evolution

B. Professional Assignments

Reviewer for the following journals:

American Museum Novitates
American Naturalist
Animal Behaviour
Annals of the Entomological Society of America
Annals of the South African Museum
Apidologie
Behavioral Ecology
Behavioral Ecology and Sociobiology
Biological Journal of the Linnean Society
Canadian Entomologist
Canadian Journal of Zoology
Cladistics
Current Biology
Ecology
Ecological Entomology
Environmental Entomology
Entomological News

Entomological Society of Washington
Ethology
Evolutionary Biology
Gene
Heredity
Insectes Sociaux
Journal of Animal Ecology
Journal of Apicultural Research
Journal of Biogeography
Journal of Insect Behavior
Journal of the Kansas Entomological Society
Molecular Ecology
Molecular Phylogenetics and Evolution
Oecologia
Pan-Pacific Entomologist
Proceedings Royal Society of London
Proceedings of the National Academy of Sciences (PNAS)
Science (AAAS)
Systematic Biology
Systematic Entomology
Zoologica Scripta

Grant reviewer for:
Australian National Research Council
National Geographic Society
National Science Foundation (USA)
National Sciences and Engineering Research Council (Canada)

C. Invited Lectures/Seminars

University of Maryland, Department of Entomology, 10 November, 1991
Harvard University, Department of Organismal and Evolutionary Biology, 20 February, 1992
York University, Department of Biology, 7 March, 1994
University of Kansas, Department of Entomology, 20 November, 1997
State University of New York, Stonybrook, 15 October, 1998
University of Maryland, Department of Entomology, 12 March, 2001
Ithaca College, Department of Biology, 26 February, 2004
Cornell University,Department of Ecology and Evolutionary Biology, 24 January, 2005
American Museum of Natural History, Department of Invertebrate Zoology, 15 April, 2005
University of Illinois, Urbana-Champagne, Apr. 17, 2006
Harvard University, Cambridge, MA, Oct. 5, 2006
Dresden meeting on insect phylogeny September 21-23, 2007
International Pollination Symposium June 24-28, 2007
Evolution Joint Annual Meeting, July 1-3, 2008
XXIII International Congress of Entomology, July 6-12, 2008
Society for Integrative and Comparative Biology, January 3-7, 2009

56th Annual Systematics Symposium, Missouri Botanical Garden, October 9-11, 2009
Department of Entomology, Cornell Experiment Station, Geneva, NY, November 2, 2009
The role and importance of native bees in apple pollination. New York Pollinator Conservation Planning Short Course. September 23, 2010, Big Flats Plant Materials Center, Big Flats, NY [extension talk]
UC Davis, Entomology, September 20, 2012, "*The new view of bee phylogeny*"
Entomology Society of America, Knoxville, TN, November 11-14, 2012
Rutgers University, Rutgers, NJ, November 29, 2012
Easter Branch, Entomological Society of America, "*How molecular data have altered our understanding of bee phylogeny and evolution*", Lancaster, PA, March 16-19, 2013

D. Invited Symposia

ESA Symposium on the Biology of Native Bees, 20 December, 1992
ESA Symposium on Phylogenomics, 26 October, 2003
ESA Symposium on Bee Phylogeny, 15 November, 2004
International IUSSI meeting; Symposium on Bee Phylogeny, Aug. 2006
Dresden meeting on insect phylogeny, 21 September 2007
ESA Symposium on fossil-calibrated phylogenies. 15 December, 2010

E. University, College, and Departmental Committees

Faculty Representative to the Career Development Office (1998-2002)
Cornell University Insect Collection Committee/Bradley Committee (1996-present)
Department of Entomology representative to the CALS Faculty Senate (1998-2000)
Chair, Department of Entomology Curriculum Committee (2005-2011)
CALS Curriculum Committee representative for Entomology (2005-2011)
Department of Entomology Graduate Admissions Committee (1998-2002)
CALS Committee on Teaching and Learning (2008-2011)
Department of Entomology Griswold Committee Chair (2011-2012)
CUIC Collections Manager Search Committee (Fall 2011)
CUIC Collections Committee (2000-present)
University Faculty Senate, Entomology representative (Fall, 2012-present)

F. Outside activities (and extension)

Advisory Panel, Southwestern Research Station, Portal, AZ. (Three year term: 1997-1999)

Doctoral Dissertation Improvement Grant Panel, National Science Foundation (24-25 Feb., 2000). Reviewed 25 grants.

Research Associate, Division of Invertebrate Biology, American Museum of Natural

History, Central Park west @ 79th St., New York, NY

Editor, Special Issue of *Apidologie* [vol. 39(1)], “Insights into Bee Evolution: A tribute to Charles D. Michener” (co-editor: Eduardo Almeida)

International Scientific Board of *Apidologie* (January 2012-December 2015). INRA Centre PACA/ Dept SPE, 400 route des Chappes, 06903 Sophia-Antipolis Cedex, FRANCE [http://www.apidologie.org/]

The Bee Course

"The Bee Course" has been taught annually for the past ten years and will be offered again this year (August, 2012). The course is organized by Jerome G. Rozen, Jr. and Ronald J. McGinley and is taught at the Southwestern Research Station, Portal, AZ for ten days in August or September. The course is limited to 20 students and has been over-subscribed for the past two years. The course provides instruction in bee identification (to the generic level) for all genera collected in North and Central America (using the following text book: Michener, C.D., R.J. McGinley & B.N. Danforth.1994. The Bee Genera of North and Central America (Hymenoptera: Apoidea). Smithsonian Institution Press, Washington, DC. vii+209pp.).

More information can be obtained from the web site:

http://research.amnh.org/invertzoo/beecourse/

Invited public lectures

Museum of the Earth, Ithaca, NY 19 March, 2005 [Public lecture on bees]
Finger Lakes Native Plant Society, 17 Oct., 2006 [Public lecture on bees]
Tompkins County Beekeepers Association, 19 Nov., 2006 [Public lecture on bees]
Jupiter Island Club, West Palm Beach, FL 19 Jan., 2008 [Public lecture on bees]
Taft School, Watertown, CT 16 Nov., 2012 [Lecture to AP Biology class]
Finger Lakes Beekeeping club, 21 April, 2013 [Public lecture on apple pollination]

Current grant funding:

Atkinson Center for a Sustainable Future (Cornell University): ($99,581) (Sept. 1, 2012 to August 31, 2013) Title: Impacts of Pathogens and Pesticides on Wild Pollinators in Eastern Apple Orchards. Collaborators: Motoko Mukai (VTPMD), Eric Nelson (PLPA), and Andre Kessler (EEB)

National Science Foundation Improvements to Biological Research Collections (BRC) Program: ($150,314) (May 1, 2010 to April 30, 2014. Title: Collaborative databasing of North American bee collections within a global informatics network. Collaborative grant with John Ascher and Jerome Rozen (AMNH) and Douglas Yanega (UC Riverside).

USDA-AFRI grant: ($495,925) (Feb. 1, 2011 to January 31, 2015). Title: Quantifying and enhancing pollination services provided by native bees for sustainable apple production.

USDA-Specialty Crop Research Initiative (SCRI) grant: ($129,488) (Jan. 2, 2012 to Dec. 31, 2016). Title: Pollination and Security for Fruit and Vegetable crops in the Northeast. Lead PI: Anne Averill, Umass, Amherst. Cornell subcontract.

Past Grant Funding (in reverse chronological order):

NSF (Systematics Program): ($370,000) [DEB-0742998] (February 15, 2008 to May 31, 2013). Title: REVSYS: Phylogeny and systematics of megachilid bees. *Collaborative grant with Dr. Terry Griswold, USDA Bee Biology and Systematics Laboratory, Logan Utah*

NSF (Systematics Program): ($393,736 + $7,500 REU supplement) [DEB-0814544] (September 1, 2008 to August 30, 2012). Title: Phylogeny of Apidae (Hymenoptera) with an emphasis on the evolution and antiquity of eusociality

USDA Hatch Grant: ($57,900) (Oct. 1, 2008 to Sept. 30 2011). Title: Diversity and Pollination Biology of Native and Managed Bees in Apple Orchards in New York

National Geographic Society (Fideliini) ($10,000). (Oct. 1, 2008 to Oct. 14, 2009) Title: Phylogeny, historical biogeography, and host-plant evolution of the Fideliini (Hymenoptera: Apoidea).

NSF (Doctoral Dissertation Improvement Grant Program): ($11,992) [DEB-0709956] (July 1, 2007 to June 30, 2008). Title: DISSERTATION RESEARCH: Evolution of cleptoparasitism in apid bees (Hymenoptera: Apidae).

