

## CURRICULUM VITAE

### MICHAEL L. KAHN

#### EDUCATION

1970	B.S.	Physics (Honors)	California Institute of Technology
1976	Ph.D.	Biophysics	Stanford University

#### EXPERIENCE

1970 - 1976	Public Health Service Trainee, Stanford University, Stanford, CA
1976 - 1979	Postdoctoral Research Fellow, Smith Kline Fellow, USPHS Fellow, University of California, San Diego
1979 - 1985	Assistant Professor of Bacteriology and Public Health and of Genetics and Cell Biology, Washington State University, Pullman
1985 - 1995	Associate Professor of Microbiology and of Genetics and Cell Biology, WSU
1987 - 1995	Associate Fellow, Institute of Biological Chemistry, WSU, Pullman
1997 - 1999	Acting Chair and Chair, Department of Microbiology, WSU, Pullman
1984 - 2005	Associate in Biochemistry and Biophysics, WSU, Pullman
1987 - 2022	Faculty Associate in Molecular Plant Sciences, WSU, Pullman
1995 - 2015	Professor of Molecular Biosciences, WSU, Pullman
1995 - 2022	Fellow, Institute of Biological Chemistry, WSU, Pullman
2005 - 2006	Detaillee, Department of Energy, Energy Biosciences Program
2008 - 2015	Associate Director, Agricultural Research Center, WSU, Pullman
2022 – present	Emeritus Professor, Institute of Biological Chemistry, WSU, Pullman
2022 – present	Emeritus Professor, Molecular Plant Sciences, WSU, Pullman
2022 – present	Affiliate Professor, Molecular Biology, New Mexico State Univ, Alcalde, NM
2022 – present	Affiliate Professor, Plant and Environmental Sciences, New Mexico State Univ

#### HONORS

Presidential Scholar from New Mexico, 1966  
National Merit Scholar, 1966 - 1970  
USPHS Predoctoral Trainee, 1970 - 1976  
Smith Kline Postdoctoral Fellow, 1977 - 1978  
USPHS Postdoctoral Fellow, 1978 - 1979  
Program Manager, USDA Competitive Research Grants  
Program in Nitrogen Fixation and Metabolism, 1988-1989  
Adviser of the Year, WSU College of Sciences, 2002  
North American Agricultural Biotechnology Council, Chair, 2015-7

#### GENERAL RESEARCH ACTIVITIES

Gene expression and intermediary metabolism in the Rhizobium-legume symbiosis.  
Symbiotic and associative nitrogen fixation.

## THESIS

Kahn, M. Intermediates in bacteriophage P4 DNA replication. Ph.D. (Biophysics), Stanford University. 1976. Major Professor, Philip C. Hanawalt

