



### **Lloyd W. Sumner, Ph.D.**

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### **EDUCATION:**

Ph.D. in Analytical Chemistry from Oklahoma State University (December, 1993, Stillwater, OK)  
B.S. Cameron University (May 1989, Lawton, OK) Major: Chemistry, Minor: Mathematics  
Fundamental Electronics Certificate (1984, Lawton, OK) Great Plains Vocational School.  
High School Diploma (1983, Lawton, OK) Lawton High School.

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### **AWARDS, HONORS & APPOINTMENTS**

Board of Directors, Metabolomics Society, Sept2016-Oct2018.  
Aug2015-Aug2016 – President, Phytochemistry Society of North America  
12Aug14 – President Elect, Phytochemistry Society of North America  
2013 Lifetime Honorary Fellow of the Metabolomics Society for contributions towards establishing the Metabolomics Society as a truly international and financially sound organization, and for influential research contributions to the field of plant metabolomics.  
2013-2015 Front Pages Co-Editor with Robert Hall, Metabolomics.  
Scientific Advisory Board Member, The Netherlands Metabolomics Center, Thomas Hankemeier (PI) July 2011-present  
Scientific Advisory Board Member, Center for Advanced Biofuel Systems, Richard Sayre (PI), March 2011-2014  
Review Editorial Board for Frontiers in Plant Proteomics, March 2011-present  
Review Editor, Frontiers in Plant Biotechnology, Jan 2011 - present  
Treasurer, The Metabolomics Society, Oct. 2010 – Sept.2012  
Advisory Committee Member, Southern Oklahoma Technology Center Biotechnology Aug. 2010 – Dec 2015  
President, The Metabolomics Society, Oct.2008 - Sept. 2010  
Interim Treasurer, The Metabolomics Society, Oct. 2007 to Dec. 2008  
Adjunct Professor, Oklahoma University, Dept. of Botany and Microbiology, Jan 2008-present  
Faculty of 1000, 2008-present  
Board of Directors, Metabolomics Society, Oct 2007-2010.  
Cameron University Distinguished Alumni 2007 Award  
Editorial Board: Plant Physiology (American Society for Plant Biology), Jan 2007-present.  
Fellow, The American Association for the Advancement of Science (Sept. 2005-present)  
Editorial Board: Metabolomics journal (Kluwer), Oct. 2004 to date.

Scientific Advisory Board, Metabolomics Society, Cambridge, MA (2004-2007)  
External Scientific Advisory Committee Member – Colorado State University Metabolomics Consortium (2004-2006)  
Scientific Consultant for Sigma-Aldrich Plant Biotech Initiative (2004-2005)  
Adjunct Associate Professor, Oklahoma State University, Department of Biochemistry and Molecular Biology, 2004-present.  
Co-founding and Current Member of the International Advisory Committee for Plant Metabolomics (2001-present)  
Graduate Faculty Appointment, Texas A&M Univ., Department of Chemistry, August 1999  
Graduate Research Fellowship, Samuel Roberts Noble Foundation, 1990-1993.  
Temple W. Chronister Memorial Scholarship, 1989  
Ansley Memorial Scholarship, 1988

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## **EMPLOYMENT EXPERIENCE:**

- University of Missouri (Columbia, MO) Professor, Department of Biochemistry and Director of Missouri Metabolomics Center, 2016-present)
- The Samuel Roberts Noble Foundation (*Ardmore, OK*) *Professor, Analytical Biochemistry, Plant Biology Division (January 2011 to December 2015)*
- The Samuel Roberts Noble Foundation (*Ardmore, OK*) *Associate Professor, Analytical Biochemistry, Plant Biology Division (February, 2005 to 2011)*
- The Samuel Roberts Noble Foundation (*Ardmore, OK*) *Assistant Professor, Analytical Biochemistry, Plant Biology Division (August, 1999 to February, 2005)*
- Texas A&M University (*College Station, TX*) *Associate Director of the Laboratory for Biological Mass Spectrometry (September, 1994 to August, 1999).*
- Texas A&M University (*College Station, TX*) *Manager of The Applied Mass Spectrometry Laboratory (September, 1993 to August, 1999)*
- Oklahoma State University, *Mass Spectrometry Facility Analyst (September, 1991 to September, 1993).*
- Oklahoma State University (*Stillwater, OK*) *Research Assistant (May, 1990 to September, 1993)*
- Oklahoma State University, *Teaching Assistant (August, 1989 to May, 1990)*
- Home Repair Business Owner (*May, 1987 to May, 1989*) *These experiences provided a solid electrical and mechanical background that is highly useful in instrumental construction, maintenance, and repair. Profits from this business were used to finance my graduate education.*
- Commercial and Home Rental Maintenance/Repair (*June, 1981 to May, 1987*)

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## **Synergistic Activities**

- Led development and secured NSF funding for a Research Coordination Network entitled 'Integrating and Coordinating an International Plant, Algae, and Microbial Metabolomics Network' with Profs. Oliver Fiehn, James Liao, Georg Jander and Basil Nikolau.
- Program Committee for 61<sup>st</sup> ASMS Conference on Mass Spectrometry, Minneapolis, MN.
- Chair, ThOB: Metabolomics Informatics Session at the 61<sup>st</sup> ASMS Conference on Mass Spectrometry, Minneapolis, MN.
- Chair Parallel Session 3B: Plant Physiology at the 9th Annual Metabolomics Society Meeting, Glasgow Scotland.
- Co-chair of The American Society for Mass Spectrometry Metabolomics Interest Group (2010-2012)

- Invited organizer of joint a NSF-JST Metabolomics Workshop (6-7May2010) which resulted in a new funding program focused upon metabolomics NSF DBI PGRP Project #701846 Advisory Panel Member & Meeting; An interdisciplinary approach to deciphering the molecular dialogue between the plasma membrane and nucleus of *Medicago truncatula*. June 21-22, 2009 – University of Wisconsin Biotechnology Center, Madison WI, hosts Michael Sussman, Jean-Michel Ane, Josh Coon
- Chair of the chemical analysis working subgroup for the Metabolomic Standardization Initiative (<http://msi-workgroups.sourceforge.net/>).
- Invited participant NIH-sponsored Standards Workshop for Metabolomics, August 1 and 2, 2005, Bethesda, MD.
- Scientific Advisory Board, Metabolomics Society, Cambridge, MA (2004-2007).
- Program Committee Member and Plant Session Co-chair for the 1<sup>st</sup> International Conference of Metabolomics Society (June 2005, Tsuruoka, Japan). Co-organizer of The 2<sup>nd</sup> (Boston, MA, USA 2006), 3<sup>rd</sup> (Manchester, UK, 2007), 4<sup>th</sup> (Boston, MA, 2008), 5<sup>th</sup> (Edmonton, Alberta, Canada 2009), 6<sup>th</sup> (Amsterdam, The Netherlands 2010), and 7<sup>th</sup> (Tsuruoka, Japan, 2011), 8<sup>th</sup> (Washington, DC 2012), 9<sup>th</sup> (Glasgow, Scotland), 10<sup>th</sup> (Tsuruoka, Japan) and upcoming 11<sup>th</sup> (San Francisco, CA) International Conferences of the Metabolomics Society.
- Cofounding member of the International Advisory Committee for Plant Metabolomics (ICPM; 2001-Present). Organizational committee member of the 1<sup>st</sup> (Wageningen, The Netherlands, 2001), 2<sup>nd</sup> (Golm, Germany, 2002), 3<sup>rd</sup> (Iowa State University, Ames, IA, 2004), 4<sup>th</sup> (Reading, UK, 2006) and 5<sup>th</sup> (Yokohama, Japan, 2008) International Conference on Plant Metabolomics
- Organizer of multiple day, hands-on workshop focused on Metabolomics (annually with most recent March 23-27, 2009), Proteomics Workshop (annually and most recent September 22-26, 2008), and Integrated Functional Genomics Workshop. These workshops are hosted in Ardmore, OK and sponsored by the Noble Foundation, and external funding agencies such as the NSF Plant Genome Research Award #010973.  
<http://www.noble.org/medicago/NSF/Nsf.main/Workshops.html>.
- Annual contributing instructor including on-site training and demonstration of proteomic and metabolomic approaches for Instrumental Analysis (Course #CHEM 3525, Southeastern Oklahoma State University) since 2006.
- Local organizing committee member for Molecular Breeding of Forage & Turf, 3<sup>rd</sup> International Symposium, May 18-22, 2003, Dallas, TX.
- Panelist NSF Major Research Instrumentation 2002 & 2003.
- Panelist NIEHS RFA-ES-04-008: Metabolomics: Application to Environmental Health Research. Research Triangle Park, North Carolina, March 3, 2005.
- Panelist Canadian Foundation for Innovation (CFI), Vancouver, BC, Canada, April 25-26, 2006.
- Ad-hoc reviewer for BBSRC, NSF 2010, NSF-FIBR, NSF-IOB, NSF-MRI, NSF Plant Genome, NIEHS, Research Corporation, and USDA NRI programs.
- Peer reviewer for *Analytica Chimica Acta*, *Analytical Biochemistry*, *Analytical Chemistry*, *Bioinformatics*, *BMC Bioinformatics*, *BMC Plant Biology*, *Briefings in Bioinformatics*, *Comparative and Functional Genomics*, *Electrophoresis*, *Genomics*, *John Wiley & Sons Publishing*, *Journal of Agriculture and Food Chemistry*, *Journal of Chromatography B*, *Journal of Experimental Botany*, *Journal of The American Society for Mass Spectrometry*, *Journal of Chemical Ecology*, *Journal of Proteome Research*, *Kluwer/Springer Publishing*, *Mass Spectrometry Reviews*, *Metabolomics*, *Molecular and Cellular Proteomics*, *Molecular Plant Biology*, *Molecular Plant-Microbe Interactions*, *Nature Biotechnology*, *Nature Chemical Biology*, *Nature Methods*, *New Phytologist*, *Nucleic Acid Research*, *Plant Journal*, *Plant Molecular Biology*, *Plant Physiology*, *Planta*, *Physiological & Molecular Plant Pathology*, *Phytochemistry*, *Phytochemistry Reviews*,

## **STUDENTS, POSTDOCS, RESEARCH STAFF, & VISITING SCIENTISTS:**

### **Current:**

Lei, Zhentian; Ph.D., Asst. Director, Univ. of Missouri Metabolomics Center, 2016-present.  
Qiu, Feng; Postdoctoral Research Fellow NSF-JST IOS# 1139489 Metabolomics: Advancing the Scientific Promise to Better Understand Plant Specialized Metabolism for a Low-Carbon Society, 2013-present.  
Hartanto, Christopher; graduate student rotation Aug-Oct2016.  
Kumar, Santosh; Postdoctoral Fellow, June 2016 – present  
Schroeder, Mark; graduate student Biochemistry, March 2016-present  
Moskowitz, Jake; DVM, Graduate Student, Comparative Medicine, 2016-present  
Reith, Dennis, part-time administrative assistant, 2016-present  
Sumner, Barbara; part-time laboratory manager, May 2016-present

### **Former**

Asirvatham, Victor; Ph.D., Noble Postdoctoral Research Fellow. Currently: Florida Atlantic University  
Bedair, Mohamed; Ph.D., Noble Postdoctoral Research Fellow. Currently: Crop Analytics, Monsanto Company, St. Louis.  
Bench, Bennie J.; Ph. D., Noble Postdoctoral Research Fellow. Currently: Chemist, Tyson Foods Safety and Research Laboratory, Fayetteville, AR  
Broeckling, Alan; Undergraduate summer intern 2002 & 2003  
Broeckling, Corey; PhD, Noble Research Associate 2004-2006, Currently: Metabolomics Core Colorado State University  
Brown, Kelsea: 2011 NSF MCB #820823summer REU, Metabolomics: A functional genomics tool for deciphering functions of Arabidopsis genes in the context of metabolic and regulatory networks  
Caro, Michael; Summer inter 2015, and part-time Research Technician, Nov-Dec2015  
Dao, Kristin: 2012 summer REU NSF-JST Metabolomics for a Low Carbon Society  
Dixon, Arthur: 2011 summer intern: metabolite spectral libraries  
Donnelly-Davis, Bryna; PhD. Postdoctoral Research Fellow  
Duran, Anthony; MSc. Research Assistant, Currently: Cargill  
Elmer, Aaron; Ph.D., Currently: Murray State College  
Ershadi, Phillip; Summer intern 2001, graduate school, OSU  
Farang, Mohamed; PhD, Asst. Professor, Pharmacognosy Department, University of Cairo  
Fennell, Patrick; Summer intern 2001 & 2002, Emergency Medical Technician  
Fields, Stephen D.; Visiting Professor from East Central University (Ada, Oklahoma) sponsored through a NSF EPSCoR Research Opportunity Award for the Summer of 2013 and for the *'Identification of secondary metabolites secreted by a dinoflagellate'*  
Fine, Dennis; PhD, Noble Postdoctoral Fellow, 2012-2015, NSF-JST Metabolomics for a Low Carbon Society  
Fuego, Marianni; BSc., Research Technician, Current: OU graduate school  
Grant, Treyon; Research Experience for Undergraduates Summer 2013 and 2014.  
He, Xian Zhi; Research Associate 2012-2013, Noble Foundation  
Henson, Shelagh; BSc. part-time Research Technician, Noble Foundation, 2010-2015

Hightower, Aaron; BSc., Sumner Intern 2008, Current: University of Oklahoma Medical School  
Hilou, Adama; Visiting Assoc. Professor, University of Ouagadougou, Burkina Faso. March-October, 2014.  
Hudelston, Karista summer intern 2004  
Huhn, Steven; BSc. NMR Instrument Coordinator, 1 week, 2012  
Huhman, David V.; BSc. Analytical Chemistry Core Facility Coordinator, 1999-2015, Noble Foundation  
Jantz, Amanda; Summer Intern 2010; NSF Oklahoma EPSCoR 2011 summer REU Metabolomics and Genome Wide Association Mapping for the Elucidation of Triterpene Saponin Molecular Biochemistry in Medicago, #EPSCoR-2011-15  
Landers, Lucas; undergraduate summer intern 2010, Current: undergraduate Pratt Institute, NY.  
Lee, Jeonghoon; Ph.D., Noble Proteomics Research Associate, Noble Foundation Analytical Chemistry Core Facility  
Lei, Zhentian; Ph.D., Noble Research Scientist, Noble Foundation, 2001-2015.  
Li, Wensheng; Ph.D., Postdoctoral Research Fellow, Current: Monsanto Company  
Liu, Zhaoyang; Ph.D., Postdoctoral Research Fellow, Current: China  
Moreira, Cesar; undergraduate Noble Scholar, 2007, Current: Graduate Student, The University of Florida  
Nagaraj, Satish; Postdoctoral Research Fellow, Current: Research Associate, Mysore Lab, The Noble Foundation  
Pang, Ni; MSc., Research Technician, Noble Foundation, Current: mother and head of household  
Ray, Sutanuka; Plant, Algae, Microbial Metabolomics Research Network Coordinator. NSF-IOS Award#1340058, 2014-2015.  
Robins-White, Rebecca; BSc., summer teacher intern 2005, Ardmore High School Biology/Chemistry teacher  
Richardson, Kristy; MSc. Greenhouse assistant, Current: self-employed.  
Snyder, John H.; BSc., Graduate Student, Joint Noble Foundation & Cornell University  
Solkey, Laura, BA., Research Technician, Jan 2008 - June 2008  
Shen, Guoan; Ph.D., Postdoctoral Research Fellow, 2008-2009, Noble Foundation  
Tawfall, Amanda; GCMS Applications Research Associate, Analytical Chemistry Core Facility, Noble Foundation  
Tzin, Vered; Ph.D., Former Noble Postdoctoral Research Fellow, Currently Postdoctoral Research Fellow at Boyce Thompson Institute, Ithaca, NY.  
Urbanczyk-Wochniak, Ewa; Ph.D., Former Noble Postdoctoral Research Fellow, Currently Monsanto Company.  
Wang, Hua, part-time laboratory assistant, 2016.  
Warner, Sylvia; Research Technician, Noble Foundation  
Watson, Bonnie S.; MS.c., Sr. Research Associate, Noble Foundation, 2003-2015.  
Watson, Michael; Undergraduate intern 2010, Currently University of Oklahoma  
Wherritt, Daniel; Ph.D.; Noble NMR Instrument Coordinator, NSF-MRI Acquisition of a 600 MHz NMR with cryoprobe for Integration with Existing UPLC-MS-SPE to Enable High throughput Chemical Annotation in Plant Metabolomics, 2013-2015.  
Wood, Keisha; undergraduate summer intern 2006 & 2007, Physician Assistant Program Oklahoma Univ.  
Yang, Dong Sik; Ph.D., Postdoctoral Research Fellow 2009-2012, Currently Analytical Team Leader Biomaterials Research Center, Samsung Advanced Institute of Technology (SAIT)  
Zhao, Qiao; Ph.D.; Noble Postdoctoral Research Fellow 2013, NSF-MCB Metabolomics and Genome Wide Association Mapping for the Elucidation of Triterpene Saponin Molecular Biochemistry in Medicago