NSF (Systematics Program): ($286,681) [DEB-0412176] (September 1, 2004 to August 31, 2008). Title: Phylogeny and historical biogeography of the primitive bee family Colletidae.

NSF (Systematics Program): ($185,745) [DEB-0211701] (July 15, 2002 to June 30, 2005 Title: Collaborative Research: Reconstructing the early evolution of the bees and the history of bee/angiosperm relationships.

NSF (Multi-user Equipment and Instrumentation Resources for Biological Sciences): ($123,745) [DBI-0400433] (July 1, 2004 to June 30, 2005). Title: A new capillary sequencer for the evolutionary genomics core facility at Cornell University (with K. Zamudio [project director], R. Harrison, J.J. Doyle, C.D. Hopkins).

NSF (Systematics Program): ($7,300) [DEB-0211701] (July 15, 2002 to June 30, 2005). REU supplement to DEB-0211701.

National Geographic Society: ($18,574, September 1, 2001 to July 31, 2003). Title: Historical biogeography and sociality of African halictine bees (NGS grant no. 6946-01)

NSF (Doctoral Dissertation Improvement Grant Program): ($9,383) [DDIG-0104893] (July 1, 2001 to June 30, 2003) Title: DISSERTATION RESEARCH: Phylogeny and evolution of subsocial behavior in the New World Treehopper family Membracinae (Homoptera: Membracidae).

NSF (Doctoral Dissertation Improvement Grant Program): ($7,000) [DDIG-0206096] (May 1, 2002 to April 31 2004). Title: DISSERTATION RESEARCH: Native Hawaiian bees (*Hylaeus*): phylogenetics and pollen usage.

NSF (Doctoral Dissertation Improvement Grant Program): ($9,880) [DDIG-0206093] (June 1 2002 to November 30 2003). Title: DISSERTATION RESEARCH: Phylogeny and evolution of host associations and fighting behavior in Neotropical derelomine weevils (Coleoptera: Curculionidae).

NSF (Systematics Program): ($150,000) [DEB-9815236] (April 15, 1999 to March 31, 2003). Title: Phylogenetic analysis of the subfamily Halictinae (Hymenoptera: Halictidae) with an analysis of social evolution.

Smithsonian Scholarly Studies Grant ($35,000; Jan. 2000- Dec. 2002). Title: Comparative population genetic structure and within-group genetic relatedness of solitary and social neotropical sweat bees (*Lasioglossum*, Halictidae) (in collaboration with William Wcislo, Smithsonian Insturition).

NATO Collaborative Research Grant. In collaboration with Prof. F. Andrietti in Milan, Italy ($6,000 for travel and per diem related expenses to study solitary ground-nesting bees)

NSF (Systematics Program): ($189,000) [DEB-9508647] (April 15, 1996 to March 31 1999). Title: Phylogenetic systematics and social evolution in the bee genus *Lasioglossum* (Hymenoptera: Halictidae).

NSF (Multi-user Equipment and Instrumentation Resources for Biological Sciences): ($120,234) [DBI-9970113] (April 1, 1999 to May 31 2001). Title: An Automated DNA sequencing and genotyping facility for studies of ecology, systematics, evolution, and behavior (with K. Zamudio [project director], R. Harrison, J.J. Doyle, H.K. Reeve).

USDA Hatch Grant: ($40,000) (July 1 1997 to June 31 2002) . Title: Phylogenetic analysis, faunal studies, and social behavior of halictine bees in New York State.

Publications

Refereed publications (in reverse chronological order; n=76):

76. Bartomeus, I., M.G. Park, J. Gibbs, B.N. Danforth, A.N. Lakso, & R. Winfree (2013). Biodiversity as insurance against plant-pollinator phenological asynchrony. Ecology Letters [*submitted*]

75. Hedtke, S., S. Patiny, **B.N. Danforth** (2013). Resolving the Bee Tree of Life : bioinformatic approaches to apoid phylogeny. BMC Evolutionary Biology [*submitted*]

74. Gibbs, J., L. Packer, S. Dumesh, and **B.N. Danforth** (2013). Revision and reclassification of Lasioglossum (Evylaeus), L. (Hemihalictus) and L. (Sphecodogastra) in eastern North America (Hymenoptera: Apoidea: Halictidae). Zootaxa [*in press*]

73. Litman, J.R., C.J. Praz, T.L. Griswold, **B.N. Danforth**, S.C. Cardinal (2013). Origins, evolution, and diversification of cleptoparasitic lineages in long-tongued bees. Evolution [*in press*]

72. Cardinal, S. & **B.N. Danforth** (2013). Bees diversified in the age of eudicots. Proc. Royal Soc. Lond (B) 280: 1-9 [*available online January 30, 2013*]

71. Kennedy, C.M., E. Lonsdorf, M.C. Neel, et al. (2013). A global quantitative synthesis of local and landscape effects on native bee pollinators in agroecosystems. Ecology Letters 16(5): 584-599 [*published online 11 Mar. 2013, DOI: 10.1111/ele.12082*]

70. Bartomeus, I., J.S. Ascher, J. Gibbs, **B.N. Danforth**, D.L. Wagner, S.M. Hedtke, and R. Winfree (2013). Historical changes in northeastern United States bee pollinators related to shared ecological traits. Proc. Natl. Acad. Sci. (USA) 110(12): 4656-4660 [*published online 4 Mar. 2013, DOI: 10.1073/pnas.1218503110*]

69. Danforth, B.N., S.C. Cardinal, C. Praz, E. Almeida, D. Michez (2013). Impact of molecular data on our understanding of bee phylogeny and evolution. Ann. Rev. Entomology 58: 57-78 [*http://www.annualreviews.org/toc/ento/forthcoming*]

68. López-Uribe, C.K. Santiago, S.M. Bogdanowicz, **B.N. Danforth** (2012). Discovery and characterization of microsatellites for the solitary bee *Colletes inaequalis* using Sanger and 454 pyrosequencing. Apidologie 44(2): 163-172. *DOI: 10.1007/s13592-012-0168-3* [*published online 26 October, 2012*]

67. Gibbs, J., S. Brady, K. Kanda, & **B.N. Danforth** (2012).Phylogeny of halictine bees supports a shared origin of eusociality for *Halictus* and *Lasioglossum* (Apoidea: Anthophila: Halictidae). Mol. Phylogen. Evol. 65: 926-939.

66. Debevec, A.H., S. Cardinal, & **B.N. Danforth** (2012). Identifying the sister group to the bees: a molecular phylogeny of aculeata with an emphasis on the

superfamily Apoidea. Zoologica Scripta 41: 527-535 [*published ahead of print 14 June 2012, DOI: 10.1111/j.1463-6409.2012.00549.x*]

65. Gonzalez, V.H., T. Griswold, C.J. Praz, & **B.N. Danforth** (2012). Phylogeny of the bee family Megachilidae (Hymenoptera: Apoidea) based on adult morphology. Systematic Entomology 37: 261-286

64. De Meulemeester, T., D. Michez, A.M. Aytekin & **B.N. Danforth** (2012). Taxonomic affinity of halictid bee fossils (Hymenoptera: Anthophila) based on geometric morphometrics analyses of wing shape. J. Syst. Paleo. DOI:10.1080/14772019.2011.628701

63. Almeida, E.A.B., M.R. Pie, S.G. Brady, & **B.N. Danforth** (2012). Biogeography and diversification of colletid bees (Hymenoptera: Colletidae): emerging patterns from the southern end of the World. J. Biogeography 39(3): 526–544 [*published ahead of print December 6, 2011, DOI: 10.1111/j.1365-2699.2011.02624.x*]

62. Bartomeus, I., J.S. Ascher, D. Wagner, **B.N. Danforth**, S.R. Colla, S. Kornbluth, & R. Winfree (2011). Climate-associated phenological advances in bee pollinators and bee-pollinated plants. Proc. Natl. Acad. Sci., USA 108(51): 20645-20649 [*published ahead of print December 5, 2011, doi:10.1073/pnas.1115559108*]

61. Litman, J.R., **B.N. Danforth**, C.D. Eardley, & C.J. Praz (2011). Why do leafcutter bees cut leaves? New insights into the early evolution of bees. Proc. Royal Society of London (B) 278: 3593-3600

60. Cardinal, S.C. & **B.N. Danforth** (2011). The antiquity and evolutionary history of social behavior in bees. PLoS ONE 6(6): e21086. doi:10.1371/ journal.pone.0021086.

59. Brady, S.G., J.R. Litman, & **B.N. Danforth** (2011). Rooting phylogenies using gene duplications: An empirical example from the bees (Apoidea). Mol. Phylogen. Evol. 60: 295–304.