## PUBLICATIONS

1. Kahn, M. 1974. The effect of thymine dimers on DNA:DNA hybridization. *Biopolymers* 13, 669-675.
2. McKeown, M., Kahn, M. and Hanawalt, P.C. 1976. Thymidine uptake and utilization in *E. coli*: A new gene controlling nucleoside transport. *J. Bacteriol.* 126, 814-822.
3. Kahn, M. and Hopkins, A. 1978. Restriction endonuclease cleavage map of bacteriophage P4 DNA. *Virology* 85, 359-363.
4. Kahn, M. and Helinski, D.R. 1978. Construction of a novel plasmid-phage hybrid: Use of the hybrid to demonstrate CoIE1 DNA replication in vivo in the absence of a CoIE1-specified protein. *Proc. Natl. Acad. Sci. (USA)* 75, 2200-2204.
5. Figurski, D., Kolter, R., Meyer, R., Kahn, M., Eichenlaub, R. and Helinski, D.R. 1978. Replication regions of plasmids CoIE1, F, R6K, and RK2. In (D. Schlessinger, ed) *Microbiology - 1978*, American Society for Microbiology, Washington, D.C., p. 105-109.
6. Kahn, M. and Hanawalt, P. 1979. Size distribution of DNA replicative intermediates in bacteriophage P4 and *E. coli*. *J. Mol. Biol.* 128, 501-525.
7. Kahn, M., Figurski, D., Ito, L. and Helinski, D.R. 1979. Essential region for replication of a stringent and a relaxed plasmid in *E. coli*. *Cold Spring Harbor Symposium for Quantitative Biology* 43, 99-103.
8. Kahn, M., Kolter, R., Thomas, R.C., Figurski, D., Meyer, R., Remaut E. and Helinski, D. R. 1980. Use of plasmid cloning vehicles derived from CoIE1, F, R6K and RK2. *Methods Enzymol.* 68, 268.
9. Kahn, M., Ow, D., Sauer, B., Rabinowitz, A. and Calendar, R. 1980. Genetic analysis of bacteriophage P4 using P4 plasmid CoIE1 hybrids. *Mol. Gen. Genet.* 177, 399.
10. Calendar, R. and Kahn, M. 1982. Helper dependent bacteriophage P4, *Genetic Maps* 2, 48-49.
11. Krevolin, M., Roof, D., Kahn, M., Corless, C., Young, J. and Calendar, R. 1983. Satellite phage P4: Initiation of DNA replication in vivo and in vitro, In (D. Schlessinger ed.) *Microbiology-1984* American Society for Microbiology, Washington, D.C ,p. 100-103.
12. Samuel, J.E., Frazier, M.E., Kahn, M.L., Thomashow, L.S. and Mallavia, L.P. 1983. Isolation and characterization of a plasmid from phase I *Coxiella burnetii*. *Infect. Immun.* 41 488-493.
13. Somerville, J.E. and Kahn, M.L. 1983. Cloning of the glutamine synthetase I gene from *Rhizobium meliloti*. *J. Bacteriol.* 156, 168-176.
14. Mallavia, L.P. Samuel, J.E., Kahn, M.L., Thomashow, L.S. and Frazier, M.E. 1984. Studies on plasmid DNA from *Coxiella bunetii*, In: (D. Schlessinger ed.) *Microbiology - 1984*. p. 293-296, American Society for Microbiology, Washington, D.C.
15. Kahn, M.L. and Timblin, C.R. 1984. Gene fusion vehicles for the analysis of gene expression in *Rhizobium meliloti*. *J. Bacteriol.* 158, 1070-1077.
16. Timblin, C.R. and Kahn, M.L. 1984. Lactose inhibits the growth of *Rhizobium meliloti* cells that contain an actively expressed *Escherichia coli* lactose operon. *J. Bacteriol.* 158 1204-1207.
17. Pierson, L.S. III and Kahn, M.L. 1984. Cloning of the integration and attachment regions of bacteriophage P4. *Mol. Gen. Genet.* 194 44-51.
18. Calendar, R., Kahn, M.L., Six, E., Goldstein, R., Lindqvist, B., Deho, G., Inman, R., Lin, C., Lee, S., Christie, G., Dale, E. and Pierson, L. 1984. *Genetic Maps*, Cold Spring Harbor Press, pp. 62-65.
19. Kahn, M., Somerville, J. and Kraus, J. 1985. Glutamine auxotrophs of *Rhizobium meliloti*, pp. 58-60. In (A.A. Szalay and R.P. Legocki, eds.) *Advances in the Molecular Genetics of the Bacterial-Plant Interaction*, Cornell University.