Zhao, Weiguo; MSc., Bioinformatics staff, April 2008-August 2009

Zhang, Chao; BSc. Summer intern 2009, Current: Bioinformatics graduate student University of Missouri

**Former Visiting Scientists:**

Noureddine Benkeblia, Ph.D. Visiting Scientist, Graduate School of Agriculture, Hokkaido University, Sapporo, Japan

Prof. Dr. R.J. (Raoul) Bino, Sabbatical, Cluster leader, Technology Development, Plant Research International, Business Unit Bioscience

Lalita M. Calabria, Visiting graduate student w/ T. Mabry, University of Texas at Austin

Prof. Sixue Chen: The Summer lab hosted visiting Professor Sixue Chen from the University of Florida from 01-15May14 for initial metabolomics training and experiments on Arabidopsis and Brassica napus Guard Cells Signal transduction following exposure to a flagillin elicitor.

Clelia de la Pena, Ph.D. Visiting Graduate Student, Department of Horticulture and Landscape Architecture, Colorado State University, Fort Collins, CO

Ms. Samira Hassan, April 27-May 15, 2011, Graduate Student, Australian National University

Aaron Hightower, B.S. Southeastern Oklahoma State University graduate. Attending Oklahoma University Medical School in August, 2009 Oklahoma City, OK

Li Jing, BSc. Visiting Graduate Student, 01Aug12 to 01Aug14, Southwest University, China, PhD. Awarded summer 2015, Metabolomics of Citrus and Large-scale MRM Methods Development and Application.

Dr. Adama Hilou: visiting Fullbright Scholar, Dr. Adama Hilou from the Université de Ouagadougou, Burkina Faso, Africa to study the beneficial metabolic interactions between *Medicago truncatula* and a mutualistic arbuscular mycorrhizal fungus *Glomus intraradices* and the biochemical protective benefits of this mutualistic interaction against the pathogenic fungi *Aphanomyces euteiches*.

Dr. Lars Kamphuis, visiting Postdoctoral Research Fellow, 08Aug11-31Aug11, CSIRO Plant Industry, Perth, Australia.

Dr. Kota Kera: visiting collaborator and postdoc Dr. Kota Kera (H. Suzuki Lab) from the Kazusa DNA Research Institute from 01Sep-12Sep14. The goal is to compare ultra-high resolution FT-ICRMS of labeled and unlabeled *Medicago truncatula* extracts to UHPLC-MS-SPE-NMR data to facilitate a greater number of identifications in this model legume.

Ken Korth, Ph.D. Professor, University of Arkansas, Fayetteville, AR, Visiting Professor, September 2010 - March 2011

Lanfeng Levine, Ph.D. Senior Research Chemist, Biological/Analytical Chemistry, Core Lead, Dynamac Corporation, NASA, Fl.

Mohammed Meetani, Ph.D. Assistant Professor, Department of Chemistry, College of Science, United Arab Emirates University

Pilon, Alan; Visiting Graduate Student, Nuclei of Bioassays, Biosynthesis and Ecophysiology of Natural Products (NuBBE) Chemistry Institute - São Paulo State University – UNESP. August 1, 2013 to July 23, 2014.

Narumon Sawasdipuksa, Visiting Graduate Student, Department of Chemistry, Chulalongkorn University, Bangkok, Thailand

Nakabyashi, Ryo, RIKEN Center for Sustainable Resource Science, Metabolomics Research Group, Aug – Sep 2015.

Craig Schenck, visiting graduate student, University of Wisconsin, Metabolomics analysis of MtPDH1, 16-22Aug15.

Prof. Joel Tim Smith, Ph.D. Department of Chemistry, Southeastern Oklahoma State University, Durant, OK.

John H. Snyder, Ph.D Candidate, Visiting Graduate Student, Department of Plant Biology, Cornell University, Ithaca, NY

Ms. Leepika Tuli, Visiting Graduate Student, Virginia Bioinformatics Institute, Blacksburg, VA

Prof. Hui Xie: The Sumner lab hosted visiting Professor Hui Xie from Fudan University, China to expand her training in modern molecular, biochemical and analytical approaches associated with the study of phytochemicals; especially bioactive compounds relevant to pharmacognosy and Traditional Chinese Medicine (Nov2013-Nov2014).

Dr. Zhigang Yang: The Sumner lab hosted collaborator Dr. Zhigang Yang (Saito Lab) as an international visiting scientist from the RIKEN Center for Sustainable Science Nov-Dec. 2013 as part of our International Exchange Program from 15Oct-15Dec, 2013. During this visit, Dr. Yang was provided with hands-on UHPLC-MS-SPE-NMR training by the Sumner Lab and UHPLC-MS-SPE-NMR was used to identify approximately 15 metabolites from Arabidopsis.

Chao Zhang, Ph.D Candidate, Visiting Graduate Student, Department of Computer Science, University of Missouri, Columbia, MO

Hua Zhang, Visiting Graduate Student, 28Nov11 through 15Sep12, Southwest University, China.

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## **PROFESSIONAL ORGANIZATIONS:**

Treasurer (Oct2010-Sep2012), President (Oct2008-Sept2010), Interim Treasurer (2007-08) and 2013 Lifetime Honorary Member of the Metabolomics Society

Fellow & Member of The American Association for the Advancement of Science

Member of The American Society for Mass Spectrometry

Member of The American Chemical Society

Member of The Phytochemical Society of North America

Member of The American Society for Plant Biology

Member and former vice-president (1993) of OSU section of Phi Lambda Upsilon, a national chemistry honor society.

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## **PATENTS:**

United States Patent No.: US 8,138,392 B2, Mar. 20, 2012. Disease Resistant Plants. Srinivasa Rao Uppalapati, Kirankumar S. Mysore, Wensheng Li, Lloyd Sumner, Richard A. Dixon.

US Provisional Patent 12/760,440: Metabolic Engineering for Plant Disease Resistance 14 April 2010. Wensheng Li, Srinivasa Rao Uppalapati, Kirankumar S. Mysore, Richard A. Dixon, Lloyd W. Sumner.

US Provisional Patent Application: Metabolic Engineering for Plant Disease Resistance 14 April 2009. Wensheng Li, Srinivasa Rao Uppalapati, Kirankumar S. Mysore, Richard A. Dixon, Lloyd W. Sumner.

U.S. Provisional Patent Application No. 61/080,633: Cotton Root Rot Disease Resistant Plants. Srinivasa Rao Uppalapati, Kirankumar S. Mysore, Wensheng Li, Lloyd Sumner, Richard A. Dixon.

US Pre-grant Abstract 200500230255: A method for removing transition metal stains from biological samples including protein, DNA, and RNA using hydrogen peroxide.

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## PUBLICATIONS:

131. Bibi Rafeiza Khan, Daniel J. Wherritt, David Huhman, Lloyd W. Sumner, Kent D. Chapman and Elison B. Blancaflor. Malonylation of Glucosylated N-Lauroylethanolamine: A New Pathway that Determines N-Acylethanolamine Metabolic Fate in Plants, submitted, J. Biol. Chem, 29Jul16.
  130. Bonnie S. Watson, Daniel Wherritt, David V. Huhman, Derek Nedveck, Dennis Fine, Peter Tiffin, Nevin Young, Lloyd W. Sumner. A novel M. truncatula DDMP-transferase (MtDPT) plays a key role in saponin biosynthesis. Nature Plants, in revision.
  129. Srinivasa Rao Uppalapatia, Upinder S. Gill, Lina Gallego-Giraldo, Yasuhiro Ishiga, Wensheng Li, Lloyd W Sumner, Richard A. Dixon, and Kirankumar S. Mysore. Targeted Lignin Modification Induces Tolerance to Soil-Borne Fungal Pathogens in Alfalfa. New Phytologist, submitted, NPH-MS-2016-21843.
  128. Feng Qiu, Dennis D. Fine, Daniel J. Wherritt, Zhentian Lei, and Lloyd W. Sumner. PlantMAT: A Metabolomics Tool for Predicting the Metabolic Potential of a System and for Large-scale Metabolite Identifications. Analytical Chemistry, resubmitted 12Jul16.
  127. Sisi Geng, Biswapriya Biswas Misra, Evaldo de Armas, David Huhman, Hans T. Alborn, Lloyd W. Sumner, Sixue Chen. Jasmonate-mediated stomatal closure under elevated CO<sub>2</sub> revealed by time-resolved metabolomics, Plant Journal, in-press, TPJ-00252-2016.
  126. Arthur S. Edison, Robert D. Hall, Christophe Junot, Peter D. Karp, Irwin J. Kurland, Robert Mistrik, Laura K. Reed, Kazuki Saito, Reza M. Salek, Christoph Steinbeck, Lloyd W. Sumner and Mark R. Viant, The Time Is Right to Focus on Model Organism Metabolomes. Metabolites, 2016, 6, 8; doi:10.3390/metabo6010008.
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125. Avinash C Srivastava, Fang Chen, Tui Ray, Sivakumar Pattathil, Maria J Peña, Urku Avci, HongJia Li, David V Huhman, Jason Backe, Breeanna Urbanowicz, Jeffrey S Miller, Mohamed Bedair, Charles E Wyman, **Lloyd W Sumner**, William S York, Michael G Hahn, Richard A Dixon, Elison B Blancaflor, and Yuhong Tang. Loss of Function of Folylpolyglutamate Synthetase 1 Reduces Lignin Content and Improves Cell Wall Digestibility in Arabidopsis. Biotechnol Biofuels. 2015 Dec 21;8:224. doi: 10.1186/s13068-015-0403-z. eCollection 2015. PMID: 26697113 Free PMC Article
  124. Daniel Abate-Pella, Dana M Freund, Yan Ma; Yamil Simon-Manso, Juliane Hollender, Corey D Broeckling, David V Huhman; Oleg V Krokhin, Dwight R Stoll, Adrian D Hegeman, Tobias Kind, Oliver Fiehn, Emma L Schymanski, Jessica E Prenni, Lloyd W Sumner, P. G. Boswell, Retention Projection Enables Accurate Calculation of Liquid Chromatographic Retention Times Across Labs and Methods, Journal of Chromatography A, 2015 Sep 18;1412:43-51. doi: 10.1016/j.chroma.2015.07.108. Epub 2015 Aug 3. PMID: 26292625
  123. Wenchao Zhang, Zhentian Lei, David Huhman, Lloyd W. Sumner and Patrick X. Zhao. MET-XAlign: A Metabolite based Cross-Alignment Tool for LC/MS based Comparative Metabolomics. Analytical Chemistry, Anal Chem. 2015 Sep 15;87(18):9114-9. doi:10.1021/acs.analchem.5b01324. Epub 2015 Aug 31. PMID: 26247233 Free Article
  122. Lei, Zhentian; Jing, Li; Qiu, Feng; Zhang, Hua; Huhman, David; Zhou, Zhiqin; Sumner, Lloyd W. Construction of a UHPLC-Tandem Mass Spectral Library of Plant Natural Products and Comparative Spectral Analyses. Analytical Chemistry, 2015, 87(14)7373-7381.
  121. Taehyong Kim, Kate Dreher, Ricardo Nilo-Poyanco, Insuk Lee, Oliver Fiehn, Bernd Markus Lange, Basil J. Nikolau, **Lloyd W. Sumner**, Ruth Welti, Eve S. Wurtele and Seung Y. Rhee. Patterns of metabolite changes identified from large-scale gene perturbations in *Arabidopsis thaliana* using a genome-scale metabolic network. Plant Physiology, in-press, <http://www.plantphysiol.org/cgi/content/short/pp.114.252361?keytype=ref&ijkey=3zxlEot3el6KIDs>.



- 120.\* Watson, Bonnie S.; Urbanczyk-Wochniak, Ewa; Bedair, Mohamed F.; Huhman, David V. ; Allen, Stacy N.; Tang, Yuhong; **Sumner; Lloyd W.** Integrated Metabolomics and Transcriptomics Reveal Enhanced Specialized Metabolism in *Medicago truncatula* Root Border Cells. *Plant Physiology*, 2015, 167(4), 1699-1716.  
<http://www.plantphysiol.org/cgi/content/short/pp.114.253054?keytype=ref&ijkey=YwhOHkaR1byKg7z>.
- 119.\* Li Jing, Zhentian Lei, Guiwei Zhang, Alan Cesar Pilon, David V Huhman, Rangjin Xie, Wanpeng Xi, Zhiqin Zhou, **Lloyd W Sumner**. Metabolite profiles of Chinese native Citrus species and their taxonomic implications. *Metabolomics*, 2015, 11(4). DOI:10.1007/s11306-014-0751-x.
- 118.\* **Sumner, Lloyd W.**; Lei, Zhentian; Nikolau, Basil J.; Saito, Kazuki. Modern Plant Metabolomics: Advanced Natural Product Gene Discoveries, Improved Technologies, Challenges and Future Prospects. *Natural Product Reports*, 2015, 32, 212 – 229. DOI: 10.1039/c4np00072b.
- 117.\* **Lloyd W. Sumner**, Mark Styczynski, John McLean, Oliver Fiehn, Georg Jander, James Liao, Susan Sumner, Philip Britz-McKibbin, Ruth Welti, A. Daniel Jones, Peter Dorrestein, Dan Bearden, Rima Kaddurah-Daouk. Introducing the USA Plant, Algae and Microbial Metabolomics Research Coordination Network (PAMM-NET). *Metabolomics*, 2015, 11(1) 3-5.
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- 116.\* **Sumner, Lloyd W.**; Lei, Zhentian; Nikolau, Basil J.; Saito, Kazuki, Ute Roessner, Robert Trengove. Proposed Quantitative and Alphanumeric Metabolite Identification Metrics, *Metabolomics*, 2014, 10(6), 1047-1049.
115. Jing, L; Lei, Z.; Li, L.; Xie, R.; Xi W.; Guan, Y.; **Sumner, L.W.**; Zhou, Z. Antifungal Activity of Citrus Essential Oils. *J Agric Food Chem*. 2014, 62(14) 3011-3033 Mar 27. [Epub ahead of print]
114. Zhang, JY; Cruz DE Carvalho MH, Torres-Jerez I, Kang Y, Allen SN, Huhman DV, Tang Y, Murray J, **Sumner LW**, Udvardi MK. Global reprogramming of transcription and metabolism in *Medicago truncatula* during progressive drought and after rewatering. *Plant Cell Environ*. 2014 Mar 24, 37(11) 2553-2576. doi: 10.1111/pce.12328.
113. Hall, R.; **Sumner, L.W.**; Viant, M.; Goodacre, R. 2014 Honorary fellows of the Metabolomics Society, *Metabolomics*, 2014, 10(5) 537-538.
112. Zhang, Wenchao; Chang, Junli; Lei, Zhentian; Huhman, David; **Sumner, Lloyd**; Zhao, Patrick Xuechun. MET-COFEA: A Novel Liquid Chromatography-Mass Spectrometry Data Processing Platform for Metabolite Compound Feature Extraction and Annotation. *Analytical Chemistry*, 2014, Jul 1; 86(13), 6245-6253. doi: 10.1021/ac501162k. Epub 2014 Jun 9. PMID: 24856452
111. Creek, D.J.; Dunn, W.B.; Fiehn, O.; Griffin, J.L.; Hall, R.D.; Lei, X.; Mistrik, R.; Neumann, S.; Schymanski, E.L.; **Sumner, L.W.**; Trengove, T.; Wolfender, J-L. Metabolite identification: are you sure? And how do your peers gauge your confidence? *Metabolomics*, 2014, 10(3) 350–353. DOI 10.1007/s11306-014-0656-8
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## Pending External Research Support:

**Project title:** Expansion and Translation of Custom Plant Metabolite Identification Tools for the Identification of Mammalian Metabolites and Mining NIH Metabolomics Datasets Involving Plants

**Source of support:** National Institutes of Health, Metabolomics Data Analysis (R03) (RFA-RM-15-021)

**Investigators:** Lloyd W. Sumner (PI), William Folk, Mark Hannink, Dong Xu, Zhentian Lei

**Total award amount:** \$149,256

**Total award period:** 09/01/16 – 08/31/17

**Effort:** Cal: 0.5

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## Current and Prior External Research Support:

**Project title:** Development of UHPLC-Trapped Ion Mobility Mass Spectrometry for Metabolomics

**Source of support:** Bruker Daltonics, GmbH

**Investigators:** Lloyd W. Sumner (PI),

**Total award amount:** \$450,000 in kind instrumentation contribution of an Bruker TIMS-QToFMS/MS

**Total award period:** 01/01/17 – 12/31/18

**Effort:** Cal: 1.0

**Project title:** RCN: Integrating and Coordinating a National and International Plant, Algae, and Microbial Metabolomics Research Coordination Network

**Source of support:** National Science Foundation IOS Award#1340058

**Investigators:** Lloyd W. Sumner (PI), Georg Jander, Oliver Fiehn, James C. Liao, Basil J. Nikolau

**Total award amount:** \$499,797

**Total award period:** 09/01/13 – 08/31/18

**Effort:** Cal: 0.5

**Project title:** Metabolomics: Advancing the Scientific Promise to Better Understand Plant Specialized Metabolism for a Low-Carbon Society

**Source of support:** National Science Foundation IOS and Japanese Science and Technology Agency joint Metabolomics initiative, # 1139489

**Investigators:** Lloyd W. Sumner (PI), Richard A. Dixon, Ji He, Basil Nikolau

**Total award amount:** \$1,499,970

**Total award period:** 12/01/11 – 11/30/17 (2 year creativity extension award 2015)

**Effort:** Cal: 1

**Project title:** Identification of novel plant Metabolites using LC-SPE-MS-NMR in plant Metabolomics experiments

**Source of support:** Bruker BioSpin

**Investigators:** \$450,000 (in-kind provision of a Bruker maXis QToF-MS/MS)

**Total award period:** 09/01/11 – 08/31/14

**Effort:** Cal: 0.5

**Project title:** MRI: Acquisition of a 600 MHz NMR with cryoprobe for Integration with Existing UPLC-MS-SPE to Enable Higher-throughput Chemical Annotation in Plant Metabolomics

**Source of support:** National Science Foundation, Major Research Instrumentation, DBI #1126719

**Investigators:** Lloyd W. Sumner (PI), Michael Beale, Richard A. Dixon, Randy Allen, Joel T. Smith Total award amount: \$1,554,488

**Total award period:** 09/01/11 – 08/31/14

**Effort:** Cal: 2

**Project title:** Development of Plant Metabolite Tandem Mass Spectral Libraries for a Triple-quadrupole Mass Spectrometer

**Source of support:** Waters Inc Instrumentation Award

**Investigators:** Lloyd W. Sumner (PI)  
**Total award amount:** \$250,000 (in-kind provision of a Waters Xevo triple quadrupole MS/MS instrument)  
**Total award period:** 9/1/2011 – 8/30/13  
**Effort:** 0%

**Project title:** Metabolomics and Genome Wide Association Mapping for the Elucidation of Triterpene Saponin  
Molecular Biochemistry in Medicago  
**Source of support:** National Science Foundation, Molecular and Cellular Biosciences #1024976  
**Investigators:** Lloyd W. Sumner (PI) and Nevin D. Young (CoPI)  
**Total award amount:** \$692,394  
**Total award period:** 09/01/10 – 8/31/13 (Currently in a no cost extension until 8/31/14)  
**Effort:** Cal: 1.3

**Project title:** Metabolomics and Genome Wide Association Mapping for the Elucidation of Triterpene Saponin  
Molecular Biochemistry in Medicago  
**Source of support:** Oklahoma EPSCoR Research Experience for Undergraduates; Summer 2011 (Primary Award  
#EPS-0814361, subaward #EPSCoR-2011-15  
**Investigators:** Lloyd W. Sumner (PI & Mentor) and Amanda Jantz (REU Student)  
**Total award amount:** \$4,800  
**Total award period:** 05/23/11 – 8/12/11  
**Effort:** 0.1

**Project title:** Development of Plant Metabolite Tandem Mass Spectral Libraries for a Triple-quadrupole Mass  
Spectrometer  
**Source of support:** Agilent Corp. Instrumentation Award  
**Investigators:** Lloyd W. Sumner (PI)  
**Total award amount:** \$250,000 (in-kind provision of a Agilent 6430 triple quadrupole MS/MS instrument)  
**Total award period:** 9/1/2010 – 8/30/12  
**Effort:** 5%

**Project title:** Metabolomics 2010 Conference Support  
**Source of support:** National Institutes of Health, NIH Support for Conferences and Scientific Meetings (Parent  
R13/U13), NIGMS and NIEHS #GM095229-01  
**Investigators:** Lloyd W. Sumner (PI) and Oliver Fiehn (CoPI)  
**Total award amount:** \$7,000  
**Total award period:** 06/27/2010 – 6/26/11  
**Effort:** Cal: 0

**Project title:** A Joint NSF and JST Workshop: Identifying Potential Collaborative Research Opportunities in  
Metabolomics  
**Source of support:** National Science Foundation, Molecular and Cellular Biosciences #1038679  
**Investigators:** Lloyd W. Sumner (PI) and Oliver Fiehn (CoPI)  
**Total award amount:** \$35,157  
**Total award period:** 05/05/10 – 05/05/11  
**Effort:** Cal: 0

**Project title:** Elucidation of Medicago triterpene saponin biosynthesis  
**Source of support:** Oklahoma Center for the Advancement of Science and Technology (OCAST; #PSB10-027;  
graduate student support and seed grant)  
**Investigators:** Lloyd W. Sumner (PI)  
**Total award amount:** \$88,833  
**Total award period:** 03/01/10 – 02/28/12  
**Effort:** 8%

**Project title:** Metabolomics: A functional genomic tool for deciphering functions of Arabidopsis genes  
**Source of support:** National Science Foundation 2010, MCB #0520140  
**Investigators:** Basil Nikolau (PI), Bernd M. Lange (CoPI), Oliver Fiehn (CoPI), Seung Rhee (CoPI), Lloyd W. Sumner (CoPI), and Ruth Welti (CoPI)  
**Total award amount:** \$5,886,429 (\$433,811 Sumner Lab)  
**Total award period:** 3/01/09 – 08/30/13  
**Effort:** Cal: 1

**Project title:** Functional Analysis of Pollen Exine Assembly  
**Source of support:** National Science Foundation 2010, Molecular and Cellular Biosciences #520283  
**Investigators:** Daphne Preuss, Anna Edlund, Robert J. Swanson and Lloyd W. Sumner (CoPI)  
**Total award amount:** \$1,685,616 (\$345,682 Sumner Lab)  
**Total award period:** 09/01/05 – 08/30/09 (no cost extension until 8/30/10)  
**Effort:** Cal: 1

**Project title:** Development of an Ultra-high Resolution Liquid Chromatography Time-of-flight Mass Spectrometer Platform for Metabolomics  
**Source of support:** LECO Instrumentation Award  
**Investigators:** Lloyd W. Sumner (PI)  
**Total award amount:** \$200,000  
**Total award period:** 09/01/05 – 4/31/10  
**Effort:** 5%

**Project title:** GEPR: Comparative genomics of secretory trichomes – biofactories for production of plant secondary metabolites  
**Source of support:** National Science Foundation Plant Genome Research Program #0605033  
**Investigators:** Richard Dixon, David Marks, Pierre Broun,  
**Collaborators:** Lloyd W. Sumner and Xuechun (Patrick) Zhao  
**Total award amount:** \$1,406,599 (~\$384,899 Sumner Lab)  
**Total award period:** 05/01/06 – 04/30/09  
**Effort:** 10%

**Project title:** The Consortium for Legume Research: An integrated approach to cotton root rot disease of alfalfa  
**Source of support:** The State of Oklahoma  
**Investigators:** Richard A. Dixon, Joe Bouton, Bruce Roe, Steve Marek, Kiran Mysore, Mary Sledge and Lloyd Sumner  
**Total award amount:** \$1,400,000 (\$136,612 Sumner Lab)  
**Total award period:** 09/01/05 – 08/30/09  
**Effort:** Cal: 1

**Project title:** Metabolomics: A functional genomic tool for deciphering functions of Arabidopsis genes  
**Source of support:** National Science Foundation 2010, MCB 0520140  
**Investigators:** Basil Nikolau, Bernd M. Lange, Oliver Fiehn, Seung Rhee, Lloyd W. Sumner and Ruth Welti  
**Total award amount:** \$1,000,000 (\$63,337 Sumner Lab)  
**Total award period:** 09/01/05 – 08/30/07  
**Effort:** Cal: 1

**Project title:** An integrated approach to functional genomics and bioinformatics in a model legume  
**Source of support:** National Science Foundation (Award DBI#0109732)  
**Investigators:** Pedro-Mendes (PI), Richard Dixon (Co-PI), Lloyd Sumner, Greg May and Tim Smith (Collaborators)  
**Total award amount:** \$3,587,432 (\$1,130,845 Sumner lab)  
**Total award period:** 08/01/02-07/31/05  
**Effort:** Cal: 3

Agency	Division	Award#	Proposal Title	PI	Start Date	End Date	Award Amount	Amount to Sumner Lab
NSF-JST	IOS	1139489	Creativity Extension: Metabolomics: Advancing the Scientific Promise to Better Understand Plant Specialized Metabolism for a Low-Carbon Society	Sumner (PI)	1/1/2015	8/31/2020	\$ 1,000,000.00	\$ 500,000.00
NSF	IOS	1340058	RCN: Integrating and Coordinating a National and International Plant, Algae, and Microbial Metabolomics Research Coordination Network	Sumner (PI)	9/1/2013	8/31/2018	\$ 499,797.00	\$ 25,000.00
NSF-JST	IOS	1139489	Metabolomics: Advancing the Scientific Promise to Better Understand Plant Specialized Metabolism for a Low-Carbon Society	Sumner (PI)	12/1/2011	11/30/2014	\$ 1,499,970.00	\$ 775,452.00
Bruker Daltonics (in-kind provision of a Bruker)			Identification of novel plant Metabolites using LC-SPE-MS-NMR in plant Metabolomics experiments	Sumner (PI)	9/1/2011	8/31/2014	\$ 450,000.00	\$ 450,000.00
NSF	MRI	1126719	MRI: Acquisition of a 600 MHz NMR with cryoprobe for integration with Existing UHPLC-MS-SPE to Enable Higher-throughput Chemical Annotation in Plant Metabolomics	Sumner (PI)	9/1/2011	8/31/2014	\$ 1,554,488.00	\$ 1,554,488.00
Waters Inc. (in-kind provision of a Waters Xevo)			Development of Plant Metabolite Tandem Mass Spectral Libraries for a Triple-quadrupole Mass Spectrometer	Sumner (PI)	9/1/2011	8/31/22013	\$ 250,000.00	\$ 250,000.00
NSF	EPSCoR-REU	EPS-0814361	Metabolomics and Genome Wide Association Mapping for the Elucidation of triterpene Saponin Biosynthesis	Sumner (PI)	5/23/2011	8/12/2011	\$ 4,800.00	\$ 4,800.00
NSF	MCB	1024976	Metabolomics and Genome Wide Association Mapping for the Elucidation of triterpene Saponin Biosynthesis	Sumner (PI)	9/1/2010	8/31/2013	\$ 692,394	\$ 692,394
Agilent Corp.			Development of Plant Metabolite Tandem Mass Spectral Libraries for a Triple-quadrupole Mass Spectrometer	Sumner (PI)	9/1/2010	8/30/2013	\$ 250,000.00	\$ 250,000.00
NSF	MCB	1038679	A Joint NSF and Jst Workshop: Identifying Potential Collaborative Research Opportunities	Sumner (PI)	5/5/2010	5/5/2011	\$ 35,733.00	\$ 35,733.00
NIH	R13/U13	GM095229-01	Metabolomics 2010 Conference Support	Sumner (PI)	6/27/2010	6/26/2011	\$ 7,000.00	\$ 7,000.00
NSF	MCB	1038679	A Joint NSF and JST Workshop: Identifying Potential Collaborative Research Opportunities in Metabolomics	Sumner (PI)	5/5/2010	5/5/2011	\$ 35,157.00	\$ 35,157.00
OCAST (Oklahoma Plant Science)	PSB10-027		Elucidation of Medicago triterpene saponin biosynthesis	Sumner (PI)	3/1/2010	2/28/2012	\$ 88,833.00	\$ 88,833.00
NSF	MCB-2010	520140	Metabolomics: A functional genomic tool for deciphering functions of Arabidopsis genes	Nikolau (PI) Sumner (CoPI)	3/1/2009	8/30/2013	\$ 5,886,429.00	\$ 433,811.00
NSF	MCB-2010	520283	Functional Analysis of Pollen Exine Assembly	Preuss (PI) Sumner (CoPI)	9/1/2005	8/30/2009	\$ 1,685,616.00	\$ 345,682.00
LECO			Development of an Ultra-high Resolution Liquid Chromatography Time-of-flight Mass Spectrometer Platform for Metabolomics	Sumner (PI)	9/1/2005	4/31/10	\$ 200,000.00	\$ 200,000.00
NSF	IOS/PGRP	605033	Comparative genomics of secretory trichomes – biofactories for production of plant secondary metabolites	Dixon (PI) Sumner (CoPI)	5/1/2006	4/30/2009	\$ 1,406,599.00	\$ 384,899.00
State of Oklahoma			The Consortium for Legume Research: An integrated approach to cotton root rot disease of alfalfa	Dixon (PI) Sumner (CoPI)	9/1/2005	8/30/2009	\$ 1,400,000.00	\$ 136,612.00
NSF	MCB-2010	520140	Metabolomics: A functional genomic tool for deciphering functions of Arabidopsis genes	Nikolau (PI) Sumner (CoPI)	9/1/2005	8/30/2007	\$ 1,000,000.00	\$ 63,337.00
NSF	IOS/PGRP	109732	An integrated approach to functional genomics and bioinformatics in a model legume	Mendes (PI) Sumner (Collaborator)	8/1/2002	7/31/2005	\$ 3,587,432.00	\$ 1,130,845.00
Totals							\$ 21,534,248.00	\$ 7,364,043.00