58. Danforth, B.N. & G.O. Poinar (2011) Morphology, classification, and antiquity of *Melittosphex burmensis* (Apoidae: Melittosphecidae) and implications for early bee evolution. J. Paleontology 85(5): 882–891.

57. Martinson, V., **B.N. Danforth**, R. Minckley, O. Rueppell, S. Tingek, & N. Moran (2011). A simple and distinctive microbiota exclusively associated with honey bees and bumble bees. Molecular Ecology, 20: 619–628.

56. Cardinal, S., J. Straka, & **B.N. Danforth** (2010). Comprehensive phylogeny of apid bees reveals the evolutionary origins and antiquity of cleptoparasitism. Proc. Natl. Acad. Sci. (USA) 107(37): 16207–16211. *Open access*: http://www.pnas.org/content/107/37/16207.full.pdf+html?sid=5fc14c42-749f-479a-b872-8bf3344481f7

55. Michez, D., C.D. Eardley, K. Timmermann & **B.N. Danforth** (2010). Unexpected polylecty in the bee genus *Meganomia* (Hymenoptera, Apoidea, Melittidae). J.

Kansas Entomological Society 83(3): 221–230.

54. López-Uribe, M.M., A.N. Green, S. Ramírez, S.M. Bogdanowicz, and **B.N. Danforth** (2010). Isolation and cross-species characterization of polymorphic microsatellites for the orchid bee *Eulaema meriana* (Hymenoptera: Apidae: Euglossini). Conservation Genet Resources DOI 10.1007/s12686-010-9271-9

53. Bradley, T.J., Briscoe, A.D., Brady, S,G., Contreras, H.L., **Danforth, B.N.**, Dudley, R., Grimaldi, D., Harrison, J.F., Kaiser, A., Merlin, C., Reppert, S.M., Vandenbrooks, J.M., and Yanoviak, S.P. (2009) Episodes in insect evolution. Integrative and Comparative Biology 49: 590-606

52. Michez, D., S. Patiny & **B.N. Danforth** (2009). Phylogeny of the bee family Melittidae (Hymenoptera: Anthophila) based on combined molecular and morphological data. Syst. Entom. 34: 574-597

51. Almeida, E.A.B. & **B.N. Danforth** (2009). Phylogeny of colletid bees (Hymenoptera: Apoidea: Colletidae) inferred from four nuclear genes. Molecular Phylo. Evol. 50(2): 290-309.

50. Praz, C.J., A. Muller, **B.N. Danforth**, T.L. Griswold, A. Widmer, & S. Dorn (2008). Phylogeny and biogeography of bees of the tribe Osmiini (Hymenoptera: Megachilidae). Molecular Phylo. Evol. 49(1): 185-197.

49. Almeida, E.A.B, L. Packer & **B.N. Danforth** (2008). Phylogeny of the Xeromelissinae (Hymenoptera: Colletidae) based upon morphology and molecules. Apidologie 39:75-85

48. Danforth, B.N., C. Eardley, L. Packer, K. Walker, A. Pauly, & F. Randrianambinintsoa (2008). Phylogeny of Halictidae with an emphasis on the endemic African Halictinae. Apidologie 39:86-101

47. Patiny, S., D. Michez, & **B.N. Danforth** (2007). Phylogenetic relationships and host-plant associations within the basal clade of Halictidae (Hymenoptera: Apoidea). Cladistics online: 8-Nov-2007 doi: 10.1111/j.1096-0031.2007.00182.x

46. Danforth, B.N. (2007). Bees - a primer. Current Biology 17(5): R156-R161.

45. Magnacca, K.N. & **B.N. Danforth** (2007) Low nuclear DNA variation supports a recent origin of Hawaiian *Hylaeus* bees (Hymenoptera: Colletidae). Mol. Phylogenet. Evol. 43(3): 908-915.

44. Magnacca, K.N. & **B.N. Danforth** (2006). Evolution and biogeography of native Hawaiian *Hylaeus* bees (Hymenoptera: Colletidae). Cladistics 22: 393-411

43. Poinar, G.O., Jr. & **B.N. Danforth** (2006). A fossil bee from Early Cretaceous Burmese amber. Science 314: 614.
See news story: http://sciencenow.sciencemag.org/cgi/content/full/2006/1025/1

42. Schwarz, M.P., M.H. Richards & **B.N. Danforth** (2006) Changing paradigms in

insect social evolution: insights from halictine and allodapine bees. Annual Review of Entomology 52:127-150.

41. Danforth, B.N., S.D. Sipes, J. Fang, & S.G. Brady (2006). The history of early bee diversification based on five genes plus morphology. Proc. Natl. Acad. Sci. (USA) 103(41): 15118-15123. *Open access*: http://www.pnas.org/content/103/41/15118.full.pdf+html?sid=5fc14c42-749f-479a-b872-8bf3344481f7

40. Danforth, B.N., J. Fang, & S.D. Sipes (2006). Analysis of family-level relationships in bees (Hymenoptera: Apiformes) using 28S and two previously unexplored nuclear genes: CAD and RNA polymerase II. Mol. Phylogenet. Evol. 39 (2): 358-372.

39. Brady, S.G., S.D. Sipes, A. Pearson, **B.N. Danforth** (2006). Recent and simultaneous origins of eusociality in halictid bees. Proc. Royal Soc. London, Series B (Biological Sciences) 273:1643-1649.
See news story:
http://www.news.cornell.edu/stories/March06/social.bees.evolution.ssl.html

38. Danforth, B.N., C.-P. Lin & J. Fang (2005). How do insect nuclear ribosomal genes compare to protein-coding genes in phylogenetic utility and DNA substitution patterns? Systematic Entomology 30:549-562.

37. Lin, C.-P., **B.N. Danforth**, & T.K. Wood (2004). Molecular phylogenetics and evolution of maternal care in membracine treehoppers. Systematic Biology 53(3): 400-421.

36. Danforth, B.N., S.G. Brady, S.D. Sipes & A. Pearson (2004). Single copy nuclear genes recover Cretaceous age divergences in bees. Syst. Biol. 53(2): 309-326.

35. Brady, S.G. & **B.N. Danforth** (2004). Recent intron gain in elongation factor-1α (EF-1α) of colletid bees (Hymenoptera: Colletidae). Mol. Biol. Evol. 21(4):691-696.

34. Lin, C.P. & **B.N. Danforth** (2004). How do insect nuclear and mitochondrial gene substitution patterns differ? Insights from Bayesian analyses of combined data sets. Mol. Phylo. Evol. 30: 686-702.

33. Danforth, B.N., S. Ji, & L.J. Ballard (2003). Gene flow and population structure in an oligolectic desert bee, *Macrotera* (*Macroteropsis*) *portalis* (Hymenoptera: Andrenidae). J. Kansas Entomological Society 76(2): 221-235.

32. Danforth, B.N., L.Conway, & S. Ji (2003). Phylogeny of eusocial *Lasioglossum* reveals multiple losses of eusociality within a primitively eusocial clade of bees (Hymenoptera: Halictidae). Syst. Biol. 52(1): 23-36.

31. Danforth, B.N. (2002). Evolution of sociality in a primitively eusocial lineage of bees. Proc. Natl. Acad. Sci. (USA) 99(1): 286-290.

30. Soucy, S.L. & **B.N. Danforth** (2002). Phylogeography of the socially polymorphic sweat bee *Halictus rubicundus* (Hymenoptera: Halictidae). Evolution 56 (2): 330-341.

29. Ascher, J.S., **B.N. Danforth**, S. Ji (2001). Phylogenetic utility of the major opsin in bees (Hymenoptera: Apoidea): a reassessment. Mol. Phylo. Evol. 19: 76-93.

28. Danforth, B.N. & S. Ji. (2001). Australian *Lasioglossum* + *Homalictus* form a monophyletic group: resolving the "Australian enigma." Syst. Biol. 50(2): 268-283.

27. Tilmon, K.J., **B.N. Danforth**, M.P. Hoffmann, W.H. Day (2000). Determining parasitoid species composition in a host population: a new molecular approach. Ann. Entomol. Soc. America 93(3): 640-647.

26. Danforth, B.N. (1999). Phylogeny of the bee genus *Lasioglossum* (Hymenoptera: Halictidae) based on mitochondrial cytochrome oxidase. Syst. Entomol. 24(4): 377-393.

25. Danforth, B.N., H. Sauquet, L. Packer (1999). Phylogeny of the bee genus *Halictus* (Hymenoptera: Halictidae) based on parsimony and likelihood analyses of nuclear EF-1α sequence data. Molecular Phylogenetics and Evolution 13(3):605-618.