20. Krevolin, M., Inman, R., Roof, D., Kahn, M and Calendar, R. 1985. Phage P4 DNA replication: Location of the P4 origin and an additional essential region. *J. Mol. Biol.* 182, 519-527.
21. Kahn, M.L., Kraus, J. and Somerville, J.E. 1985. A model of nutrient exchange in the Rhizobium-legume symbiosis. In (H. J. Evans, et al. eds.) *Nitrogen Fixation Research Progress*, pp. 193-199, M. N. Nijhoff, Pub.
22. Kerppola, T.K. and Kahn, M.L. 1985. Characterization of auxotrophs of *Rhizobium meliloti* 104A14 and cloning of the genes for carbamylphosphate synthetase. In (H.J. Evans, et al. eds.) *Nitrogen Fixation Research Progress*, p. 223, M. N. Nijhoff, Pub.
23. Argos, P., Landy, A., Abremski, K., Egan, J.B., Hoess, R., Kahn, M.L., Kalionis, B., Ljungquist, E., Narayana, S.V.L., Pierson, L.S. III, Sternberg, N. and Leong, J.M. 1986. The integrase family of site-specific recombinases: Regional similarities and global diversity. *EMBO J.* 5, 433-440.
24. Kerppola, T.K. Serwold-Davis, T., Gross, D.C. and Kahn, M.L. 1987. Effect of increased  $\beta$ -glucosidase activity on virulence of *Erwinia amylovora*. *Appl. Env. Micro.* 53, 677-682.
25. Pierson, L.S. and Kahn, M.L. 1987. Integration of satellite bacteriophage P4 in *E. coli*: DNA sequences of the phase and host regions involved in site-specific recombination. *J. Mol. Biol.* 196:487-496.
26. Kahn, M.L., Kraus, J., and Shatters, R.G. 1988. Bacterial catabolism of nitrogen containing compounds in symbiotic nitrogen fixation, In (O'Gara, F. et al, eds.) *Physiological Limitations and the Genetic Improvement of Symbiotic Nitrogen Fixation* pp. 21-27.
27. Kerppola, T.K. and Kahn, M.L. 1988. Symbiotic phenotypes of auxotrophic mutants of *Rhizobium meliloti* 104A14. *J. Gen. Micro.* 134:913-919.
28. Kerppola, T. K., and Kahn, M.L. 1988. Genetic analysis of carbamoylphosphate synthesis in *Rhizobium meliloti* 104A14. *J. Gen. Micro.* 134:921-929.
29. Shatters, R. G. and M. L. Kahn. 1989. Glutamine synthetase in Rhizobia: Reexamination of the proposed horizontal transfer of DNA from eukaryotes to prokaryotes. *J. Molecular Evolution* 29:422-428
30. Somerville, J.E., R.G. Shatters and M.L. Kahn. 1989. Isolation, characterization and complementation of *Rhizobium meliloti* 104A14 mutants that lack glutamine synthetase II activity. *J. Bacteriology* 171:5079-5086
31. Shatters, R.G., J.E. Somerville and M.L. Kahn 1989. Regulation of glutamine synthetase II activity in *Rhizobium meliloti* 104A14. *J. Bacteriology* 171:5087-5094
32. Kraus, J. and M. L. Kahn. 1988. Glutamate catabolism by *Rhizobium meliloti* 104A14 In *The Molecular Genetics of Plant-Microbe Interactions*, R. Palacios and D.P. Verma, ed pp. 135-136
33. C. Halling, Calendar, R., G.E. Christie, E.C. Dale, S. Finkel, J. Flensburg, M.L. Kahn, K.B. Lane, C.-S. Lin, B.H. Lindqvist, L.S. Pierson III, E.W. Six, M.G. Sunshine, and R. Ziermann. 1990. DNA sequence of bacteriophage P4. *Nucleic Acids Research* 18, 1649
34. Kahn, M.L., R. Ziermann, G. Deho, D.W. Ow, M.G. Sunshine and R. Calendar. 1991. Use of bacteriophages P2 and P4. *Methods in Enzymology* 204:264-280.
35. Alfano, J.R. and M.L. Kahn. 1990. Isolation and characterization of three amino acid aminotransferase genes from *Rhizobium meliloti* In (Gresshoff, P. et al. eds) *Nitrogen Fixation: Achievements and Objectives*. Chapman and Hall, New York. p 507.
36. Liu, Y., R.G. Shatters, and M.L. Kahn. 1990. Purification and characterization of a novel glutamine synthetase from *Rhizobium meliloti*. In (Gresshoff, P. et al. eds) *Nitrogen Fixation: Achievements and Objectives*. Chapman and Hall, New York. p 556.
37. Xu, J., M.E. Olson, M.L. Kahn, and R.E. Hurlbert. Characterization of Tn5-Induced Mutants of *Xenorhabdus nematophilus* ATCC 19061. *Applied Environ. Microbiol.* 57:1173-1180.
38. Udvardi, M.K. and M.L. Kahn. 1991. Isolation and analysis of a cDNA clone that encodes an alfalfa (*Medicago sativa*) aspartate amino transferase. *Molecular and General Genetics* 231:97-105
39. Udvardi, M.K. and M.L. Kahn. 1992. Evolution of the (Brady) *Rhizobium-Legume Symbiosis*: Why Do Bacteroids Fix Nitrogen? *Symbiosis* 14:87-101