## **NSF IOS Award#1340058: RCN: Integrating and Coordinating an International Plant, Algae, and Microbial Metabolomics Network**

The primary goal of this project is to develop a Plant, Algae and Microbial Metabolomics Research Coordination Network (PAMM NET) that will promote effective communication, enhance opportunities for collaboration, build community consensus, identify key challenges in metabolomics, and facilitate coordinated community empirical efforts to meet these challenges. Participation in PAMM NET will be open to the public, and will begin with the unification of four independent and international projects funded through the joint NSF-JST Metabolomics for a Low Carbon Society program. This unification will further amplify NSF's current investment in plant, algae and microbial metabolomics, and will be achieved through regular videoconferences and annual face-to-face program meetings and workshops. This team will serve as a nucleus to build forth a more unified national and international PAMM NET that will identify and pursue solutions to the key challenges that still impede the full potential of metabolomics. This will be facilitated through the recruitment of a 50% network coordinator who will serve as a dedicated advocate for the organization, facilitate integration, and provide logistical support for consensus reporting of the network outcomes. The initial nucleus and network coordinator will then recruit public participants from the US and global plant, algae, and microbial metabolomics communities to build working focus groups. These focus groups will actively discuss the current grand challenges associated with metabolomics and potential solutions to these challenges. The PAMM NET recognizes that many challenges will need the involvement of the larger biology, technology, and bioinformatics communities and PAMM NET will therefore recruit feedback and active participation from these diverse groups to best formulate empirical solutions to the grand challenges. PAMM NET will further contribute to the development of a US National Chapter of the Metabolomics Society to better serve and provide long-term solutions for the needs of the US metabolomics community. PAMM NET will build a repartee with other federally funded programs such as the NIH-supported National Metabolomics Centers to better coordinate efforts across federal funding divisions and scientific disciplines. Finally, PAMM NET will initiate conversations with the global metabolomics community to identify and pursue cooperative international metabolomics funding opportunities. A coordinated community effort is expected to be more cordial, efficient, and productive; leading to new and enabling scientific discoveries and innovations.

The Plant, Algae and Microbial Metabolomics Research Coordination Network (PAMM NET) will promote effective communication, enhance opportunities for collaboration, build community consensus, identify key challenges in metabolomics, and facilitate coordinated community empirical efforts to meet these challenges. These efforts are expected to have substantial broader impacts on building community consensus and facilitating more cordial, efficient and productive scientific discoveries and innovations. The PAMM NET RCN also considers research-based education and training as an integral part of preparing young scientists for fruitful careers. Accordingly, the PAMM NET will encourage, coordinate and support the attendance of young scientists (young faculty, graduate students, post-docs and a limited number of undergraduate students) at annual workshops that are associated with each of the NSF-JST Metabolomics programmatic projects through a limited number of scholarships. These programmatic workshops will include hands-on demonstrations of different aspects of metabolomics research that will range from the use of sophisticated chromatographic, mass-spectrometric and NMR-based tools for metabolite analyses, to computational and statistical analyses and interpretation of metabolomics data. In addition, this RCN will organize and support an annual workshop associated with international plant biology or metabolomics meetings (e.g., Annual Meeting of the Metabolomics Society or the Annual Meeting of the American Society of Plant Biologists). Information about the activities of the PAMM NET will be housed at the project website (to be developed) with long-term plans to transfer the resources generated to the Metabolomics Society website for long-term maintenance and support.

**NSF-JST IOS# 1139489 Metabolomics: Advancing the Scientific Promise to Better Understand Plant Specialized Metabolism for a Low-Carbon Society**

*Scientific Merit:* Metabolites are the building blocks and energy of life. The large-scale study of metabolites known as metabolomics is revolutionizing our understanding of plant metabolism and novel gene functions. Although the growing utility of metabolomics is well documented in the literature, its full scientific promise has not yet been realized due to multiple technical challenges. These challenges include the accurate chemical identification of metabolites and a sophisticated understanding of the spatial/temporal distribution of metabolism. To address these issues, a synergistic international team of plant metabolomics and metabolism experts will use an integrated approach that unites clear biological drivers to both push key technical developments and then pull from these enabling technologies a better understanding of carbon sequestration and allocation in relationship to energy and a low carbon society.

The major biological objective of this project seeks to discover and elucidate key genes involved in cell wall metabolism (especially lignin and phenylpropanoids) and energy dense lipids. These two biochemical classes have been purposely selected because 1) cell walls represent the largest biological reserve of carbon (biomass), which could be used as an energy source if its structure and metabolic origins could be understood, and 2) lipids represent nature's molecules for storing carbon and energy. Therefore, understanding and mimicking these biological systems should provide an efficient means for the development of a low carbon society.

The major technical objective of this project is to develop advanced technologies and use these for the systematic and data directed annotation of the metabolomes of two model plant species, namely *Arabidopsis thaliana* and the leading model legume *Medicago truncatula*, which is a close relative of alfalfa (*Medicago sativa*). This will be performed using a combination of literature mining, computational prediction, authentic standards, and sophisticated experimental approaches including high resolution separation, mass spectrometry, and nuclear magnetic resonance technologies for metabolite annotation. Increased metabolite annotations will increase the depth-of-coverage and biological context of our metabolomics experiments, thereby providing greater opportunities for the functional understanding of carbon sequestration and partitioning in cell walls and lipids.

*Broader Impacts:* The outcomes of this project will be significant advances in our understanding of carbon allocation and partitioning in plant specialized and lipid metabolism which will lead to greater opportunities to engineer renewable bioenergy resources resulting in a low carbon society. Novel and sophisticated metabolomics technologies will be developed resulting in increased metabolomics coverage. Valuable spectral libraries will be generated and distributed to the metabolomics community. Collaborative relationships between multiple Japanese and US scientists and institutions will be strengthened through a foreign exchange program for our postdoctoral researchers and principal investigators involving extended reciprocal visits at international host institutes. This project will provide multi-disciplinary training for 4 postdoctoral researchers in plant metabolomics, molecular biology, integrated systems biology, and cutting-edge analytical biochemistry. All postdoctoral researchers will be actively mentored in the fundamental educational processes of discovery and dissemination of new knowledge through scientific presentations and publications. Hands-on metabolomics workshops will be conducted each year and sequentially hosted by each of the participating institutes (Noble Foundation, Iowa State University, and RIKEN Plant Science Center) to provide advanced educational opportunities for the international metabolomics community. Funded postdoctoral researchers will actively participate and lead the above workshops to improve their organizational and communication skills. This proposal will support 3 summer Research Experiences for Undergraduates (REUs) each year. The REUs will support the objectives of this proposal, foster enhanced educational opportunities and stimulate competitive careers in science and technology for the undergraduates. The postdoctoral researchers will supervise the day-to-day activities of the REUs which will provide key personnel management training for the postdoctoral researchers that is rarely taught as part of the formal doctoral education process.

## **NSF MCB #1024976 Metabolomics and Genome Wide Association Mapping for the Elucidation of Triterpene Saponin Molecular Biochemistry in Medicago**

*Intellectual Merit:* The fundamental goal of this project is to identify and characterize novel genes responsible for triterpene saponin biosynthesis in *Medicago truncatula* using revolutionary technologies. Triterpene saponins are a class of structurally diverse plant natural products with a wide range of demonstrated bioactivities including allelopathic, antifungal, antibacterial, antiinsect, anticancer, antinutritive activities. The antinutritive properties of triterpene saponins in legume forages such as alfalfa and soybean are of particular and substantial economic importance. However, the biosynthesis of triterpene saponins is poorly characterized and this pathway is absent from most textbooks. This project will use cutting-edge metabolomics, genome wide association mapping, correlated gene expression profiling, and traditional molecular validation approaches for gene discovery and characterization related to triterpene saponin biosynthesis in *M. truncatula*. The goal of this project will be accomplished through the following specific aims: 1) Metabolome analyses of a large and diverse *M. truncatula* germplasm collection to identify hyper- (high) and hypo- (low) saponin accumulating lines and to enable genome-wide association mapping between specific loci with saponin content 2) Comparative gene expression analyses of hyper and hypo saponin accumulating lines to identify putative genes involved in triterpene saponin biosynthesis and regulation, and 3) Molecular and biochemical confirmation of select targeted saponin biosynthetic genes prioritized based upon multiple levels of evidence. Preliminary data document substantial metabolic diversity in saponin accumulation which is a necessary prerequisite for successful association mapping and comparative microarray analyses.

*Broader Impacts:* This project will identify and characterize specific genes involved in legume triterpenoid saponin biosynthesis. Specific genes identified in this project have the potential for future metabolic-engineering of crop varieties with: 1) improved fitness and defense, 2) decreased bloat and antinutritive properties resulting in optimized livestock weight gain performance, and 3) potential plant neutraceuticals and adjuvants related to human and animal health. High resolution biochemical phenotype data generated for a large number of *M. truncatula* accessions core collection will be generated and will be made publicly available via an anonymous FTP server (<ftp://summerftp.noble.org/pub>). This data will highlight specific germplasm critical for further molecular and biochemical dissection of saponin biosynthesis. More importantly, the copious metabolomics data generated will provide substantial community value in that it will enable association mapping with a wealth of other metabolites (both known and unknown) and related fitness traits including, but not limited, to symbiosis (flavonoids, isoflavonoids, dicarboxylic acids), drought/salinity tolerance (proline, mannitol, and other osmoprotectants), and/or aluminum tolerance (malate). Funding of this project will provide multi-disciplinary training for two postdoctoral researchers and one undergraduate summer intern/hourly worker in advanced technologies, plant molecular biology, large-scale integrated systems biology, and large-scale analytical biochemistry. During the three year tenure, the postdoctoral researcher will be mentored in scientific writing, scientific presentations, publishing, grant applications, constructive peer review, project management, time management, and personnel management to further mold a great scientific mind more towards the realistic and professional expectations of modern academic and commercial research. A series of enrichment workshops focused upon local high school students will be provided. Participating groups include Oklahoma Upward Bound Science/Math Program, Ardmore High School AP and Science Club, and Southern Oklahoma Technology Center Biotechnology Program. These annual enrichment opportunities will stimulate student interests in science, plant biology, and natural product biochemistry. An international symposium will be hosted in year 3 which will provide a forum for the latest advances in saponin research and serve to highlight the outcomes of this project. Postdocs funded by this proposal would serve key leadership roles in organizing and executing the workshops.

## **NSF MC #1038679 A Joint NSF and JST Workshop: Identifying Potential Collaborative Research Opportunities in Metabolomics.**

*Intellectual Merit:* The specific aims of this proposal are 1) to acquire funds to enable a workshop that will lead to a consensus report that identifies and prioritizes key strategic areas where metabolomics offers the greatest opportunity to advance novel biological knowledge in the areas of energy and environment, and 2) to foster greater collaborative interactions between Japan and US scientists in these priority research areas. The Japanese have invested heavily in metabolomics and are ideal partners for collaborative research. To achieve the above



goal, a team composed of approximate 10-15 scientists from Japan and from the USA will meet for two days, May 6-7, 2010, at The University of California, Davis. The workshop will focus upon current technical challenges and optimum collaborator opportunities related to plant, algal, and microbial metabolomics. Specific technical challenges to be discussed include defining the Metabolome, metabolite annotation, spatially and temporally resolved sampling, flux'omics', dynamic range and depth-of-coverage, instrumentation and infrastructure, informatics and databases, standardization, putative national plant, algal, microbial metabolomics facility(s). Collaborative application opportunities will be discussed with regards to bioenergy, environment, functional genomics & gene discovery, secondary metabolism, metabolomics & genome-wide association mapping (plant, algae, microbe), systems biology and metabolic modeling in plant, algal, and microbial metabolomics. A report of the meeting outcomes will be drafted on-site, refined through peer review, and a final report delivered to NSF and JST. This report will be considered by NSF and JST in developing a future and joint Research Funding Announcement.

*Broader Impacts:* This meeting will bring together an international team of leading scientists in the field of plant, algal, and microbial metabolomics, and provide a forum for the critical discussion of current challenges. These discussions are expected to identify and prioritize the current and most critically limiting challenges. More importantly, the discussions are also expected to lead to a consensus opinion for the best scientific approaches to address these challenges. The consensus opinions are also expected to unify the community towards a systematic attack on the challenges which will ultimately provide the most efficient approach to solving the challenges. The meeting will also foster and encourage collaborative interactions between US and Japanese scientists that will provide combined resources in applying advanced metabolomics technology to the solution of major questions related to plant, microbial, and algal biology.

**NSF MCB #820823, Arabidopsis 2010 Renewal: Metabolomics: A functional genomics tool for deciphering functions of Arabidopsis genes in the context of metabolic and regulatory networks**

*Summary of the proposed project:* Global profiling technologies enable comprehensive overview of the consequences of genetic alterations and can be used to annotate gene functions. However, the functions of over 1/3 of the annotated protein-coding genes of the Arabidopsis genome are still unknown, and the annotation of an even larger portion of the genome is not sufficiently accurate for unambiguous assignment function at the biochemical and physiological levels. This proposal builds on a prior pilot project that enabled a consortium of multidisciplinary collaborators to establish pipelines for generating metabolomics data streams and to integrate the outcomes with bioinformatics, computational, and database capabilities. Our goal is to develop novel capabilities that will enhance the research community's ability to formulate testable hypotheses concerning Arabidopsis gene function. The consortium has developed metabolomic platforms that together detect approximately 1,800 metabolites, of which 900 are chemically defined. The aims of the current proposal is to apply these established platforms to reveal changes in the metabolome associated with knockout mutations in 450 genes of unknown function and compare these to similar mutants in 50 genes of known function. To enhance the power of the metabolomics platforms the consortium will begin analytical efforts to expand the chemical identity of the Arabidopsis metabolome. Finally, the consortium will disseminate these data via the multifunctional metabolomics database developed in the pilot project. Enhancement of this database and associated statistical and visualization toolsets will enable researchers to formulate testable computational models of the metabolic network of Arabidopsis. The successful completion of these goals and integration with other NSF-sponsored functional genomics and cyber infrastructure developments will generate transformational resources for ultimately modeling the complex metabolism of Arabidopsis.

*Broader Impacts of the proposed research project:* The proposed consortium will develop new resources for the research community that will enhance the capability to globally profile genome expression at the metabolite level. These resources are critical to reveal the function of genes of currently unknown function. These resources will be developed in collaboration with other NSF-funded resource development projects, and will enable researchers in the community to formulate credible, testable hypotheses concerning gene function. The consortium will foster the development of the science of metabolomics as a functional genomics tool through workshops, internships and organization of national and international meetings. The consortium will also develop new activities to enhance the impact of science education and training in the community. Specifically, workshops for researchers will be provided at consortium labs and at international biological meetings. In addition, research internships will be offered to undergraduate students, eight of whom will have the opportunity to experience

international science training in a European genomics laboratory. These research-based training internships will illustrate to the students the synergy that is accompanied with the integrated applications of chemistry, biochemistry, genetics, bioinformatics and computational sciences to solving complex biological problems.