24. Danforth, B.N. (1999). Emergence dynamics and bet hedging in a desert bee *Perdita portalis*. Proc. Royal Society of London 266:1985-1994.

23. Danforth, B.N. & C. A. Desjardins (1999). Male dimorphism in *Perdita portalis* (Hymenoptera: Andrenidae) has arisen from preexisting allometric patterns. Insectes Sociaux 46:18-28.

22. Danforth, B.N. & W.T. Wcislo (1999). Two new and highly apomorphic species of the *Lasioglossum* subgenus Evylaeus (Hymenoptera: Halictidae) from Central America. Ann. Entomol. Soc. Am. 92:624-630.

21. Danforth, B.N, P. Mitchell & L. Packer (1998). Mitochondrial DNA differentiation between two cryptic *Halictus* species. Ann. Entomol. Soc. Am. 91:387-391.

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Debevec, A., S.C. Cardinal, **B.N. Danforth**, & J.W. Whitfield. Investigating outgroup taxon sampling: empirical examples from Noctuoidea (Lepidoptera) and bees (Hymenoptera: Apoidea). North Central Branch ESA meeting, Rapid City, South Dakota (June 16-19, 2013).

Blitzer, E.J., M.G. Park, **B.N. Danforth**. Native and managed bees of New York apple orchards: Connecting biodiversity, pollination services, and production. Eastern Branch ESA meeting, Lancaster, PN (March 16-19, 2013).

Danforth, B.N. How molecular data have altered our understanding of bee phylogeny and evolution. Eastern Branch ESA meeting, Lancaster, PN (March 16-19, 2013). [*Invited symposium: Natural History and Diversity of Arthropods*]

Blitzer, E.J., M.G. Park, **B.N. Danforth**. Connecting native and managed pollinators to apple production in New York orchards. ESA meeting, Knoxville, TN (November 11-14, 2012). [*Invited symposium*]

Park, M.G., **B.N. Danforth**. Effects of landscape and farm management on wild pollinators of eastern apple orchards. ESA meeting, Knoxville, TN (November 11-14, 2012).

Soro A, M. Bönn, **B.N. Danforth**, J. Field, I. Grosse, I. Lemnian, M. Lopez-Uribe, R.J. Paxton. The genetic basis of the solitary-eusocial transition in a socially polymorphic sweat bee. 5th European Conference of Apidology, Halle an der Saale, Germany (September 3-7, 2012).

Gibbs, J., Brady, S., Kanda, K., and **Danforth, B.N.** Phylogeny and social evolution of the Halictidae. International Congress of Entomology, Daegu, South Korea (August 24, 2012). [*Invited speaker*]

Hedtke, S., S. Patiny, S., **B.N. Danforth**. A supermatrix approach to resolving bee family-level phylogeny. X Encontro Sobre Abelhas, Ribeirão Preto, Brazil (July 25-28, 2012). [*Invited speaker*]

López-Uribe, C.K. & **B.N. Danforth**. Genetic diversity and population declines in solitary bees: Is there a pattern? X Encontro Sobre Abelhas, Ribeirão Preto, Brazil (July 25-28, 2012). [*Invited speaker*]

López-Uribe, C.K., K. Zamudio, C. Cardoso, & **B.N. Danforth**. Assessing the impact of climatic changes on neotropical pollinators: Comparative multi-locus phylogeography of three orchid bee species. X Encontro Sobre Abelhas, Ribeirão Preto, Brazil (July 25-28, 2012). [*Invited speaker*]

Debevec, A., S. Cardinal, B.N. Danforth. Identifying the sister group to the bees: a molecular phylogeny of Aculeata with an emphasis on Apoidea. Evolution meeting, Ottawa, Ontario (July 6-10, 2012)

Cardinal, S. & B.N. Danforth. Dating the antiquity of bees (poster). Evolution meeting, Ottawa, Ontario (July 6-10, 2012)

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Cardinal, S.C. & **B.N. Danforth**. Dating the antiquity of bees using multiple nuclear genes and relaxed-clock methods. ESA meeting, San Diego, CA (December 12-15, 2010). [*Invited speaker*]

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Research Interests

1. Bee Phylogeny

A major focus of my work over the past 15 years has been on resolving higher-level relationships in bees. Bees include over 20,000 described species currently placed into 7 families and 23 subfamilies. Bees arose sometime between 140 and 100 million years ago and bee diversification almost certainly influenced the explosive diversification of the angiosperms (flowering plants) in the early to mid Cretaceous. Understanding the evolutionary history of bees can therefore help provide insights into the diversification of the angiosperms, or what Darwin called the "abominable mystery."

My lab has worked on all seven extant bee families, as well as relationships among closely-related apoid wasps (Debevec, et al. 2012). Our approach has been heavily focused on single-copy nuclear gene data, but some studies combine morphological and molecular data, and some studies are based entirely on morphology. Single-copy nuclear genes provide excellent data sets for resolving deep divergences in bees because (1) alignments of protein-coding regions are unambiguous, (2) the bee genome consists of over 12,000 protein-coding genes, making these data readily available for phylogenetic analysis, and (3) these genes have been shown to perform more effectively than mitochondrial (Lin & Danforth 2004) and ribosomal genes (Danforth et al. 2005) in comparative studies. My laboratory pioneered the use of single-copy nuclear genes as phylogenetic markers in bees and closely related wasps.

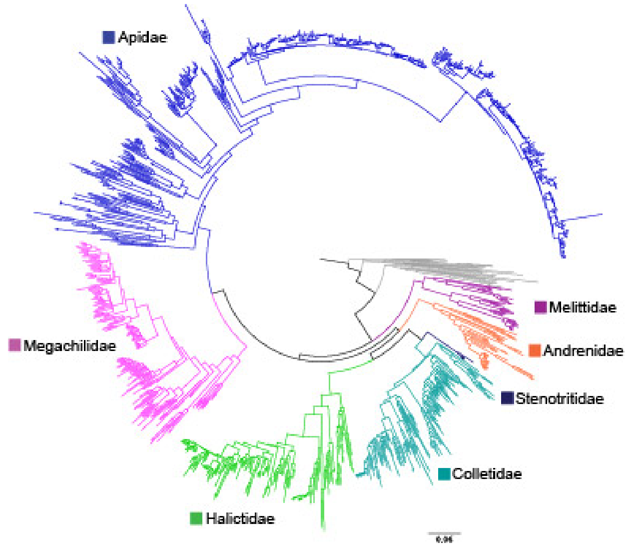

Figure 1 – Maximum likelihood estimate of relationships among bees based on a supermatrix approach. Our matrix consists of 20 genes, with over 17,000 aligned nucleotide sites, for over 1,300 bee and apoid wasp species, representing over two-thirds of the described bee genera. The following genes were included in the analysis: abdominal A (abdA), arginine kinase (ak), mitotic checkpoint control protein (bub3), calcium/calmodulin-dependent protein kinase II (cad), carbamoylphosphate synthetase/aspartate transarbamylase/dihydroorotase (camkii), deoxyribonucleoside kinase (dnk), ecdysone receptor B1 (ecrb-1), elongation factor 1a f1 and f2 copies (ef1af1, ef1af2), feminizer (fem), glycerol kinase (gk), sodium potassium adenosine triphosphate (nak), odorant receptor 2 (or2), phosphoenolpyruvate carboxykinase (pepck), long wavelength rhodopsin (rho), RNA polymerase II (polII), ultraspiracle (ultra), vasa, white, and wingless (wg). (From Hedtke et al., in review.)