40. McDermott, T.R. and M.L. Kahn. 1992. Cloning and mutagenesis of the *Rhizobium meliloti* isocitrate dehydrogenase gene. *J. Bacteriol.* 174: 4790-4797
41. Kahn, M.L.. 1992. A technique for rapidly collecting serial sections for light microscopy, *Microscopy Research and Technique* 22: 306
42. Shatters, R.L., Y.Liu, and M.L. Kahn. 1993. Isolation and characterization of a novel glutamine synthetase from *Rhizobium meliloti*. *Journal of Biological Chemistry* 268:469-475.
43. Udvardi, M.K., T.R. McDermott and M.L. Kahn. 1993. Isolation and characterization of a cDNA encoding an NADP<sup>+</sup>-specific isocitrate dehydrogenase from soybean (*Glycine max*). *Plant Molecular Biology* 21:739-752
44. Alfano, J.R. and M.L. Kahn. 1993. Isolation and characterization of a gene coding for a novel aspartate aminotransferase from *Rhizobium meliloti*. *J. Bacteriology* 175: 4186-4196
45. Bezdicek, D.F., M.A. Quinn, L. Forse, D. Heron, and M.L. Kahn. 1994. Ecology and insecticidal activity of *Rhizobium* spp. in nodules containing the *Bacillus thuringiensis* delta endotoxin gene. *Soil Biology and Biochemistry* 26:1637-1646.
46. Robinson, D.L., M.L. Kahn, and C.P. Vance. 1994. Cellular localization of nodule-enhanced aspartate aminotransferase in *Medicago sativa* L. *Planta* 192:202-210.
47. Perez-Galdona, R. and M.L. Kahn. 1994. Effects of organic acids and low pH on *Rhizobium meliloti* 104A14 *Microbiology* 140: 1231-1235.
48. McDermott, T.R. and M.L. Kahn. 1994. Phosphorus metabolism in the (Brady)Rhizobium-Legume symbiosis: A review. *Proceedings of the Phaseolus Beans Advanced Biotechnology Research Network Conference*. W.M.Roca, J.E. Meyer, M.A. Pastor-Corrales and J. Tohme, eds. pp. 362-378.
49. Liu, Y. and Kahn, M.L. 1995. ADP-ribosylation of *Rhizobium meliloti* glutamine synthetase III in vivo *J. Biol. Chem.* 270: 1624-1628.
50. McGurl, B., S. Mukherjee, M. Kahn and C.A. Ryan. 1995. Cloning and characterization of two proteinase inhibitor (ATI) cDNAs from alfalfa leaves (*Medicago sativa* var Venema): the expression of ATI genes in response to wounding and soil microorganisms. *Plant Molecular Biology* 27:995-1001
51. Kahn, M.L., M. Mortimer, K.S. Park and W. Zhang. 1995. Carbon metabolism in the *Rhizobium*-legume symbiosis. In "Nitrogen Fixation: Fundamentals and Applications" I.A. Tikhonovich, V.J. Romanov, N.A. Provorov, and W.E. Newton, eds. Kluwer Academic Publishers pp. 525-532
52. Greene, T.W., S.E. Chandler, M.L. Kahn, G. F. Barry, J. Preiss, and T.W. Okita. 1996. Mutagenesis of potato tuber ADP-glucose pyrophosphorylase and characterization of allosteric mutant defective in 3-PGA activation. *Proc. Natl. Acad. Sci. U.S.A.* 93, 1509-1513
53. Dalton, D.A., L. Diaz del Castillo, M.L. Kahn and J.M. Chatfield. 1996. Heterologous expression and characterization of soybean cytosolic ascorbate peroxidase. *Arch. Biochem. Biophys.* 328, 1-8.
54. Xu, Y., M. W. Mortimer, M. L. Kahn, F. J. Brockman and L. Xun. 1997. Cloning and Sequencing of a Gene Cluster Encoding Nitrilotriacetate Monooxygenase of *Chelatobacter heintzii* ATCC 29600. *J. Bacteriology* 179:1112-1116
55. Al-Niemi, T. S., T. R. McDermott, and M. L. Kahn. 1997. Phosphorus Metabolism in the Bean - *Rhizobium tropici* Symbiosis. *Plant Physiology* 113:1233-1242
56. Al-Niemi, T. S., M. L. Summers, J. G. Elkins, M. L. Kahn and T. R. McDermott. 1997. Regulation of the Phosphate Stress Response in *Rhizobium meliloti* by PhoB *Applied and Environmental Microbiology*. 63: 4978-4981.
57. Deng, S., M.L. Summers, M.L. Kahn and T.R. McDermott. 1998. Cloning and characterization of a *Rhizobium meliloti* nonspecific acid phosphatase. *Arch Microbiol* 170:18-26
58. Al-Niemi, T. S., T. R. McDermott, and M. L. Kahn. 1998. Bacteroid Nutrient Acquisition From the Rhizosphere. *Plant and Soil.* 198: 71-78
59. Kahn, M.L., T. R. McDermott and M.K. Udvardi. 1998. Carbon and Nitrogen Metabolism in Rhizobia. In "The Rhizobiaceae", HP Spaink, A. Kondorosi and PJJ Hooykaas, eds. pp 461-485.