**Oklahoma Center for the Advancement of Science and Technology (OCAST) #PSB10-027: Elucidation of *Medicago* triterpene saponin biosynthesis (graduate student support)**

The fundamental goal of this project is to discover and characterize novel genes responsible for triterpene saponin biosynthesis in the model legume *Medicago truncatula*. Triterpene saponins are structurally diverse plant natural products with a wide range of demonstrated bioactivities including allelopathic, antifungal, antibacterial, antiinsect, antinutrient, and anti-cancer activities. Saponins in legume forages, such as alfalfa, are of particular and substantial economic importance because they result in impaired digestion in ruminant animals, and reduced weight gain. This project will use cutting-edge genomic, metabolomics, transcriptomics, and genetic approaches for gene discovery and the fundamental elucidation of the triterpene saponin biosynthetic pathway in the model legume *Medicago truncatula*. This will be achieved via the following specific aims.

- SPECIFIC AIM 1: *Medicago truncatula* genome analysis will be used to identify gene clusters and specific genes co-localized with  $\beta$ -amryin synthase which are highly likely co-regulated gene candidates associated with triterpene saponin biosynthesis.
- SPECIFIC AIM 2: Cutting-edge, high resolution biochemical profiling will be utilized to identify hyper and hypo accumulation of triterpene saponin content in a *Medicago truncatula* core germplasm collection.
- SPECIFIC AIM 3: Comparative gene expression analyses of hyper and hypo saponin accumulating lines will be performed using Affymetrix *Medicago* Gene Chips™ to identify putative biosynthetic enzymes involved in triterpene saponin biosynthesis and regulation.
- SPECIFIC AIM 4: Molecular and genetic confirmation of the two highest priority candidate genes related to triterpene saponin biosynthesis will be performed using molecular cloning and recombinant DNA-based *in vitro* functional characterization. The functional confirmation of the two candidates will also be sought outside of this project using reverse-genetic screens of a *Medicago truncatula* retrotransposon mutant population to identify specific saponin biosynthetic mutants useful in future genetic validation of function in these knock-out lines.

**NSF Plant Genome Research (0605033): Comparative genomics of secretory trichomes – biofactories for production of plant secondary metabolites**

Collectively, plants are a rich source of natural products, chemicals that often function to protect the plant from infection or insect pests. Natural products also form the basis of many currently used drugs, such as aspirin, morphine, taxol or the antimalarial compound artemisinin. Plant natural products are often synthesized and accumulated in secretory trichomes, which are appendages found on the aerial organs of plants. Trichomes have a unique capacity for chemical synthesis and secretion, and have been described as biofactories for the production of natural products. However, with few exceptions, little is known about the molecular aspects of trichome metabolism and secretion. The production of many natural products in specialized trichome cells facilitates genomics-based approaches to characterize biosynthetic and secretory processes. In this project, a large number of expressed sequence tags (ESTs) will be generated corresponding to genes expressed in trichomes of five species representing different plant families and both model and crop plants; *Medicago truncatula* and *M. sativa* (alfalfa), Leguminosae; *Nicotiana benthamiana* and *Lycopersicon esculentum* (cultivated tomato), Solanaceae; and hops (*Humulus lupulus*), Cannabaceae. Potato leafhopper resistant and susceptible alfalfa lines will be compared. At the same time, the full spectrum of natural products produced in the trichomes of these five species will be determined. The EST collection will be mined for genes involved in the regulation, biosynthesis and transport of natural products, and the functions of a selection of those genes that are common to multiple species will be determined by over- or under-expressing them in *Arabidopsis thaliana*.

The project is multidisciplinary, combining genomics, informatics and molecular biology with analytical biochemistry, enzymology, and metabolic engineering, and provides excellent training for postdoctoral fellows and undergraduate students in the skills increasingly required in the post-genomics age. The Noble Foundation and University of Minnesota will link the subject area of the project to the curricula of their existing student outreach

programs. A major deliverable of the project, TrichOME, a publicly available database of genes and metabolites expressed in plant trichomes, will be an important addition to plant genome sequence information, as genes only expressed in trichomes may be under-represented in non-tissue-targeted EST sequencing projects. As the project develops, gene sequences in the database will be linked to functional information describing the involvement of the genes in trichome-specific processes. The project will also improve our understanding of the synthesis, storage and secretion of a range of useful bioactive natural products, from anti-insect lipid amides in alfalfa to health-beneficial prenyl chalcones and bitter acid flavors/antimicrobials in hops.

#### **The State of Oklahoma: The Consortium for Legume Research: An integrated approach to cotton root rot disease of alfalfa**

The objectives of this research are to characterize *Phymatotrichopsis* root rot in alfalfa at the biological, chemical and genetic levels, with the long-term goal of developing resistant alfalfa varieties. We will approach the problem from the joint perspectives of the plant and the pathogen. Sequencing the genome of the pathogen (OU Advanced Genome Center) will provide access to the genetic blueprint that determines how this fungus causes disease and evades resistance mechanisms in so many plant species, as well as suggest molecular targets for disease control mechanisms. Developing a transformation system and other genetic resources for the fungus (OSU, Department of Plant Pathology) will enable us to delete specific fungal genes to test their involvement in causing disease. Breeding, selection and mutant screening strategies will identify lines of alfalfa and the closely related model legume *Medicago truncatula* with varying degrees of tolerance or susceptibility to the fungus (Noble Foundation Forage Improvement and Plant Biology Divisions). Application of genomic technology, metabolite profiling and antifungal screens (Noble Foundation Plant Biology and Forage Improvement Divisions) will determine how infected plants respond at the molecular level, and define chemical pathways and gene regulatory regions that can be used for engineering novel resistance mechanisms against the fungus.

The development of a cotton root rot resistant variety of alfalfa will greatly expand the alfalfa growing region of Oklahoma. This will allow Oklahoma farmers to produce a valuable crop which can be sold at a profit to a growing dairy industry in both western Oklahoma and Texas, as opposed to the present practice of importing alfalfa from other states.

#### **Arabidopsis 2010 Award# 0520140: Metabolomics: A functional genomics tool for deciphering functions of Arabidopsis genes in the context of metabolic and regulatory networks**

*Summary of the proposed project:* The aim of this proposal is to establish a multi-institutional, international consortium of labs that will develop metabolomics as a new functional genomics tool for elucidating the functions of Arabidopsis genes whose functions are currently unknown. The consortium has developed metabolomic platforms that detect approximately 2,000 metabolites, of which 900 are chemically defined. The consortium will apply these established platforms to reveal changes in the metabolome associated with knockout mutations in genes of unknown function and compare these to similar mutants in genes of known functions. In addition, the consortium will provide an initial genetic and morphological characterization of these mutants. Furthermore, the consortium will begin analytical efforts to expand the chemical identity of the Arabidopsis metabolome. Finally, the consortium will develop unique databases for the dissemination of these data. The successful completion of these goals will generate new tools and resources for ultimately determining the function of the many Arabidopsis genes, whose functions are still to be defined.

*Broader Impacts of the proposed research project:* The proposed consortium will develop new resources for the research community, which is required for determining the function of genes whose functions are currently unknown. These resources will be developed in collaboration with other NSF-funded resource development projects, and will enable researchers in the community to formulate credible hypothesis-driven projects that will ultimately define the functions of these genes. The consortium will foster the coordinate international development of metabolomics as a tool in functional genomics by collaborating with key European efforts, by organizing metabolomics workshops at international meetings, and in the 3rd year of the project offering a-for-fee metabolomics service to the research community. The consortium will also develop new activities that will enhance the impact of science education and training in the community. Specifically, workshops for high school science teachers will be offered during the three summers of the project. In addition, research internships will be offered to undergraduate students, and 8 of these students will be provided with an international experience to observe science in European genomics, metabolomics and bioinformatics laboratories. These research-based

training internships will illustrate the synergy accompanied by the integrated application of chemistry, biochemistry, genetics and bioinformatics to solving biological problems in post-genomic sciences.

**Arabidopsis 2010 (MCB # 0520283): Functional analysis of pollen exine assembly**

*Summary of Proposed Project:* This project will determine the function of the gene network required for exine synthesis, patterning and adhesion. This outer pollen wall is made of sporopollenin, an unusually strong, chemically inert, and distinctively patterned biopolymer. Exine protects desiccated pollen and binds to the stigma with strong and selective adhesives. Its importance in pollination, implications for polymer chemistry, and utility as a contact adhesive make an understanding of exine composition a high priority; nonetheless, its inert and irregular nature has confounded chemical analyses. Recent Arabidopsis genetic surveys are more promising, revealing genes and pathways required for exine structure and function. This project addresses the 2010 program goal of functional analysis of every Arabidopsis gene by screening mutant lines for exine phenotypes, assessing gene roles in exine assembly, patterning and adhesion, and sorting these genes into genetic and metabolic pathways. This work will impact multiple disciplines, improving the understanding of 1) genes that mediate pollination and crop breeding, 2) evolutionary controls over exine diversity and plant speciation, 3) exine moieties that form two-component adhesives, 4) phenolic and fatty acid metabolism, 5) biopolymer self-assembly, and 6) >250 genes in exine development, ~75% of which have not been targeted in other 2010 projects.

*Broader Impacts of the Proposed Project:* This project will integrate research and education in several ways. First, the Preuss laboratory will host Drs. Edlund and Swanson and an undergraduate from each of their home institutions (Spelman and Valparaiso) for each summer of the proposal period. This will provide minority undergraduates with experience in planning and performing experiments and in presenting their work at undergraduate research conferences. Moreover, it will provide their mentors with information that they will incorporate into their laboratories and courses. Second, two undergraduates from the PI's laboratory will collaborate with these visitors to perform phenotypic analyses and genetic screens. Over the past 10 years, the PI has trained 32 undergraduates (14 women and 7 underrepresented minorities). Third, this project will enable a postdoctoral associate to supervise technicians and undergraduate students, providing her with invaluable mentoring experience. Fourth, researchers from the PI's laboratory will spend 6 months at the Noble Foundation, sharing their knowledge of pollination biology, and receiving training in plant biochemistry that will benefit their home institution. Lastly, the PI regularly participates in venues that introduce policy makers to plant genetic engineering, and in opportunities to teach and train business leaders in the challenges of translating research to the commercial sector.

**NSF Plant Genome Research Award #0109732: An Integrated Approach to Functional Genomics and Bioinformatics in a Model Legume**

*Medicago truncatula* is a close relative of the world's most important forage legume, alfalfa (*Medicago sativa*). It is a rich source of natural products, such as flavonoids, isoflavonoids and triterpenes, which impact its properties as a forage legume. The main experimental approach of this project is to perturb the expression of these natural products, and other areas of metabolism, by exposing cell cultures to biotic and abiotic elicitors. Use of cell suspension cultures will allow sufficient material to be collected and analyzed in parallel. Three experimental conditions have been chosen that mimic natural environmental challenges. The ultimate goal of this project is to generate a truly functional genomics data set for control and elicited cell cultures. Such data will encompass expressed sequence information and the associated mRNA, protein and metabolite identities and concentrations. This project will produce a variety of data so it becomes imperative to establish integrative models and software to facilitate relational analysis of the data to each other and to previous knowledge on sequences and pathways. Software is a facilitator of the discovery process when it enables the user to "navigate" the biological data in a dynamic and transparent way, requiring only the most basic computational skills. The bioinformatics component of this project will: i) construct a relational database to store all data; ii) construct an expandable analysis server that will facilitate processing the data with several statistical and numerical algorithms; and iii) integrate the above components through a web interface. The data as well as the software will be made available publicly. The data generated by this project will be used to construct a quantitative predictive model of the time courses after elicitation, which is required to interpret the regulation of the underlying complex biological processes. The data will provide information about the extent and nature of gene expression reprogramming in response to biotic and

abiotic signals at the transcription, translation and metabolic levels. There will also be practical applications in directed gene discovery for important agronomic traits involving plant natural products. Finally, this project will make available to the scientific community a bioinformatics system capable of supporting functional genomics ranging from the transcriptome to the metabolome.

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## OUTREACH & TRAINING ACTIVITIES:

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Following are summaries of several Sumner lab outreach and training initiatives. The majority of these efforts are currently active and will continue into the future. The cumulative outcome of these outreach efforts are more competitive high school, undergraduate, postdoctoral fellows, staff, and faculty that are better prepared for academic and commercial research.

**Metabolomics and Proteomics Training Workshops:** The Sumner lab and The Noble Foundation Analytical Chemistry Core Facility have established a series of one week metabolomics and proteomics workshops. The popularity of these workshops has grown over time, and we often couple these workshops to mini symposiums. For example, the metabolomics curriculum generally includes an introductory, but substantial lecture on mass spectrometry and metabolite profiling to kickoff the event on Monday morning. The workshops then jumps immediately into detailed hands-on training related to GC/MS and LC/MS metabolite profiling. This includes experimental statistical design, lyophilization, metabolite extraction, metabolite derivatization, instrumentation overviews, instrumental parameters, methods rationale/justification, and data acquisition. Participants have the option to bring a limited number of their own real world samples and to collect real time metabolic profiles. Once data has been acquired it is used for data processing instruction which includes spectral and chromatographic deconvolution, metabolite identifications, metabolite library construction and use, high-throughput quantitative and qualitative data extraction, statistical processing, and data interpretation. The hands on sessions (Mon-Thur) are often topped with a metabolomics symposium on Friday to re-emphasize what was learned during the week and to hear more about practical applications of metabolomics in addressing modern biological questions. Workshop participants leave with enabling information and tools to continue metabolomics studies independently or collaboratively with our group. Our workshops are offered twice per year and limited to 20 participants each. We have hosted approximately a dozen of these over time, thus providing hands-on training to over 200 postdocs, staff, and faculty. Workshop attendance was originally focused on Noble Foundation postdoctoral fellows/staff. However, positive word of the workshops leaked out, and we have enjoyed hosting a large number of external collaborators and regional colleagues more recently. Although the focus of these workshops is traditionally on plant metabolomics, we have attracted significant participation from the microbial and mammalian communities as well. We will continue to offer and grow these workshops in the future. Recent Activities Include:

1. 15-19 August 2016 - MU Metabolomics Center Workshop and Symposium
2. 15-19 October 2012 – NSF-JST-Noble Metabolomics Workshop & Symposium
  - Mon – Thurs, 15-19 Oct 12 – Hands-on laboratory GC/MS and LC/MS Metabolomics Training
  - Thurs, 18Oct12 – Invited Seminar, Robert Hall, Plant Research International
  - Friday, 19Oct12 – NSF-JST Metabolomics Seminar Symposium (Kazuki Saito & Colleagues)
  - Sat, 20Oct12 – Bruker UHPLC-MS-SPE training
3. 09Jun12 – The Sumner lab hosted a 1 day workshop for the 2012 Noble Scholars. The Noble Scholars are an elite group of summer interns that are recruited through a national competition. The Scholars are paired with Noble Foundation Postdoctoral research fellows based upon internal proposals written by Noble postdocs. The workshop was organized in a similar manner

to our Science Carnivals in that the students engaged in advanced hands on demonstrations to illustrate the chromatographic and mass spectral aspects of metabolic profiling.