Insights that have been gained from these studies include the following areas:

a. **Bee antiquity** – I have been involved in a number of studies focused on both fossils and fossil-calibrated phylogenies. In collaboration with George Poinar (Oregon State), I helped described the morphology and phylogenetic significance of *Melittosphex burmensis* – the oldest known bee fossil (Poinar & Danforth 2006, Danforth & Poinar 2011). In collaboration with my students and post-docs, I have published fossil-calibrated phylogenies for Colletidae (Almeida et al. 2012), Halictidae (Gibbs et al. 2013), Apidae (Cardinal et al. 2010), Megachilidae (Litman et al. 2011) and bees as a whole (Cardinal & Danforth 2013).

b. **Family-level phylogeny** – A major focus of my lab over the past 10 years has been to establish a robust phylogeny for the bee families, subfamilies, and tribes. We have used a variety of approaches, including large, multigene, nucleotide data sets (Danforth et al. 2006a), nucleotide data sets in combination with morphology (Danforth et al. 2006b), patterns of unique intron gains and losses (Brady & Danforth 2004), and analysis of gene duplications (Brady et al. 2011). Our results have provided important new insights into where the root node of bees falls. Previous studies supported a root node near or within Colletidae. However, all our molecular studies have indicated a root node at or within the family Melittidae, a small, enigmatic, relictual, host-plant specialist family with greatest diversity in southern Africa. Subsequent studies, based on both expanded gene and expanded taxon sampling that continues to support this hypothesis (Cardinal & Danforth 2013.; Hedtke et al. in review).

c. **Social behavior** – Bees are fascinating creatures for many reasons, but one of the most important is that they exhibit multiple origins of complex forms of eusociality. The families Halictidae and Apidae include species that range from solitary nesting to advanced eusociality. My laboratory has made heavy use of phylogenetic analysis to investigate the patterns of social evolution in both Halictidae (Danforth 1999, 2002; Danforth et al. 1999, 2003, 2008; Soucy & Danforth 2002; Brady et al. 2006) and Apidae (Cardinal & Danforth 2011). Our results have revealed an unforseen pattern: eusociality in bees has had relatively few origins while within eusocial clades one can see multiple reversals to solitary nesting. Our current estimate is as few as four origins of eusociality in bees: (1) corbiculate Apidae, (2) Xylocopinae, (3) Augochlorini, (4) Halictini (*Halictus*+*Lasioglossum*).

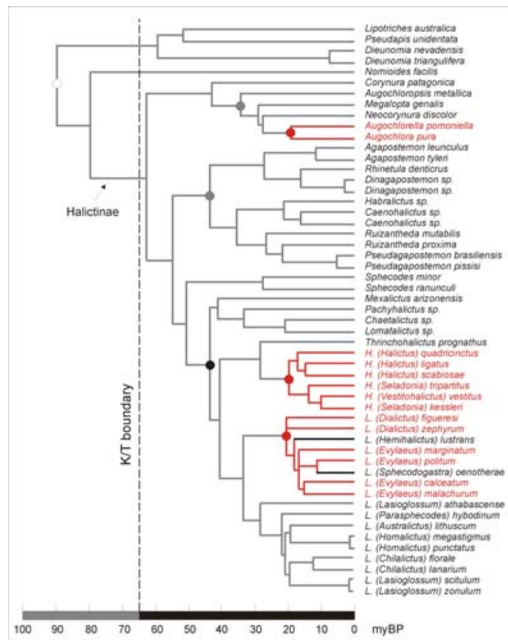

Figure 2 – Phylogeny of bees in the family Halictidae based on four nuclear protein-coding genes analyzed by Bayesian methods. Fossil calibrated topology based on analysis using R8S. Taxa in red are eusocial (Modified from Brady et al. 2006).

d. **Cleptoparasitism** – Approximately 10% of all bee species are cleptoparasitic (brood parasitic), meaning they enter the nests of other bees and lay an egg without actually collecting either pollen or nectar provisions. Cleptoparasitism has been reported from all bee families except Andrenidae, Melittidae, and Stenotritidae. Phylogenetic studies in my lab have provided a comparative framework for examining the evolution of cleptoparasitism in Halictidae, Megachilidae, and, most recently, in Apidae. My student and former post-doc Sophie Cardinal used a comprehensive phylogeny of the Apidae and Bayesian, ancestral state reconstruction methods to show that, what had previously been regarded as multiple origins of cleptoparasitism were, in fact, more likely a single, ancient origin of cleptoparasitism in Apidae (Cardinal et al. 2010). This result has significant implications for understanding the evolution of cleptoparasitism in bees because nearly 20% of apid bees are cleptoparasites.

e. **Historical biogeography** – Phylogenies play an important role in understanding how the current distribution of organisms on earth came to be. Research in my laboratory has made use of phylogenies for Halictidae (Danforth et al. 2004, Patiny et al. 2007), Melittidae (Michez et al. 2009), Megachilidae (Litman et al. 2011), and especially Colletidae (Almeida & Danforth 2009, Almeida et al. 2012) to analyze biogeographic patterns with both parsimony and model-based methods. Work by my former student, Eduardo Almeida on colletid bees has demonstrated a series of repeated interchanges between Australia and South America via Antarctica over the past 90 million years (Almeida et al. 2012). Australia's bee fauna was therefore composed entirely of colletid bees up until the Oligocene, when additional bee families arrived via Asia.

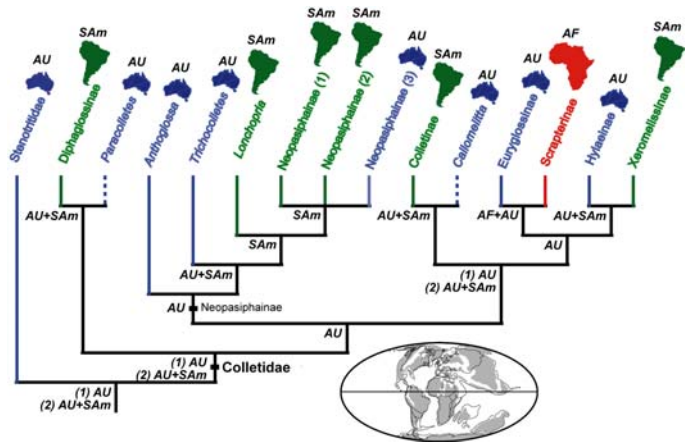

Figure 3 – Biogeographic analysis of bees in the families Stenotritidae and Colletidae based on a phylogeny at the subfamily and tribal levels constructed from a data set consisting of four nuclear genes (Modified from Almeida et al. 2012).

In summary, the phylogenetic work in my laboratory has provided significant new insights into the evolution of bees, including their historical biogeography, social behavior, antiquity, and life history evolution. Future work will focus on expanding the range of genes and data sets we use to reconstruct bee phylogeny. Currently, we are exploring two avenues of research: (1) next-generation (Illumina) sequencing of bee transcriptomes as a way to greatly expand the range of genes we can use and (2) super-matrix approaches to bee phylogeny in which we extract data from Genbank using automated, bioinformatics approaches to downloading, aligning, and analyzing large nucleotide data sets (in collaboration with Shannon Hedtke).

2. Pollination biology

I have recently expanded my research into the area of applied pollination biology. Starting in 2007, my laboratory has been surveying and characterizing native bee diversity in NY State apple orchards with the goal of understanding the role of native bees in apple pollination. We recently obtained a USDA-AFRI grant to expand this study and to relate bee diversity and abundance to fruit set in commercial apple orchards. To date, we have identified over 100 native bee species that are potentially contributing to apple pollination in central New York (Park, et al., in prep.). In addition, we have used careful experimental approaches to determine per-visit pollen deposition in a number of native bee species. Our data indicate that native bees deposit two to three times more pollen grains per visit than honey bees (Park, et al., in prep.). Finally, we have demonstrated that in central New York apple orchards, there is clear evidence of pollen limitation, as indicated by comparison of hand vs. open-pollinated flowers. This study has allowed me to use my expertise in bee taxonomy to develop more sustainable management practices in commercial apple orchards.

3. Bee biodiversity

I am currently involved in an NSF-funded, multi-institutional effort to database major bee collections across the US. The Cornell University Insect Collection is one of the 12 collections being databased for the purpose of examining long-term trends in bee distribution and phenology. This is a highly collaborative effort led by John Ascher (AMNH) and Douglas Yanega (UC Riverside). Our study has already yielded two published papers (Bartolomeus et al., 2011, 2013) documenting shifts in native bee flight phenology and geographic distribution over the past 140 years in eastern North America. Over the first two years of the grant we have databased over 30,000 bee specimens from Cornell alone.

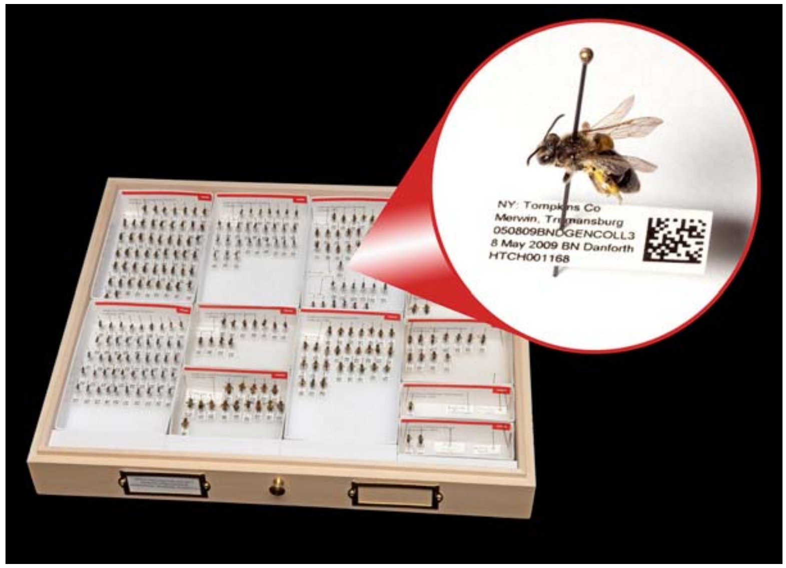

Figure 4 – A drawer of bar-coded bee specimens from biodiversity samples of native bees in apple orchards in central New York (Modified from Park et al. 2010).