60. Greene, T.W., I.H. Kavakli, M. L. Kahn, and T. W. Okita. 1998. Generation of Up-Regulated Allosteric Variants of Potato ADP-glucose Pyrophosphorylase by Reversion Genetics Proc Natl Acad Sci U S A. 95:10322-7
61. Park, K.S. and Kahn, M.L. 1999. Distribution of two isoforms of NADP-dependent isocitrate dehydrogenase in soybean (*Glycine max*), Plant Molecular Biology 40:13-21
62. Mortimer, M. W., T. R. McDermott, G. M. York, G. C. Walker, and M. L. Kahn. 1999. Citrate Synthase Mutants of *Sinorhizobium meliloti* are Ineffective and Have Altered Cell Surface Polysaccharides. J.Bacteriol. 181, 7608-13
63. Crawford, N, Kahn, ML, Leustek, T. Long, SR 2000. Chapter 16: Nitrogen and Sulfur. In "Biochemistry and Molecular Biology of Plants", B.B. Buchanan et al, eds. American Society of Plant Physiologists, Rockville, MD pp 786-849.
64. Yurgel, S., M. W. Mortimer, K. N. Rogers, and M. L. Kahn 2000. New substrates for the dicarboxylate transport system of *Sinorhizobium meliloti* J Bacteriol. 182:4216-21.
65. Mortimer, M.W. and M.L. Kahn. 2001. A simple method for sending plasmid DNA by mail. BioTechniques 30:1230
66. Barnett, MJ., RF Fisher, T Jones, C Komp, AP Abola, F Barloy-Hubler, L Bowser, D Capela, F Galibert, J Gouzy, M Gurjal, A Hong, L Huizar, RW Hyman, D Kahn, ML Kahn, S Kalman, DH Keating, C Palm, MC Peck, R Surzycki, DH Wells, K-C Yeh, RW Davis, NA Federspiel, SR Long. (2001) Nucleotide Sequence and Predicted Functions of the Entire *Sinorhizobium meliloti* pSymA Megaplasmid. Proceedings of the National Academy of Sciences, U.S.A. 98:9883-8
67. Galibert, F, TM Finan, SR Long, A Pühler, P Abola, F Ampe, F Barloy-Hubler, MJ Barnett, A Becker, P Boistard, G Bothe, M Boutry, L Bowser, J Buhrmester, E Cadieu, D Capela, P Chain, A Cowie, RW Davis, S Dréano, NA Federspiel, RF Fisher, S Gloux, T Godrie, A Goffeau, B Golding, J Gouzy, M Gurjal, I Hernandez-Lucas, A Hong, L Huizar, RW Hyman, T Jones, D Kahn, ML Kahn, S Kalman, D Keating, E Kiss, C Komp, V Lelaure, D Masuy, C Palm, MC. Peck, T Pohl, D Portetelle, B Purnelle, U Ramsperger, R Surzycki, P Thébault, M Vandenbol, F-J Vorhölter, S Weidner, DH Wells, K Wong, K-C Yeh, J Batut (2001) The complete genome sequence of the legume symbiont *Sinorhizobium meliloti*. Science, 293:668-72
68. Kahn, M. 2002. Signal transduction in symbiosis: Getting in deeper and deeper. "In Nitrogen Fixation: Global Perspectives." Finan, T.M., M.R.O'Brian, D.B. Layzell, J.K. Vessey and Newton, W (eds.) pp. 115-117.
69. Kahn, ML, A Parra, CL Ford, F Kaser, D McCaskill, RE Ketchum, 2002 A mass spectrometry method for measuring <sup>15</sup>N incorporation into pheophytin: Application to quantifying symbiotic nitrogen fixation Analytical Biochemistry 307:219-225
70. Walt, A and M. L. Kahn. 2002. The fixA and fixB genes are necessary for anaerobic carnitine reduction in Escherichia coli J Bacteriol. 184:4044-4047
71. Denison, R. F., C. Bledsoe, M. Kahn, F. O'Gara, E. L. Simms, and L. S. Thomashow. 2003. Cooperation in the rhizosphere and the "free rider" problem. Ecology, 84:838-845
72. House, B. L., Mortimer, M. W. and M. L. Kahn. 2004. New recombination methods for *Sinorhizobium meliloti* genetics. Applied Environ Microbiol 70:2806-15
73. Barnett, M. J. and M. L. Kahn. 2004. *Sinorhizobium meliloti* pSymA: Nitrogen fixation and more. In "Genomes and Genomics of Nitrogen Fixing Organisms", R. Palacios and W. Newton, eds. pp.113-132.
74. Kahn M.L., Schroeder B.K., House B.L., Mortimer M.M., Yurgel S.N., Maloney S.C., Warren K.L., Fisher R.F., Barnett M.J., Toman C., Long S.R. (2004) Foraging for meaning—Postgenome approaches to *Sinorhizobium meliloti*. In " Biology of Molecular Plant-Microbe Interactions, Volume 4, Eds: B Lugtenberg, I Tikhonovich, and N Provorov pp 416-422. IS-MPMI Press, St Paul.
75. Yurgel, S and M. L. Kahn. 2004. Dicarboxylate transport by rhizobia FEMS Microbiol Revs 28: 485-501
76. Parra-Colmenares, A and M L. Kahn. 2005. Determination of nitrogen fixation effectiveness in selected *Medicago truncatula* isolates by measuring nitrogen isotope incorporation into pheophytin. Plant and Soil. 270:159-168