4. 27-30Aug12 – Hands-on Proteomics Workshop at the Noble Foundation with approximately 20 participants.
5. March 1 & 2, 2011 - Two each, 1-day Noble Advanced Metabolomics Data Processing Courses
6. November 8-11, 2010 – Mass Spectrometry Tutorial and Noble Metabolomics Workshop
7. April 26-30, 2010 – Mass Spectrometry Tutorial and Noble Metabolomics Workshop

**Science Carnivals & Academies:** The Sumner lab has recently targeted several high school groups as part of our outreach efforts and developed a Science Carnival Series. The purpose of the Science Carnivals is to improve exposure to scientific research environments and career options, and to generate general excitement for science amongst local area high school students. Specifically, we have coordinated with the Oklahoma Upward Bound Math/Science Programs at East Central University and Southeastern Oklahoma State University (Charlotte Dailey and Corey Hammel, Directors), Ardmore High School AP classes and Science Club (Dr. Barbara Sumner, instructor and sponsor), Planview High School, Becky Smith, instructor), and Southern Oklahoma Technology Center Biotechnology Program (Dr. Fiona McAlister, instructor). The Upward Bound programs are focal partners as they provide targeted assistance to disadvantaged and underrepresented students in Southern Oklahoma. Specifically, the demographics of the ECU group include 78% low income and first-generation college bound students, 40% females, and 39% minorities (American Indian, African American, and Hispanic). Our first Science Carnival was in Dec. 2009 and they were very well received! The lab was decorated with colorful carnival paraphernalia and the students rotated among 9 booths/topics including microscopy, PCR, plant natural product extractions (ie orange carotenoids from carrots, purple anthocyanins from beets, etc), metabolite derivatization, GC/MS, LC/MS, UPLC, MALDI-TOFMS, and data visualization. The carnival even included a concession stand complete with balloons, popcorn, soda, & candy. We were surprised with level of understanding that the students were able to extract in this environment and short time based upon the hands-on interactions. The science booth concepts are typically rotated year to year based around a theme, and we work towards integrating, while simultaneously enhancing, the workshops with the existing curriculum of our partner programs. We have continued this series/concept annually and recently received modest financial support of this effort as part of a National Science Foundation award. We also expanded this concept in 2014 by offering a week long Science Academy for 3hrs per day which provided more in-depth hands-on exploratory experiments. These enrichment opportunities are intended to be basic, but effective in stimulating local student and minority interests in science, plants, natural products and systems biology. Postdocs and other Sumner lab staff have traditionally served in leadership roles in organizing and executing the carnivals and workshops. However, more recently these efforts have been significantly accelerated with the help of the Noble Academy Staff. The Noble Academy is a newly established and formalized education and outreach group at the Noble Foundation.

8. 25-26Apr2014 - The Sumner lab hosted its 5th Annual Science Carnival that was attended by approximately 150 high school students. This fun event was focused upon the improvement of scientific knowledge and generating excitement within local area high school students. These were coordinated with specific targeted groups which included Oklahoma Upward Bound Math/Science Program, Ardmore High School AP classes and Science Club, and Southern Oklahoma Technology Center's Biotechnology Program. The Upward Bound program is a focal partner as it provides targeted assistance to disadvantaged and underrepresented students. Specifically, the demographics of this group include 78% low income and first-generation college bound students, 40% females, and 39% minorities (American Indian, African American, and

Hispanic).

- 25-26Apr14 – (Outreach) Host Noble Science Carnival
  - 24Apr14 (am): 30 - Fiona McAlister –SOTC Bio Tech Academy 1<sup>st</sup> Year Students
  - 24Apr14 (pm): 18 – Fiona McAlister –SOTC Bio Tech Academy 1<sup>st</sup> & 2<sup>nd</sup> Year Students
  - 25Apr14 (all day): Becky Smith, Planview High School Chemistry, 40 Junior & Seniors
  - 26Apr13 (all day):
    - 34 – Southeastern Oklahoma State Univ, Upward Bound Program, Corey Hammel
    - 26 East Central Univ., Upward Bound, Charlotte Dailey
    - 4 – Ardmore High School Advanced Placement Chemistry
9. 19-20Apr13 – Hosted our annual Noble Science Carnival for approximately 60 high school students including AHS, SOTC, ECU Upward Bound, and others.
- 19Apr13 (am): 32 - Fiona McAlister –SOTC Bio Tech Academy
  - 19Apr13 (am): 8 – Barbara Sumner – AHS Chemistry;
  - 19Apr13 (pm): 26 - Fiona McAlister –SOTC Bio Tech Academy;
  - 20Apr13 (all day): 35 – Southeastern, Corey Hammel, CHammel@se.edu
  - 20Apr13 (all day): 12-13 – ECU Upward Bound, Charlotte Dailey, 580-272-8190
  - 20Apr13 (all day): – 3 Calvin High School, Jimmy Skinder, 580-399-3116
10. 29Jul13-01Aug13 – Led a week long Summer Science Camp for middle through high school students from the local HFV Community Center. The program included a 3hr session each morning (M-Th) of the week.
11. February 11-12, 2011 – Hosted an Science Carnival for approximately 90 area high school students including Ardmore High School Advanced Placement Chemistry, Southern Oklahoma Technology Center Biotechnology I & II students, and Oklahoma Upward Bound Science and Math group.

**Organization of International Metabolomics Meetings:** Dr. Sumner has been a key and longstanding central figure in the organization and execution of a large number of international metabolomics meetings. He was a co-founding member of the International Advisory Committee for Plant Metabolomics (ICPM; 2001-Present), which organized the first metabolomics meeting ever, i.e. the 1<sup>st</sup> International Conference on Plant Metabolomics in Wageningen, The Netherlands, 2001. He continued to serve on the organization committees of the 2<sup>nd</sup> (Golm, Germany, 2002), 3<sup>rd</sup> (Iowa State University, Ames, IA, 2004), 4<sup>th</sup> (Reading, UK, 2006), and 5<sup>th</sup> (Yokohama, Japan, 2008) International Conference on Plant Metabolomics. Dr. Sumner has also been a prominent figure in organizing international conferences for the Metabolomics Society. He was a Program Committee Member and Plant Session Co-chair for the 1<sup>st</sup> International Conference of Metabolomics Society (June 2005, Tsuruoka, Japan). Dr. Sumner joined the Metabolomics advisory board in 2006 and later held multiple officer positions within the Metabolomics Society. As a result, he was heavily involved in the co-organization of the 2<sup>nd</sup> (Boston, MA, USA 2006), 3<sup>rd</sup> (Manchester, UK, 2007), 4<sup>th</sup> (Boston, MA, 2008), 5<sup>th</sup> (Edmonton, Alberta, Canada 2009), 6<sup>th</sup> (Amsterdam, The Netherlands 2010), 7<sup>th</sup> (Cairns, Australia 2011), 8<sup>th</sup> (Washington, DC 2012), 9<sup>th</sup> (Glasgow, Scotland), 10<sup>th</sup> (Tsuruoka, Japan) and upcoming 11<sup>th</sup> (San Francisco, CA) International Conferences of the Metabolomics Society. The Metabolomics Society's and the Plant Metabolomics meetings joined together as a singular international conference with great success in 2010 under Dr. Sumner's leadership and vision as President of the Metabolomics Society. Dr. Sumner continues his support for the unification of the metabolomics community. He will continue serving the Metabolomics Society and as a pivotal community organizer.

Dr. Sumner has also organized numerous national and regional meetings. In addition to the how-to metabolomics workshops noted above, Dr. Sumner has also organized multiple day, hands-on



workshops focused on metabolomics, proteomics, and integrated functional genomics. These workshops were hosted in Ardmore, OK and sponsored by the Noble Foundation, and external funding agencies such as the NSF Plant Genome Research (Award #010973; <http://www.noble.org/medicago/NSF/Workshops.html>). This trend will continue, and in 2013 the Sumner group will host an international conference focused upon triterpene biosynthesis (estimated size 50-75) as part of the outreach component of a recent grant entitled “Metabolomics and Genome Wide Association Mapping for the Elucidation of Triterpene Saponin Molecular Biochemistry in Medicago” funded by the National Science Foundation, Molecular and Cellular Biosciences #1024976. The objective of this workshop will be to provide a forum for the discussions of the latest advances in saponin research and serve to highlight the outcomes of the NSF MCB project focused upon the elucidation of saponin biosynthesis. The workshop will be held at the Noble Foundation Campus, which has the necessary facilities and significant experience in executing similar workshops. Attempts will be made to coordinate this meeting with an ongoing International Conference on Saponins which has an alternating year cycle.

**Training, Mentoring and Career Counseling for Students, Interns and Postdoctoral Research Fellows in the Sumner Lab:** Members of the Sumner lab are mentored in scientific writing, oral presentations, grant applications, constructive peer review, project management, and personnel management according to their abilities and in an effort to further prepare young scientific minds for the realistic and professional expectations of modern academic or commercial research. More specifically, lab personnel participate in a weekly divisional seminar series that includes two staff/postdoctoral presentations. Each of our staff/postdoctoral candidates provides one oral research presentation approximately every 9-12 months to help polish their presentation skills. Participation and instructional guidance are compulsory components of this formal process; practice presentations, video recordings, and audience scorings are available on a volunteer participation basis. Less formal research presentations and discussions are also incorporated as part of the Sumner lab’s weekly group meetings. Numerous and frequent extended educational opportunities are also provided by The Noble Foundation for our postdoctoral researchers and staff. Recent examples include a custom class on English grammar and scientific writing mechanics provided by The Southern Oklahoma Technology Center (adjacent to the Noble Foundation campus) and a sponsored workshop on “Writing Winning Grants” by consultant Dr. David C. Morrison of Grant Writers’ Seminars & Workshops, LLC (<http://www.grantcentral.com>). Additional workshop opportunity example topics include resume/CV preparation, writing essentials, Power Point training, English as a Second Language, presentation coaching and critique, and effective communication skills. The Noble Foundation also organizes formal teaching and ‘guest lecture’ opportunities for our postdoctoral researchers at regional universities and public venues. Many of our staff also voluntarily contribute to local tutoring programs.

On a more personal level, Dr. Sumner provides individualized coaching, mentoring and career counseling. As part of the hiring process and early scientific planning, postdoctoral fellows and staff are queried about their long term objectives. A plan of study, goal(s) setting, experimental objectives, publications, and accountability expectations are then developed to meet the mutually agreed upon objectives. As part of meeting the goal-oriented objectives, postdoctoral fellows/staff are individually coached in experimental design, time management, and scientific writing/manuscript preparation (context, impact, and logistics). Postdocs/staff are also coached in constructive manuscript review as part of the weekly Sumner group meetings and more personally with specific confidential examples provided by Dr. Sumner on real world manuscript/proposal submissions.

Postdoctoral fellows, students and staff from the Sumner lab are active contributors to the ongoing educational outreach of the Sumner lab including the workshops described above, participation in

The Noble Scholars program, coaching/training of undergraduate summer interns, hosting of visiting scientists, and laboratory tours/demonstrations for a large number of campus visitors.

**Hosting Visiting Scientists:** The Sumner lab has hosted numerous visiting scientists as part of our educational outreach and training ([http://www.noble.org/PlantBio/Sumner/visiting\\_scientists.html](http://www.noble.org/PlantBio/Sumner/visiting_scientists.html)). These have included five distinguished faculty visits as well as seven undergraduate and graduate students. Visiting scientists are sponsored by the home institution and work in the Sumner lab for 3months to over a year. The underlying theme of the visits is the desire to obtain a sophisticated understanding of plant proteomics and metabolomics that will better enable them to address specific biological questions with modern analytical tools and to enhance their competitiveness. Following is a list of external scientists that have visited the Sumner Lab.

12. Nouredine Benkeblia, Ph.D. Graduate School of Agriculture, Hokkaido University, Sapporo, Japan
13. Prof. Dr. R.J. (Raoul) Bino, Cluster leader, Technology Development, Plant Research International, Business Unit Bioscience
14. Lalita M. Calabria, Visiting graduate student, University of Texas at Austin
15. Prof. Sixue Chen: The Sumner lab hosted visiting Professor Sixue Chen from the University of Florida from 01-15May14 for initial metabolomics training and experiments on Arabidopsis and Brassica napus Guard Cells Signal transduction following exposure to a flagillin elicitor.
16. Clelia de la Pena, Ph.D. Visiting Graduate Student, Department of Horticulture and Landscape Architecture, Colorado State University, Fort Collins, CO
17. Ms. Samira Hassan, April 27-May 15, 2011, Graduate Student, Australian National University
18. Aaron Hightower, B.S. Southeastern Oklahoma State University graduate. Attending Oklahoma University Medical School in August, 2009 Oklahoma City, OK
19. Li Jing, Visiting Graduate Student, 01Aug12 to 01Aug14, Southwest University, China
20. Dr. Adama Hilou: The Sumner lab is hosting visiting Fullbright Scholar, Dr. Adama Hilou from the Université de Ouagadougou, Burkina Faso, Africa to study the beneficial metabolic interactions between *Medicago truncatula* and a mutualistic arbuscular mycorrhizal fungus *Glomus intraradices* and the biochemical protective benefits of this mutualistic interaction against the pathogenic fungi *Aphanomyces euteiches*.
21. Dr. Lars Kamphuis, visiting Postdoctoral Research Fellow, 08Aug11-31Aug11, CSIRO Plant Industry, Perth, Australia.
22. Dr. Kota Kera: The Sumner lab will host collaborator and postdoc Dr. Kota Kera (H. Suzuki Lab) from the Kazusa DNA Research Institute from 01Sep-12Sep14. The goal is to compare ultra-high resolution FT-ICRMS of labeled and unlabeled *Medicago truncatula* extracts to UHPLC-MS-SPE-NMR data to facilitate a greater number of identifications in this model legume.
23. Ken Korth, Ph.D. Professor, University of Arkansas, Fayetteville, AR, Visiting Professor, September 2010 - March 2011
24. Lanfang Levine, Ph.D. Senior Research Chemist, Biological/Analytical Chemistry, Core Lead, Dynamac Corporation
25. Mohammed Meetani, Ph.D. Assistant Professor, Department of Chemistry, College of Science, United Arab Emirates University
26. Pilon, Alan; Visiting Graduate Student, Nuclei of Bioassays, Biosynthesis and Ecophysiology of Natural Products (NuBBE) Chemistry Institute - São Paulo State University – UNESP. August 1, 2013 to July 23, 2014.
27. Narumon Sawasdipuksa, Visiting Graduate Student, Department of Chemistry, Chulalongkorn University, Bangkok, Thailand

28. Nakabyashi, Ryo, RIKEN Center for Sustainable Resource Science, Metabolomics Research Group, Aug – Sep 2015.
29. Craig Schenck, University of Wisconsin, Metabolomics analysis of MtPDH1, 16-22Aug15.
30. Prof. Joel Tim Smith, Ph.D. Department of Chemistry, Southeastern Oklahoma State University, Durant, OK.
31. John H. Snyder, Ph.D Candidate, Visiting Graduate Student, Department of Plant Biology, Cornell University, Ithaca, NY
32. Ms. Leepika Tuli, Visiting Graduate Student, Virginia Bioinformatics Institute, Blacksburg, VA
33. Prof. Hui Xie: The Sumner lab hosted visiting Professor Hui Xie from Fudan University, China to expand her training in modern molecular, biochemical and analytical approaches associated with the study of phytochemicals; especially bioactive compounds relevant to pharmacognosy and Traditional Chinese Medicine (Nov2013-Nov2014).
34. Dr. Zhigang Yang: The Sumner lab hosted collaborator Dr. Zhigang Yang (Saito Lab) as an international visiting scientist from the RIKEN Center for Sustainable Science Nov-Dec. 2013 as part of our International Exchange Program from 15Oct-15Dec, 2013. During this visit, Dr. Yang was provided with hands-on UHPLC-MS-SPE-NMR training by the Sumner Lab and UHPLC-MS-SPE-NMR was used to identify approximately 15 metabolites from Arabidopsis.
35. Chao Zhang, Ph.D Candidate, Visiting Graduate Student, Department of Computer Science, University of Missouri, Columbia, MO
36. Hua Zhang, Visiting Graduate Student, 28Nov11 through 15Sep1212, Southwest University, China.