I also continue to conduct field work in areas of high bee diversity, including Australia, South Africa, Kenya, and Mediterranean Europe.

Future directions:

1. Next-gen sequencing and bioinformatics: the field of molecular systematics is moving incredibly fast and new technologies are transforming how we approach DNA sequencing. Next-gen sequencing (Illumina and 454) technologies now allow us to generate massive transcriptome and genome datasets. These data sets require new skills, in particular bioinformatic skills, to make effective use of the data. I would like to explore the use of transcriptome data sets across multiple bee and wasp species in order to greatly expand the range of genes we are currently using for phylogenetic analysis. We already have a pilot experiment underway using Illumina RNA-seq data from 12 bee and wasp species and there is clearly a lot of overlap in the genes sequenced across these species. However, distinguishing paralogs and orthologs is not trivial in the absence of closely related reference genomes.

2. The transition from carnivory to pollenivory – gut transcriptomics: One of the “key innovations” in the evolution of bees from predatory wasps was the transition from larval carnivory to larval pollenivory. From a nutritional standpoint, arthropod prey and pollen are similar in that both provide a diet rich in proteins and amino acids (Roulston and Cane 2000). However, extraction of these nutrients requires significant alteration in larval digestive physiology. The external layer of the pollen grain, the pollenkitt, contains nutritive lipids. There are one or two additional layers which must be broken down

before the cytoplasm of the pollen can be released and the nutrients absorbed (or further digested): the *exine* (present in most flowering plants, but not all monocots), which is made up of a tough complex carbohydrate called sporopollenin, and the *intine*, which is made up of cellulose and pectin. Digestion appears to occur through a combination of osmotic and enzymatic processes as pollen passes through the midgut of the bee, and thus requires both morphological changes in the structure of the intestine and in the enzymes that contribute to the breakdown of these pollen walls (reviewed in Roulston and Cane 2000). I propose to examine the evolutionary changes associated with pollen-feeding by comparing the gut transcriptomes of larval crabronid wasps and bees. My prediction is that we will find significant alterations in the expressed genes and that there will be an increase in genes associated with (1) carbohydrate metabolism, and (2) detoxification of plant secondary compounds.

3. <u>Chemical ecology and phylogeny of bee-plant interactions</u>: One aspect of bee evolution that has received surprisingly little attention is the co-evolutionary interactions between bees and their host-plants. Bees vary widely in their host plant preferences. Polylectic (generalist) bees collect pollen and nectar from a wide variety of host-plants while oligolectic (specialist) bees collect pollen and nectar from a much more narrow range of host-plants, usually resctricted to a family, tribe, genus or even species of host plant. Specialization in bees involves both behavioral preference for certain host plants as well as morphological adaptations to host-plant flower and pollen morphology. We know very little about the evolution of both host plant range (oligolecty and polylecty) and host plant preference in bees. Two previous studies have used phylogenies and character mapping to examine the evolution of host-plant preferences in bees (Sipes & Tepedino 2005, Sedivy et al. 2008). We have learned from these studies that (1) polylecty is often derived from within oligolectic clades and (2) host-switching, when it occurs, often involves switches to phylogenetically *unrelated* host-plants. Whether host switching is driven by floral morphology or floral chemistry remains to be seen. I propose to examine the evolution of host-plant associations within one or more bee genera in which a mixture of polylectic and oligolectic species occur (e.g., *Andrena*, *Perdita*, *Dufourea*, *Dasypoda*, *Hesperapis*). The goal of such studies would be to reconstruct species-level relationships based on multi-gene data sets and to use ancestral state reconstruction methods to trace the evolution of host-plant range and preference. When closely-related bee are on unrelated host-plants I would like to examine whether the host plants share similar morphological or chemical attributes. My prediction is that the either host-plant chemistry or host plant floral morphology drives such switches. I am actively seeking a collaborator with expertise in chemical ecology for this project.

4. <u>Bees and microbes – does “defensive mutualism” exist in mass-provisioning bees</u>: A number of insect species have been shown to have associations with beneficial microbes, primarly bacteria, that have been described as “defensive mutualisms” (Kaltenpoth 2009). These defensive mutualists can provide a variety of functions, but they are often involved in protecting valuable resources (for example, the fungal gardens in leaf-cutting ants) from invasion by pathogenic microbes. The pollen/nectar provisions of bees are rich in carbohydrates and proteins and are stored in harsh environments (soil, wood, stems) where attack by microbes would appear to be easy. I would like to explore the possible microbial symbionts of bees using metagenomic methods based on high-throughput next generation sequencing.

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Mentoring

1. **Post-docs**

Current:

Dr. Shannon Hedtke
Dr. EJ Blitzer

Past:

Dr. Jason Gibbs
Department of Entomology
Center for Integrated Plant Systems
Michigan State University
578 Wilson Road, Room 202B
East Lansing MI 48824
email: jason.gibbs@cornell.edu

Dr. Sophie Cardinal
Canadian National Collection of Insects (CNC)
Agriculture and Agri-Food Canada
960 Carling Avenue, Ottawa, Ontario
CANADA K1A 0C6
Phone: 613-759-1797
email: sophie.cardinal@agr.gc.ca

Dr. Christophe Praz
Evolutionary entomology
Institute of Biology
University of Neuchatel
Emile-Argand 11
2009 Neuchatel
SWITZERLAND
email: christophe.praz@unine.ch

Dr. Sean Brady
Department of Systematic Biology
Smithsonian Institution
POB 37012
NHB, CE517, MRC 188
Washington, DC 20013-7012
Phone: 301-238-1078
Email: bradys@si.edu

Dr. Sedonia Sipes
Department of Plant Biology
Life Science II 420

Mailcode: 6509
Southern Illinois University Carbondale
Carbondale, IL 62901-6899
Phone: 618-453-3213
E-mail: ssipes@plant.siu.edu
Web site: http://www.science.siu.edu/plant-biology/Faculty/sipes/index.html

2. **Graduate students**

Current:
Mia Park
Margarita Lopez-Uribe
Kristen Brochu
Mary Centrella

Past:
Dr. John S. Ascher (PhD 2003)
Department of Invertebrate Zoology
American Museum of Natural History
Central Park West @ 79th St.
New York, NY 10024-5192
Phone: (212) 496-3447
E-mail: ascher@amnh.org

Dr. Karl N. Magnacca (PhD 2004)
University of California, Berkeley
Department of Environmental Science, Policy and Management
137 Mulford Hall #3114
Berkeley, CA 94720
Phone: 510-642-4148
Email: magnacca@nature.berkeley.edu

Dr. Chung-Ping Lin (PhD 2002)
Department of Life Science
Tunghai University
No.181, Sec.3, Taichung-Kan Road
Taichung, Taiwan 40704
Phone: 886-4-2359-0121 ext3240 ext18
E-mail: treehops@mail.thu.edu.tw

Dr. Eduardo A. B. Almeida (PhD 2006)
Departamento de Biologia
FFCLRP - Universidade de São Paulo
Av. dos Bandeirantes, 3900
14040-901 Ribeirão Preto, SP. BRAZIL
Phone: 55-16- 3602-3813
E-mail: eduardo@ffclrp.usp.br

Dr. Sophie Cardinal (PhD 2010)

Canadian National Collection of Insects (CNC)
Agriculture and Agri-Food Canada
960 Carling Avenue, Ottawa, Ontario
CANADA K1A 0C6
Phone: 613-759-1797
email: sophie.cardinal@agr.gc.ca

Dr. Jessica Litman (PhD 2012)
SwissBOL Coordinator
Centre Suisse de Cartographie de la Faune (CSCF)
Passage Max. de Meuron 6
2000 Neuchâtel
Switzerland
email: jessica.litman@unine.ch

3. **Undergraduate students**

Undergraduate research students:

Current:
Julia Brokaw (Natural Resources, 2013 [2 year])
Christine Santiago (Human Ecology, 2014 [3 years; Undergraduate Minority Student Fellowship])
Graham Montgomery (Entomology, 2015 [1 year])
Michelle Jennifer Rogals (Biology, 2015 [1 year])
Corey Jack Keane (Biology, 2015 [1 year])
Christina Harden (Biology, 2015 [1 year])