77. Grzemski, W., J. P. Akowski and M. L. Kahn. 2005. Altering Bacterial Metabolism in a Nitrogen Fixing Symbiosis Using Conditional and Impaired Mutations in *Sinorhizobium meliloti* Citrate Synthase. *Molecular Plant Microbe Interactions* 18:134-141
78. Yurgel, S. N. and M. L. Kahn. *Sinorhizobium meliloti* dctA mutants with partial ability to transport dicarboxylic acids. 2005 *Journal of Bacteriology* 187:1161-72 Article includes cover illustration.
79. Schroeder, BK, BL House, MW Mortimer, SC Maloney, CA Taylor, KL Ward, HT Ziemkiewicz, S Clark, JJ Bovitz, H Jin, S Yurgel, and ML Kahn. 2006. Analyzing a *Sinorhizobium meliloti* 1021 ORFeome in a functional genomic platform. In Y-P Wang et al. (eds) *Biological Nitrogen Fixation, Sustainable Agriculture and the Environment*. International Nitrogen Fixation Meeting, Springer pp127-128
80. Schroeder BK, BL House, MW Mortimer, SN Yurgel, SC Maloney, KL Ward and M L Kahn. 2005. Developing a Functional Genomics Platform for *Sinorhizobium meliloti*: Construction of an ORFeome. *Applied and Environmental Microbiology* 71:5858-64
81. Yurgel S.N., B.K. Schroeder, B.L. House, M.W. Mortimer, S.C. Maloney, C.A. Taylor, K.L. Ward, H.T. Ziemkiewicz, J.J. Bovitz, H. Jin, and M.L. Kahn. 2006. Genomic and Genetic approaches to understanding the physiology of *Sinorhizobium meliloti*. In "Biology of Molecular Plant-Microbe Interactions", Volume 5, Eds: F Sanchez, C Quinto, I Lopez-Lara, and O Geiger pp 126-131. IS-MPMI Press St Paul
82. Trainer MA, SN Yurgel, and ML Kahn 2007. Role of a conserved membrane glycine residue in a dicarboxylate transporter from *Sinorhizobium meliloti*. *Journal of Bacteriology*. 189:2160-3
83. Yurgel, SN J Berrocal, C Wilson and ML Kahn. 2007. Pleiotropic effects of mutations that alter the *S. meliloti* cytochrome c respiratory system. *Microbiology*. 153:399-410
84. Humann, JL, BK Schroeder, MW Mortimer, BL House, SN Yurgel, SC Maloney, KL Ward, HM Fallquist, HT Ziemkiewicz, and ML Kahn. 2008. Construction and expression of sugar kinase transcriptional gene fusions using the *Sinorhizobium meliloti* ORFeome. *Applied and Environmental Microbiology*. 74:6756-6765
85. Yurgel SN, Kahn ML. 2008. A mutant GlnD nitrogen sensor protein leads to a nitrogen-fixing but ineffective *Sinorhizobium meliloti* symbiosis with alfalfa. *Proc Natl Acad Sci U S A*. 105:18958-63
86. Humann JL, Ziemkiewicz HT, Yurgel SN, Kahn ML. 2009. Regulatory and DNA repair genes contribute to desiccation resistance in *Sinorhizobium meliloti* Rm1021. *Appl Environ Microbiol*. 75:446-453.
87. Koziol U, Hannibal L, Rodríguez MC, Fabiano E, Kahn ML, Noya F. 2009 Deletion of citrate synthase restores growth of *Sinorhizobium meliloti* 1021 aconitase mutants. *J Bacteriol*. 191:7581-6.
88. Yurgel SN, Rice J, Mulder M, and ML Kahn. 2010. GlnB/GlnK PII proteins and regulation of the *Sinorhizobium meliloti* Rm1021 nitrogen stress response and symbiotic function. *J. Bacteriology* 192:2473-2481.
89. Yurgel SN, Rice J, Kahn ML. 2012. Nitrogen Metabolism in *Sinorhizobium meliloti*-Alfalfa Symbiosis: Dissecting the Role of GlnD and PII Proteins. *Mol Plant Microbe Interact*. 25:355-62 (epub Nov, 2011)
90. Yurgel SN, Mortimer MW, Rice JT, Humann JL, Kahn ML. 2013. Directed Construction and Analysis of a *Sinorhizobium meliloti* pSymA Deletion Mutant Library. *Appl Environ Microbiol*. Mar;79(6):2081-7. doi: 10.1128/AEM.02974-12. Epub 2013 Jan 18.
91. Yurgel SN, Rice J, Mudler M, Kahn ML, Belova V, Roumiantseva M. 2013. Truncated betB2-144 plays a critical role in *Sinorhizobium meliloti* Rm2011 osmoprotection and glycine-betaine catabolism. *Eur J Soil Biol*. 54:48-55
92. Yurgel SN, Rice J, Kahn ML. 2013 Transcriptome analysis of the role of GlnD/GlnBK in nitrogen stress adaptation by *Sinorhizobium meliloti* Rm1021. *PLoS One*. 2013;8(3):e58028.
93. Humann JL, Kahn ML. 2015. Genes involved in desiccation resistance of rhizobia and other bacteria. Chapter 39 in "Biological Nitrogen Fixation" F. deBruijn, ed. John Wiley and Sons. pp 397-403