The cumulative outcome of the above outreach efforts are more competitive high school, undergraduate, postdoctoral fellows, staff, and faculty that are better prepared for academic and commercial research.

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## PRESENTATIONS:

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### 2015

- 24-25 Feb2015 – (Outreach) Noble Science Carnival
- 9-13Mar2015 – (Outreach) Noble Foundation Metabolomics Workshop and Symposium.
- 24Mar2015 – (Outreach) Noble Leadership Tour and demos in Sumner lab.
- 31Mar15 – (Outreach) SEOSU Anal. Chemistry Class Tour & Lecture
- 02-03Apr15 – (Invited) Iowa State University Metabolomics Symposium
- 06-10Apr15 – (Invited) University of Missouri
- 31May15, 2015 – (Invited) Bruker User Meeting, St. Louis, MO.
- 31 May–4 June, 2015 - 63rd ASMS Conference on Mass Spectrometry and Allied Topics will take place in St. Louis, MO, USA.
- 12Jun15 – (Invited) Oklahoma Pecan Growers Conference, Ardmore, OK.
- 28Jun15 – (Organizer) NSF-JST RCN Satellite Meeting, 28Jun14, San Francisco, CA
- 29Jun-02Jul14 – 11th Annual Metabolomics Society Conference, San Francisco, CA
- 15Jul15-17Aug15 – (Outreach) Host visiting collaborator Ryo Nakabayashi, RIKEN, Japan
- 15Jul14 – (Outreach) Metabolomics Grand Challenges Webinar Series 2015, “Introduction to the Metabolomics Grand Challenges Webinar Series”
- 19-22Jul2015 – (Invited) Plenary lecture invitation for the 25th Australian and New Zealand Society for Mass Spectrometry Conference, Brisbane AUSTRALIA.
- 22-24Jul15 – (Invited) New School of BioSciences, the University of Melbourne
- 8-12Aug2015 - 54TH ANNUAL MEETING OF THE PHYTOCHEMICAL SOCIETY OF NORTH AMERICA, Illini Union University of Illinois, Urbana, Illinois
- 12Aug15 – (Invited) American Chemical Society – Chemical & Engineering News Webinar
- 16-22Aug15 – (Outreach) Host collaborator Craig Schenck, University of Wisconsin, Metabolomics analysis of MtPDH1
- August 19, 2015 – (Outreach) Metabolomics Grand Challenge Webinar Series, “Metabolite Identification #1 Metabolomics Grand Challenge”
- 16Sept2015 - (Invited) Midwest Mass Spec Interest Groups.
- 2-4Oct2015 - (Invited) University of Massachusetts Plant Biology Graduate Program Symposium. "Mining the Biochemical Diversity of Plants"
- 24Nov2015 – (Outreach) Metabolomics Grand Challenge Webinar Series, “Metabolomics Standards: A Review and a Call to Practice”
- 11-13Oct2015 - (Invited) Dow AgroSciences, Jeff Gilbert, We are currently planning to hold an internal symposium on the area of differential analysis the week of October 12th,
- 17-18Nov15 - (Invited) NIH Common Fund Metabolomics Workshop entitled ‘Beyond the Known Metabolome: Discovery and Identification of Biologically-Relevant Small Molecules’ in Bethesda, MD
- 03Dec15 – Noble Plant Biology Divisional presentation.

### 2014

- 06Mar14 - (Invited) IBC Washington State University, Host David Gang & Mark Lange
- 27-28Mar14 – Noble Plant Biology 25<sup>th</sup> Anniversary Symposium
- 31Mar-04Apr14 - (Invited) International data exchange and research in Metabolomics Meeting at the European Bioinformatics Institute, Cambridge, UK. Wednesday, 2 April 2014
- 10Apr14 – (Outreach) ECU Instrumental Analysis Class

16-18Apr14 - (Invited) Charles W. Gehrke Distinguished Lecture, Life Sciences Week, University of Missouri, Columbia, MO.

25-26Apr14 – (Outreach) Host Noble Science Carnival

01-15May14 – (Outreach) Host Visiting Scientist Sixue Chen

07-09 May - (Invited) Visit Monsanto, host George Harrigan.

20-24May14 - (Invited) Southeastern Metabolomics Center and NSF Metabolomics Workshop, University of Florida

03-04Jun14 – (Invited) Society for In Vitro Biology meeting in Savannah, GA, June 1-4, 2014, Plenary Session entitled, "The Omics Generation: Advances in Metabolomics, Proteomics and Genomics."

15-19Jun14 – 62nd ASMS Conference, Baltimore, MD 63rd ASMS Conference

23-26Jun14 – (Invited) 10<sup>th</sup> Annual Metabolomics Society Meeting, Tsuruoka, Japan.

27Jun14 – (Invited) NSF-JST RCN Program Satellite Meeting, Institute for Advanced Biosciences, Keio University, Tsuruoka, Japan

30Jun14 – (Invited) Samsung and Dongsik Yang

01Jul14 – (Invited) Seoul National University w/ Monsanto

06-07Aug13 – (Invited) PNNL EMSL Metabolomics Advisory Panel "Unraveling the role of metabolic exchange for BER science missions"

9-13Aug14 - (Invited) Keynote Lecture at the Phytochemical Society of North America, North Carolina State University

14Aug14 - (Invited) Presentation at Bruker Metabolomics VIP Day, Billerica, MA

4-5 September, 2014 - PGRP Awardee Meeting,

29Sept14 – (Invited) Washington University, St. Louis

23 and 24 October 2014 – (Selected Oral) Challenges and advances in the Annotation and de novo Identification of Small molecules of biological origin. Paris, France. <http://www.icsn.cnrs-gif.fr/spip.php?article979&lang=en>

## **2013**

(Education & Outreach) 19-20 April – Organize and host Noble Science Carnival(s)

(Education & Outreach) 26Apr13 – Host tour for Oklahoma School of Science & Mathematics

(Education & Outreach) 04May13 – Organize and execute Scout Science Saturday; an event for approximately 50 local cub scouts, siblings and families

Lloyd W. Sumner, Zhentian Lei, Dennis Fine, Daniel Wherritt, David V. Huhman, Kota Kera, Hidezuki Suzuki, Kazuki Saito. Sequencing' the first plant metabolome and the systematic annotation of the metabolic composition of the model legume *Medicago truncatula*. June 9-13, 2013 - 61st ASMS Conference on Mass Spectrometry, Minneapolis, MN. (Poster)

Zhentian Lei, Li Jing, Hua Zhang, David Huhman, Ziqing Zhou, and Lloyd W. Sumner. Construction of a Plant Natural Products Tandem Mass Spectral Library. June 9-13, 2013 - 61st ASMS Conference on Mass Spectrometry, Minneapolis, MN. (Poster)

(Education & Outreach) 26Jun13 – Host East Central Oklahoma University Visit to Noble

Lloyd W. Sumner, Zhentian Lei, Dennis Fine, Daniel Wherritt, David V. Huhman, Kota Kera, Hidezuki Suzuki, Kazuki Saito. The Systematic Annotation of the Metabolic Composition of the Model Legume *Medicago truncatula* Using UHPLC-MS-SPE and NMR. July 1-4, 2013 9th Annual Metabolomics Society Meeting, Glasgow Scotland. (Poster)

Bonnie S. Watson, Zhentian Lei, David Huhman, Dongsik Yang, Vered Tzin, John H. Snyder, Shelagh Henson, Derek Nedveck, Peter Tiffin, Nevin Young, Lloyd W. Sumner. An Integrated Approach to Elucidate Saponin Biosynthesis in *Medicago truncatula*. American Society for Plant Biology July 20-24, 2013, Providence, Rhode Island. (Poster)

(Education & Outreach) 29Jul13 – 01Aug13 Summer Science Camp/Week

(Invited) Lloyd W. Sumner, Dennis Fine, Zhentian Lei, Feng Qiu, Daniel Wherritt. Metabolomics: Advancing the Scientific Promise to Better Understand Plant Specialized Metabolism for a Low-Carbon Society, RIKEN Center

for Sustainable Resource Science, 18Sep13, Yokohama Japan. (Oral)

- (Invited) [Lloyd W. Sumner](#), Dennis Fine, Zhentian Lei, Feng Qiu, Daniel Wherritt, [Basil Nikolau](#), Alexis Campbell, Xin Guan, Lucas J. Showman, Chan Man Ha, Richard Dixon. Metabolomics: Advancing the Scientific Promise to Better Understand Plant Specialized Metabolism for a Low-Carbon Society, Joint NSF-JST Mid Term Review, 20Sep13, Nara, Japan. (Oral)
- (Invited) [Lloyd W. Sumner](#), Oliver Fiehn, Georg Jander, James C. Liao, Basil J. Nikolau. Integrating and Coordinating a National and International Plant, Algae, and Microbial Metabolomics Research Coordination Network (PAMM NET) Joint NSF-JST Mid-Term Review, 20Sep13, Nara, Japan. (Oral)
- (Invited) [Dennis Fine](#). Using State of the Art Instrumentation to Identify Metabolites in the Model Legume - *Medicago truncatula*. Chemistry Department Speaker Series, East Central University, Ada, OK, Nov. 1, 2013.

## 2012

- (Education & Outreach) 17Jan12 –Vered Tzin, Rao Uppalapati, Yuhong Tang, Yun Kang. MapMan tutorial for *Medicago truncatula*.
- (Invited) 18-26Jan12 – Presentation and instrument Demo; Bruker Daltonics & Bruker Biospin, Breeman, Germany
- (Invited) 15-19 February, 2012: NSF-JST Metabolomics Kick-off meeting, Narita Hilton & RIKEN Yokohama Institute.
- (Education & Outreach) 23Feb12 – Oak Hall Leadership League Visit & Interview
- (Invited) Mar 2, 2012 - University of North Texas, Denton, TX. Hosts Kent Chapman & Guido Verbeck. Title: ““Current Success Stories and Future Directions for Integrated Plant Metabolomics and Functional Genomics”.
- (Invited) March 14, 2012 – PittCon session entitled “Mass spectrometry advances conversion of biomass to biofuels”, PittCon, Orlando, FL Roland Hirsch and Arthur Katz
- (Invited) 17Mar12 –57<sup>th</sup> Annual ACS Pentasectional Meeting, Cameron University, Lawton, OK.
- (Education & Outreach) 13-14 Apr12 – Host, tour, discuss with Presidential Leadership Program from East Central University, Ada, OK.
- (Education & Outreach) 13-14 Apr12–Noble Science Carnival
- (Invited) April 16-17, 2012 – NSF Major Research Instrumentation Review Panel, Arlington, VA.
- (Invited) April 30, 2012 –Dow AgroSciences, Indianapolis, IN. Host Daniel Gachotte
- (Invited Session Chair) 20-24 May, 2012 – ASMS Conference on Mass Spectrometry and Allied Topics, Vancouver Convention Center, Vancouver, BC, Canada. “Deciphering Triterpene Saponin Biosynthesis using Natural Diversity, Metabolomics and Gene Expression Profiling” Lloyd W. Sumner, John H. Snyder, Dong Sik Yang, Vered Tzin, David V. Huhman, Stacy Allen, Yuhong Tang.
- (Education & Outreach) 09 June 2012 – Noble Scholars Workshop
- (Organizing Committee) 25-28June 2012 – 8<sup>th</sup> Annual International Conference of the Metabolomics Society, Washington, DC. “Exploiting Chemical Diversity for Triterpene Saponin Gene Discovery in *Medicago truncatula*” Vered Tzin, Dong Sik Yang, John H. Snyder, David V. Huhman, Bonnie Watson, Stacy Allen, Yuhong Tang, John Stanton-Geddes, Peter Tiffin, Nevin Young, and Lloyd W. Sumner.
- (Invited) 15-20 July 2012 – Plant Molecular Biology Gordon Research Conference, Holderness School in Holderness, New Hampshire. “Integrated Metabolomics Yields Novel Gene Discoveries Related to Triterpene Saponin Biosynthesis in *Medicago truncatula*” Vered Tzin, Dong Sik Yang, John H. Snyder, David V. Huhman, Bonnie Watson, Stacy Allen, Yuhong Tang, John Stanton-Geddes, Peter Tiffin, Nevin Young, and Lloyd W. Sumner.
- (Education & Outreach) 15-19 October 2012 – NSF-JST-Noble Metabolomics Workshop & Symposium
- (Invited) 05-07 November 2012 – University of Minnesota, St. Paul. Graduate student representatives for the Colloquium Committee of the Plant Biological Sciences program. Large-scale Biochemical Profiling for Gene Discovery. Vered Tzin, Dong Sik Yang, John H. Snyder, David V. Huhman, Bonnie Watson, Stacy Allen, Yuhong Tang, John Stanton-Geddes, Peter Tiffin, Nevin Young, and Lloyd W. Sumner.
- (Invited) 09 November, 2012 – (Invited Presentation) Cameron University Alumni Symposium, Lawton, OK.
- (Invited) 15 November 2012 – Oklahoma Section of the American Chemical Society, OSU, Stillwater, OK.
- (Invited) 28Nov-01December 2012 – Advisory Board Meeting for the Center for Advanced Biofuels Annual Meeting, San Juan, Puerto Rico
- (Education & Outreach) 03-04Dec12 – Host Southeastern Oklahoma State University, Chemistry Undergraduate lecture and laboratory tours