Past:
Chris Desjardins (Entomology, 1997 [2 years])
Luke Ballard (Biology, 1999 [3 years; Cornell Presidential Research Scholar Program])
Lindsay Conway (Animal Science, 2000 [2 years])
Adam Pearson (Biology, 2002 [3 years; Cornell Presidential Research Scholar Program])
Alison Novick (Biology, 2003[2 years])
Stephanie Johnson (Entomology, 2005[1 semester])
Alex Swanson (Biology, 2006[1 years])
Allison Meisner (Entomology, 2006[1 years])
Kojun Kanda (Entomology, 2007[2 years])
Neha Botapati (Biology, 2009[1 semester])
Chris Castorena (Engineering, 2009 [1 semester])
Michael Orr (Entomology, 2009 [2 years])
Andrew Debevec (Entomology, 2011 [2 years; Hughes Undergraduate Research Scholars Program])
Jamer Bellis (Biology, 2011[1 semester])
Yang Zhang (Biology, 2011 [1 year]
Lori Moshmann (Plant Biology, 2012 [4 years])
Kyle Rossner (Continuing Education, 2012 [1 year])

Isa Betancourt (Entomology, 2013 [1 year])
Patrick Brown (Entomology, 2013 [1 year])

Undergraduate advisees:

Elia Andrea Garcia (Entomology, 1998)
Susan Margaret Packard (Entomology, 2001)
Peter Michael Fisk (Entomology, 2004)
Megan Vidler (Entomology, 2005)
Phil Torres (Entomology; 2008)
Taro Eldredge (Entomology; 2009)
Keith Ciccaglione (Entomology; 2011)
Lori Moshmann (Entomology; 2012)
Patrick Brown (Entomology; 2013)
Dan Pearlstein (Entomology; 2013)
Leah Buchmann (Entomology; 2016)

Undergraduate publications (1999 to present):

Papers with undergraduate co-authors (in **bold**) are listed below.

Danforth, B.N. & **C. A. Desjardins** (1999). Male dimorphism in *Perdita portalis* (Hymenoptera: Andrenidae) has arisen from preexisting allometric patterns. Insectes Sociaux 46:18-28.

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Danforth, B.N., S.G. Brady, S.D. Sipes & **A. Pearson** (2004). Single copy nuclear genes recover Cretaceous age divergences in bees. Syst. Biol. 53(2): 309-326.

Brady, S.G., S.D. Sipes, **A. Pearson**, B.N. Danforth (2006). Recent and simultaneous origins of eusociality in halictid bees. Proc. Royal Soc. London, Series B (Biological Sciences) 273:1643-1649.

Debevec, A.H., S. Cardinal, & **B.N. Danforth** (2012). Identifying the sister group to the bees: a molecular phylogeny of aculeata with an emphasis on the superfamily Apoidea. Zoologica Scripta [*published ahead of print 14 June 2012, DOI: 10.1111/j.1463-6409.2012.00549.x*]

Gibbs, J., S. Brady, K. Kanda, & **B.N. Danforth** (2012).Phylogeny of halictine bees

supports a shared origin of eusociality for *Halictus* and *Lasioglossum* (Apoidea: Anthophila: Halictidae). Mol. Phylogen. Evol. 65: 926-939.

Teaching

a. Accomplishments

Over the past fourteen years I have taught 17 courses (Entom 2010 [*Alien Empire: Bizarre Biology of Bugs*], Entom 3220 [*Insect Comparative Morphology*], Entom. 3310/3311 [*Insect Phylogeny and Evolution*], and Entom. 6350 [*Insect Molecular Systematics*] to a total of 863 students. Course evaluations for all these classes were high (4.0 or above on most questions; see attached course evaluations, below).

Entom. 2010/2011 is an elective, non-majors class that is meant to introduce undergraduate students to the bizarre and fascinating world of insects. This course emphasizes insect evolution, behavior, natural history, and ecology, but also covers topics related to the interaction between humans and insects. I have worked very hard in Alien Empire to captivate the students with the bizarre and interesting lives of insects. I make heavy use of color photographs to illustrate the diversity of insect form and anatomy. I use audio recordings to introduce students to the world of insect acoustic communication. I place short films (~5 mins.) throughout the lectures to show live insects in action. I also try to keep things entertaining with occasional segments from popular movies such as "Joe's Apartment" and "Bugs Life". In 2004 I developed a stand alone website for the course:

http://instruct1.cit.cornell.edu/courses/ent201/index.html

The website provides an overview of the course as well as course materials. I use the website to post handouts (as downloadable pdf files), Powerpoint presentations (as downloadable pdf files), movie clips, reading assignments, term paper guidelines, and popular articles on insects.

Alien Empire is one of my favorite courses to teach and I think the students react well to my enthusiasm. I have been told by some students that Entom 2010/2011 is the best course they have had at Cornell. Other student comments included: "I have never had a more enthusiastic instructor since I have been at Cornell," "Bryan is an enthusiastic teacher -- he loves the subject and transferred this excitement well," "I really enjoyed this class... Bugs are really neat!", "I loved this course and would recommend it to all my friends."

Entom 3310/3311 is a graduate/undergraduate level course in insect phylogeny and evolution. I taught this class for the first time in Spring, 2007 and am currently teaching it in Fall, 2011. This course provides students with a broad overview of insect diversity, phylogeny, evolution and fossil history. This is an important course for our undergraduate and graduate program because insects are one of the largest and most diverse groups of organisms on the planet. Phylogeny provides the comparative and evolutionary framework for investigating insect biology and this course strives to develop a solid understanding of both the methods we use to reconstruct phylogeny as well as our current estimate of insect evolutionary relationships. I emphasize that phylogenies are hypotheses that are constantly changing as new data and new methods are applied. The course also investigates how phylogenies can be used to investigate evolutionary questions, such as host-plant evolution, co-evolution of hosts and symbionts, and the evolution of eusociality. Students give presentations at the end of the semester on independent research they have done on one group of insects. The laboratory portion of the course (Entom. 3311; 1 credit) involves field collections and identification to the family level.

I have also taught other courses at Cornell. Two courses (Entom 3220, *Insect Comparative Morphology* and Entom 6350, *Insect Molecular Systematics*) are no longer offered.

b. Courses taught (1997-2013)

Course number	Title	Semester	Enroll
Entom. 3220	*Insect Comparative Morphology*	Sp., 1997	22
Entom. 2010	*Alien Empire: Bizarre Bio Bugs*	Sp., 1998	65
Entom. 3220	*Insect Comparative Morphology*	Sp., 1999	22
Entom. 2010	*Alien Empire: Bizarre Bio Bugs*	Sp., 2000	55
Entom. 3220	*Insect Comparative Morphology*	Sp., 2001	24
	Sabbatical leave (Jan.-July 2002)		
Entom. 3220	*Insect Comparative Morphology*	Sp., 2003*	20
Entom. 2010	*Alien Empire: Bizarre Bio Bugs*	Sp., 2004*	65
Entom. 6350	*Insect Molecular Systematics*	Sp., 2004	8
Entom. 3220	*Insect Comparative Morphology*	Sp., 2005*	18
Entom. 2010	*Alien Empire: Bizarre Bio Bugs*	Sp., 2006*	98
Entom. 6350	*Insect Molecular Systematics*	Sp., 2006*	6
Entom. 3310/3311	*Insect Phylogeny and Evolution*	Sp., 2007*	14

Entom. 2010	*Alien Empire: Bizarre Bio Bugs*	Sp., 2008*	140
Entom. 2010/2011	*Alien Empire: Bizarre Bio Bugs*	Sp., 2009*	140
Entom. 3310/3311	*Insect Phylogeny and Evolution*	Fa., 2009*	16
	Sabbatical leave (Jan.-July 2010)		
Entom. 2010/2011	*Alien Empire: Bizarre Bio Bugs*	Sp., 2011*	136
Entom. 3310/3311	*Insect Phylogeny and Evolution*	Fa., 2011*	18
Entom. 2010/2011	*Alien Empire: Bizarre Bio Bugs*	Sp., 2013	130
Entom. 3310/3311 [*in progress*]	*Insect Phylogeny and Evolution*	Fa., 2013	20

* Please see attached spreadsheet that summarizes course evaluations for these semesters.

c. Course descriptions:

ENTOM 2010 - Alien Empire: Bizarre Biology of Bugs
Spring. 2 credits. S-U or letter grade option. B.N. Danforth

Insects are the most abundant and diverse animals on earth. This course explores the bizarre biology of insects and their interaction with humans. It examines both the detrimental roles insects play (e.g., pests and vectors of disease) as well as their beneficial roles (e.g., pollination, edible insects, insect products such as waxes, dyes, and silk). The course also explores the symbolic representation of insects in art, literature, and religion.