## **2011**

- (**Education & Outreach**) Feb 11-12, 2011 Organized & hosted “Science Carnival” for approximately 65 high school students Ardmore High School, Southern Oklahoma Technology Center Biotech Classes, and Ada Oklahoma Upward Bound
- (**Education & Outreach**) March 1 & 2, 2011 Host 2 each, 1-day Noble Advanced Metabolomics Data Processing Courses focused upon GCMS and LCMS data analyses.
- (**Invited**) March 9-10, 2011 – KSU’s Functional Genomics Consortium spring symposium for 2011.
- (**Invited**) March 20-22, 2011 – International Peer Review Commission for The Netherlands Metabolomics Centre, Leiden, The Netherlands
- (**Invited**) March 30, 2011 – Iowa State University, Science & Technology Workshop
- (**Invited**) 6 April, 2011 – Systems Biology Institute of Georgia Institute of Technology, Atlanta, GA.
- (**Education & Outreach**) 27 April-15 May, 2011 – Host visiting graduate student Samira Hassan from Australian National University
- May 13-21, 2011 - Model Legume Congress that will be held in Sainte-Maxime on the Côte d’Azur, France; website
- (**Education & Outreach**) 23 May- Aug 11 Host 2011 undergraduate summer REU Ms. Amanda Jantz from OSU.
- (**Education & Outreach**) 13 Jun-04 Aug 11 Host 2011 undergraduate summer intern Mr. Arthur Dixon, OU.
- (**Education & Outreach**) 31 May-27 Jul 11 Host 2011 undergraduate summer REU Ms. Kelsey Brown, OU.
- June 5-9, 2011 – 59th ASMS Conference on Mass Spectrometry, Denver, CO
- (**Invited**) 10 Jun 11 – Systems Biology Session hosted by David McCaskill, 42nd Meeting of the ACS Central Region meeting being held in Indianapolis June 8-10, 2011. ([http://cerm\\_regional.sites.acs.org/program.htm](http://cerm_regional.sites.acs.org/program.htm)) Zhentian Lei to present
- June 26-30, 2011 – Metabolomics 2011, 7<sup>th</sup> International Conference of the Metabolomics Society, Cairnes, Australia
- (**Invited**) 26-28 July, 2011 – (**Invited**) 3rd Annual Meeting of the Arkansas Center for Plant Powered Production (P3 Center), Heber Springs, AR
- (**Invited**) 14-17 August, 2011 - NSF-JST Finalist Interviews, Metabolomics for a Low Carbon Society.
- (**Invited**) 28-29 Aug, 2011 – Plant Research International / Wageningen University. Host Robert Hall. “Integrated Metabolomics Provides Novel Insight and Gene Discoveries in the Model Legume *Medicago truncatula*”
- (**Invited**) 30 Aug-02 Sep, 2011 – Netherlands Metabolomics Center Advisory Board meeting.
- (**Education & Outreach**) 08 Aug-02 Sept. 11 – (**Outreach**) Host visiting postdoctoral research fellow Lars Kamphuis, CSIRO Plant Industry, The University of Western Australia Institute of Agriculture, Perth, Australia.
- Sept 11-14, 2011- the Alliance of Independent Plant Research Institutes at the Danforth Plant Science Center, St. Louis, MO.
- (**Invited**) 21 Sept 11 – Oklahoma State University, Botany Dept. Host = Gerald, “Metabolomics: A Powerful Tool for Novel Insight Into Plant Metabolism.”
- (**Education & Outreach**) 23 Sept. 11 – Host, tours and demos for Cameron University undergraduate Biology Club
- September 30 - October 4, 2011 - ASMS Asilomar Metabolomics, Asilomar Conference Center Pacific Grove, California. “Integrated Metabolomics for Gene Discovery and Novel Insight Into *Medicago truncatula* Secondary Metabolism”
- (**Invited**) 20 October, 2011 – 46th Midwest & 39th Great Lakes Joint Regional ACS Meeting, St. Louis. MO (host: Henry Rohrs) “Integrated Metabolomics Provides Novel Insight Into Legume Natural Product Biosynthesis”
- (**Invited**) 21 October, 2011 – Monsanto Company, St. Louis, MO.
- (**Education & Outreach**) 31 Oct 11-4 Nov 11 – Noble Metabolomics Hands-on Workshop and Mini-symposium.
- (**Invited**) November 6-9, 2011 – External Advisory Board for Center for Advanced Biofuel Systems, Santa Fe, NM
- (**Invited**) December 8 - 15, 2011 – Phytochemistry Meeting of North America, The Fairmont Orchid, Hawai`i

## **2010**

- (**Invited**) Jan 28, 2010 – Waters Corporation, Beverly, MA.
- (**Invited**) Feb. 16, 2010 – Colorado Biological Mass Spectrometry Society Meeting, UC Denver Anschutz Medical Campus in Aurora, Colorado
- (**Education & Outreach**) Feb 19, 2010 – Host HPLC & HILIC training workshop sponsored by Supelco

(Invited) March 11, 2010 – Washington State University, Institute for Biological Chemistry, Pullman, WA.  
(Invited) March 25-26, 2010 – New Mexico Bioinformatics Symposium [NMBIS], Santa Fe, NM.  
(Invited) March 3-5, 2010 – Review Panel, NIH National Center for Complementary and Alternative Medicine (NCCAM/NIH), the Office of Dietary Supplements (ODS/NIH) and NCI  
(Invited) April 9, 2010 – 4th Professional Development Experience at Texas A&M University-Commerce  
(Organizer & Chair) May 5-7, 2010 – NSF and JST Joint Metabolomics workshop conference. UC Davis, Davis, CA.  
(Invited) Aug 15-17, 2010 – Arkansas EPSCoR meeting.  
(Education & Outreach) Sept. 8, 2010 – 01March2010 Host Prof. Ken Korth for sabbatical.  
(Invited) 18-21 Oct. 2010 - 1<sup>st</sup> Middle Eastern and Mediterranean Sea Region Countries Mass Spectrometry Workshop, Weizmann Institute of Science, Rehovoth, Israel.  
(Invited) 15-20Dec2010 – Pacifichem 2010, Honolulu, Hawaii. Metabolomics symposium in Agrochemistry session.

## **2009**

(Invited) Feb. 17-19, 2009 – Visit and presentation, University of California, Davis. Host Oliver Fiehn.  
(Education & Outreach) March 23-27, 2009 - NF Metabolomics Workshop and Mini-symposium.  
(Education & Outreach) April 23-24, 2009 – Host Alain Goossens visit to Noble  
(Education & Outreach) May 15, 2009 – Host:  
    Summer intern, Chao Zhang, MU  
    Summer intern, Aaron Hightower, SEOSU  
    Visiting Scientist, Dr. Joel T. Smith, SEOSU  
(Participant) May 31 - June 4, 2009, 57th American Society for Mass Spectrometry Conference, Philadelphia, PA.  
(Invited) June 7-8, 2009 Society for In Vitro Biology, Charleston, South Carolina.  
(Invited) June 21-22, 2009 – University of Wisconsin Biotechnology Center, Madison WI.  
(Selected Oral) July 12-16, 2009 – *Medicago truncatula* Model Legume Congress, to be held at the Asilomar Conference Grounds in Pacific Grove, CA.  
(Participant) July 18-22, 2009 – American Society for Plant Biology, Honolulu Hawaii  
(Invited & Co-organizer) August 29-September 2, 2009 – 5<sup>th</sup> International Conference of The Metabolomics Society, Edmonton, Alberta, Canada  
(Education & Outreach) September 14-18, 2009 – Noble Metabolomics Workshop  
(Participant) October 25-30, 2009 - 9th International Congress of Plant Molecular Biology (IPMB), St. Louis, Missouri.  
(Invited) October 28, 2009 – Monsanto Company, St. Louis, MO  
(Education & Outreach) December 11, 2009 – hosted “Science Carnival” for approximately 30 students from the Ardmore High School AP Chemistry class and Southern Oklahoma Biotechnology Course.  
(Education & Outreach) December 12, 2009 – hosted “Science Carnival” for Oklahoma Upward Bound Math/Science Program for approximately 30 students from East Central University, Ada, OK

## **2008**

(Invited) Feb. 23, 2008 – Cameron University Distinguished Alumni Award Luncheon  
(Invited) March 26-28, 2008 –University of North Carolina Research Campus  
(Invited) April 25, 2008 –Cornell University, Ithaca, New York  
(Outreach) April 28-May 1, 2008–Noble Analytical Chemistry Core Facility Training Course on Metabolite Profiling  
(Outreach) May 14, 2008 –Dr. Fabiola Janiak-Spens, Oklahoma City Community College tour and demos  
(Outreach) May 14, 2008 –Ardmore High School Chemistry Class & Science Club tour and demos  
(Outreach) May 16, 2008 –Oklahoma School of Science and Math, presentation, tour, & demo  
(Invited) May 20-21, 2008 –University of Minnesota Symposium, Secondary Metabolism: Good Things Made in Plants.  
(Invited) May 22-23, 2008 – University of Wisconsin Madison (Host Jan-Michel Ane, Medicago group, and Botany Dept)



(Selected Oral) June 1-5, 2008 – 57<sup>th</sup> American Society for Mass Spectrometry Conference, Denver, CO.  
(Outreach) Sept. 22-27, 2008–Noble Analytical Chemistry Core Facility Training Course on Protein Profiling  
(Outreach) Oct 1-2, 2008 –Host Dr. Peter Davies from Cornell University. Presentation - Plant Hormone Review.  
(Invited) 17-19 November, 2008 - “Plant Metabolomics As A Tool For Functional Genomics”. Busan, Korea. A Korea Conference on Innovative Science and Technology (KCIST)

## **2007**

(Invited) Jan 21-26th, 2007 - Gordon Research Conference on Temperature Stress in Plants, Ventura, CA.  
(Invited) February 23, 2007 (Invited) Graduate Recruitment and Career Awareness, Cameron University, Lawton, OK. Host Elizabeth A. Nalley  
(Invited) March 1, 2006 –Colorado State University, Cell and Molecular Biology Graduate Program, Fort Collins, CO.  
(Invited) 24-25 March, 2007 –2<sup>nd</sup> Louisville Metabolomics Symposium, Louisville, KY  
April 9-13, 2007 Noble Foundation Metabolite Analysis Workshop and Tutorial, “Weighing Molecules and The Large-scale Biochemical Analysis of Plant Proteomes and Metabolomes”  
(Invited) April 15-17, 2007 – The Role of Metabolomics & Nutrigenomics in Creating Healthful Foods and Healthy Lives, Charlotte, North Carolina  
(Outreach) May 11, 2007 – Ardmore High School Chemistry visit and tours  
(Invited) May 23-25th, 2007 –First annual Plant Proteomics Symposium at the University of Missouri-Columbia, Host Jay Thelen, organizer.  
(Organizing committee & participant) June 11-15, 2007 - 3rd Annual Metabolomics Society Meeting, Manchester International Convention Centre Manchester, UK  
(Participant) July 7-11, 2007 American Society for Plant Biologist Annual Meeting, Chicago, IL.  
(Outreach) August 7, 2007 – 2007 Noble Scholars & Teachers Workshop on “*Weighing Molecules and The Large-scale Biochemical Analysis of Plants*”  
(Outreach) September 10-14, 2007 Noble Protein Analysis Workshop and Tutorial  
(Invited) September 16-20, 2007 – 121st AOAC Annual Meeting & Exposition, Anaheim, California USA  
(Outreach) October 8, 2007 –Host Oklahoma Sectional ACS Meeting, Speaker Eugene Stevens, SUNY@Binghamton, Chemistry Dept, “Green Plastics”.  
(Invited) October 25-26, 2007 – Mass Spectrometry in the Heartland, a conference on biological mass spectrometry in the Midwest, Inn at Grand Glaize in the Ozarks, Osage Beach MO.  
(Invited) Nov. 4-7, 2007 - 63rd Southwest Regional Meeting of The American Chemical Society, Lubbock, TX. 2006  
(Outreach) Nov. 17-18, 2007 – Host project meeting for NSF 2010 Metabolomics: A functional genomics tool for deciphering functions of Arabidopsis genes in the context of metabolic and regulatory networks .

## **2006**

(Invited) January 14-18, 2006: International Plant and Animal Genome XIV Conference, workshop 'Forage and Turf Plants', San Diego, CA from 14-18 January 2006.  
(Invited) February 18-20<sup>th</sup>, 2006: AAAS Elected Fellows Forum Award Ceremony, St. Louis, MO.  
(Invited) March 20-21, 2006: Emerging Scientific Technologies: Impact on Dietary Supplement and Functional Foods Research, Kauai, Hawaii.  
(Invited) April 7<sup>th</sup> - 10<sup>th</sup>, 2006: 4<sup>th</sup> International Conference of Plant Metabolomics to be held at Wokefield Park, Reading, UK.  
(Invited) April 25-26, 2006: Review Panel, Canada Foundation for Innovation, Vancouver, BC, Canada.  
(Invited) May 15-18, 2006: Workshop Systems Biology - From Genome to Phenome; Plant Biotechnology Centre, Victoria Department of Primary Industries, Melbourne, Australia.  
(Invited) May 19, 2006 Australian National University, Canberra, Australia.

- (Invited) May 27, 2006 - Waters Users' Workshop, Seattle, WA  
 (Participant) May 28-June 01, 2006 54<sup>th</sup> ASMS Conference, Seattle, WA.  
 (Organizer) June 24-28<sup>th</sup>, 2006: 2<sup>nd</sup> Meeting of The Metabolomics Society, Harvard Medical School, Boston, MA.  
 (Invited) 1-2 August, 2006 Advisory panel for W.R. Wiley Environmental Molecular Sciences Laboratory (EMSL) National User Facility equipment/capital refreshment plan workshop for the suite of User Facility capabilities provided by the Department of Energy (but with the particular focus on environmental molecular science).  
 (Invited) 23-24 August, 2006 University of Arkansas Medical School, INBRE invitation  
 (Invited) October 16-18 2006: French society for electrophoresis and proteomic analysis. St Malo, France. LWS Presentation Title: "*Discoveries through Integrated Functional Genomics Studies of the Model Legume Medicago truncatula*"

## **2005**

- (Invited) January 16, 2005 "Proteomics and Integrated Functional Genomics of Medicago", Proteomics Workshop, Plant and Animal Genome XIII Conference, San Diego, CA.  
 (Invited) January 19, 2005 "Metabolomics and Integrated Functional Genomics of Medicago", Functional Genomics Workshop, Plant and Animal Genome XIII Conference, San Diego, CA.  
 (Invited) February 18, 2005: University of Kentucky, Plant and Soil Science Departmental Seminar, Lexington, KY.  
 (Invited) April 20-22, 2005 – NSF Plant Genome Grant sponsored Proteomics Workshop and Symposium at the Donald Danforth Plant Science Center (<http://www.danforthcenter.org/symposia/proteomics/>).  
 (Invited) May 2-4, 2005. Metabolomics Workshop: Techniques - data processing – applications. Wageningen, The Netherlands. Host: Raoul Bino.  
 (Invited) May 10,, 2005 - Institute of Food Research, Norwich Research Park, Norwich UK.  
 (Oral) June 5-9, 2005, Metabolomics Session, 53rd ASMS Conference on Mass Spectrometry San Antonio, Texas.  
 (Invited) June 8-12, 2005 - 5<sup>th</sup> Symposium on Post-Transcriptional Regulation of Plant Gene Expression, University of Texas at Austin.  
 (Invited) June 20-23, 2005 1<sup>st</sup> International Conference of The Metabolomics Society, Tsuruoka City, Yamagata Prefecture, Japan.  
 (Invited) July 10-15, 2005: Gordon Research Conference on "Plant Metabolic Engineering," Tilton, NH.  
 (Invited) July 17-22, 2005 – XII International Congress on Molecular Plant-Microbe Interactions, Cancun, Mexico. "Innovative approaches to study plant-microbe interactions" session.  
 (Invited) August 1-2, 2005 - NIH-sponsored Standards Workshop for Metabolomics, Bethesda, MD  
 (Oral) August 3-4, 2005 – Joint Salk Institute and Noble Meeting, La Jolla, CA.  
 (Invited) August 28 – Sept. 1, 2005, ACS National meeting in Washington D.C., Chemical Biology Division of the ACS "Studying the Metabolome."  
 (Invited) 21-24 Sep. 2005, Umea Plant Science Center, Dept. Forest Genetics and Plant Physiology, Swedish University of Agricultural Sciences, SE-901 87 Umeå, Sweden.  
 (Invited) Oct. 13, 2005, 9:30am-5pm Symposium on Frontiers in Plant Science and Agriculture, Hosted by the Samuel Roberts Noble Foundation, Goddard Center, Ardmore  
 (Oral) October 17-18, 2005 – Noble-York Retreat, Ardmore, OK  
 (Invited) October 25-27, 2005 Noble FID Conference "Medicago Genomic Function and Response to Biotic Stress" (<http://www.noble.org/events/medicago2005/index.html>).  
 (Organizer & Oral) October 31 – November 2, 2005 NSF-VBI-Noble Summer Workshop, Integrated Systems Biology, Ardmore, OK

(Invited) November 6-9, 2005 - Emerging Scientific Technologies: Impact on Dietary Supplement and Functional Foods Research, Kauai, Hawaii.