ENTOM 2011 - Alien Empire: Bizarre Biology of Bugs
Spring. 3 credits. S-U or letter grade option. B.N. Danforth

Insects are the most abundant and diverse animals on earth. This course explores the bizarre biology of insects and their interaction with humans. It examines both the detrimental roles insects play (e.g., pests and vectors of disease) as well as their beneficial roles (e.g., pollination, edible insects, insect products such as waxes, dyes, and silk). The course also explores the symbolic representation of insects in art, literature, and religion. Students taking the course for 3 credits meet once per week for small group discussions, debates, demonstrations, and documentary films on the biology of insects.

ENTOM 3220 Comparative Insect Morphology [NO LONGER OFFERED]
Spring. 4 credits. Prerequisite: ENTOM 2120 or 2410. Lec, lab. B.N. Danforth.

Provides a detailed introduction to the external and internal anatomy of insects. Lectures introduce basic concepts in insect morphology, such as the organization of the insect body plan and organ systems, functional morphology, homology, phylogeny, modularity, and development. The lab introduces students to the basic methods of insect microdissection, specimen preparation, and scientific illustration. High-quality, publishable illustrations are produced based on student artwork.

ENTOM 3310 - Insect Phylogeny and Evolution
Fall. 3 credits. Prerequisite: ENTOM 2120. Co-requisite: ENTOM 3311. Offered alternate years.
B. N. Danforth.

This course will provide a broad overview of insect diversity, morphology, phylogeny, evolution, and fossil history. Evolution of the insects will be discussed in light of real data sets based on morphology and/or DNA sequence data. Basic principles of phylogeny reconstruction using both morphological and DNA sequence data will be presented using published data sets. Analytical methods such as parsimony, maximum likelihood, and Bayesian methods will be discussed and compared. We will also cover how phylogenies are used to analyze evolutionary patterns, such as historical biogeography, coevolution, and host–parasite relationships.

ENTOM 3311 - Insect Phylogeny and Evolution Laboratory
Fall. (Offered alternate years) 1 credit. Prerequisite: ENTOM 2120. Co-requisite: ENTOM 3310. Course fee: Lab fee $40. B.N. Danforth.

This laboratory will introduce students to the diversity of insects and their identification. Collections will be made in the early part of the semester. Labs will introduce students to insect collecting techniques and insect identification to the family level. Optional weekend field trips to natural areas will take place early in the semester. Entomology undergraduates wishing to count Insect Phylogeny and Evolution toward their Group A requirement should take the laboratory as well as the lecture for a total of 4 credits.

ENTOM 6350 - Insect Molecular Systematics [NO LONGER OFFERED]

Spring. 2 credits. Prerequisite: permission of instructor. B.N. Danforth

Analysis of DNA sequence variation can provide a powerful tool for resolving problems in insect systematics, from species-level taxonomic decisions to higher-level (ordinal) relationships. This course introduces students, through readings of the primary literature, to the basic methods of insect molecular systematics, including DNA extraction, gel electrophoresis, PCR, DNA purification, and DNA sequencing (manual and automated). Results are analyzed using available computer programs. Students are encouraged to collect preliminary data for thesis or post-doctoral reserearch.

d. Student Evaluations

I have summarized the student evaluations over the past 11 semesters in the spreadsheet on the following page and have provided the most recent course evaluations for two classes: Entom 2010/2011, *Alien Empire, Spring 2011* and Entom 3310/3311, *Insect Phylogeny and Evolution, Fall 2009*. Overall, my teaching evaluations are good. Out of a total of 5 points, the students evaluated my overall teaching between 4.06 and 4.86. Similarly, the courses I have taught are ranked between 3.96 and 4.86. Entom 2010/2011 (*Alien Empire: Bizarre Biology of Bugs*) has the largest enrollment of undergraduate students (between 60 and 140 students since inception) and the students ranked this class between 4.1 and 4.48 over the past four offereings. The graduate-level courses (Entom 3220, 3310/3311, and 6350) have similarly high ratings. My teaching skills receive some of the highest scores: between 4.31 and 4.75. There do not appear to be obvious changes in the ratings my classes receive over time.

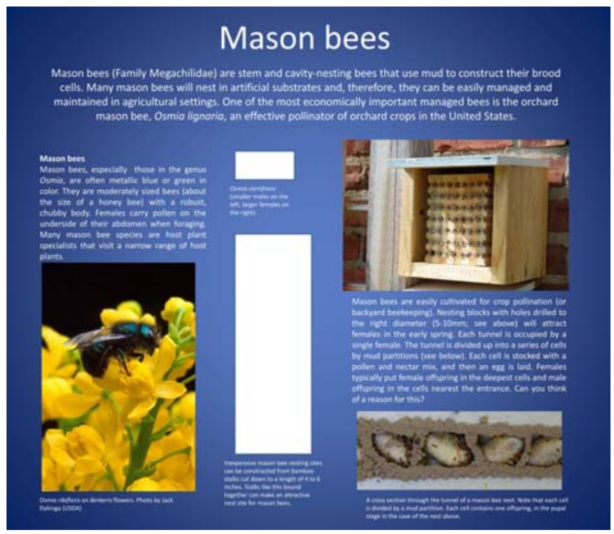
Recent student evaluations of Entom 2010/2011, *Alien Empire, Spring 2011* were overall extremely positive. Students gave the course an overall rating of 4.34 and scored my teaching skills as 4.69. One student commented: “Danforth was AWESOME! Unbelievably caring, nice, and a great teacher. By far one of the best professors I've had at Cornell. The class was incredibly enjoyable, and I'd recommend it to anyone. His organization (i.e. the website) was great, and truly wanted us to learn. A+” Another student commented: “I really loved this class. I wish I had time to take more entomology courses because they are so interesting, but it will probably be a while before I can if I ever can. This is a good course for anyone, no matter their interest. Professor Danforth is also a really effective lecturer and I never had trouble paying attention, which has been the case in some of my other classes."

Recent student evaluations of Entom 3310/3311, *Insect Phylogeny and Evolution, Fall 2011* were very high. The course was given an overall rating of 4.75 and my teaching skills were rated 4.75. Recent student comments included: "Professor Danforth was particularly good at explaining methodology, and treating it as a variable tool which must be considered along with results. His explanation of molecular phylogenetic modeling and analysis was the most clear and easiest to grasp of many that I have been exposed to." and "I loved the lecture course!"

Extension

I do not have a formal extension appointment at Cornell, but I am a strong believer that scientific results, including studies of biodiversity, phylogeny, and pollination ecology, be made readily accessible to the general public. As part of our USDA-funded apple pollination project (see Research section), we are making a serious effort to disseminate our findings to the apple growers, orchard managers and anyone who can make effective use of our findings. We do this in a number of ways. First, a number of people in my lab (Mia Park, EJ Blitzer, myself) have given extension talks at regional meetings of New York apple growers. We have developed recommendations for managing and maintaining native bee diversity in and around apple orchards in central NY. We have also recent published one extension publication (Park, M.G., et al. 2010) and and one extension booklet based on funding from the Northeast IPM program (Park, M.G., et al. 2012)

My lab is also heavily involved in the annual open house sponsored by the Department of Entomology at Cornell. This one-day event (Insectapalooza!) attracts over 3000 visitors to our department every fall semester. My lab presents displays and posters about bee biodiversity, bee biology and ecology, and the importance of conserving native pollinators. We have developed a powerpoint template that allows anyone in my lab to develop a high-quality, professional-style display on any topic. Our displays include photos, text, pinned insects, and other biological specimens relevant to the topic (see figure at right). We have prepared over 12 such displays over the past three years.



Finally, I have been involved with a local elementary school (Cayuga Heights Elementary) in developing a 5th grade project on the biology of mason bees. This project was initially developed in 2010 with the help of a fifth grade teacher, Connie Patterson. The program is now run every year by Cayuga Heights instructors.

Park, M.G., M.C. Orr, & **B.N. Danforth** (2010). The role of native bees in apple pollination. New York State Fruit Quarterly 18(1): 21-25.

Park, M.G., **B.N. Danforth**, J. Losey, D. Biddinger, Mace Vaughan, J. Dollar, E. Rajotte, & A. Agnello (2012). Wild Pollinators of Eastern Apple Orchards and How to Conserve Them. Cornell University, Penn State University, and The Xerces Society. URL: http://www.northeastipm.org/park2012

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