94. Long SR, Kahn ML, Seefeldt, L, Tsay, Y-F, Kopriva S 2015 “Nitrogen and Sulfur” Chapter 16, Biochemistry and Molecular Biology of Plants. Ed: BB Buchanan, W Gruissem, RL Jones. Am Soc Plant Biol., Rockville MD pp. 711-768
95. Hagberg KL, Yurgel SN, Mulder M, Kahn ML. 2016. Interaction between Nitrogen and Phosphate Stress Responses in *Sinorhizobium meliloti*. *Frontiers in Microbiology: Microbial Physiology and Metabolism*. doi: 10.3389/fmicb.2016.01928
96. Ogden AJ, Gargouri M, Park J, Gang DR, Kahn ML. 2017. Integrated analysis of zone-specific protein and metabolite profiles within nitrogen-fixing *Medicago truncatula*-*Sinorhizobium medicae* nodules. *PLoS One*. 12(7):e0180894. doi: 10.1371/journal.pone.0180894.
97. Ogden AJ, McAleer JM, Kahn ML. 2019. Characterization of the *Sinorhizobium meliloti* HslUV and ClpXP protease systems in free-living and symbiotic states. *J Bacteriol*. Jan 22. pii: JB.00498-18. doi: 10.1128/JB.00498-18. PubMed PMID: 30670545.
98. Ghosh P, Adolphsen KN, Yurgel SN, Kahn ML *Sinorhizobium medicae* WSM419 genes that improve symbiosis between *Sinorhizobium meliloti* Rm1021 and *Medicago truncatula* Jemalong A17 and in other symbiotic systems *Appl Environ Microbiol*. 2021 Jul 13;87(15):e0300420. doi: 10.1128/AEM.03004-20.
99. Yurgel SN, Qu Y, Rice J, Ajeethan N, Zink E, Brown J, Purvine S, Lipton M, Kahn M. 2021 Specialization in a nitrogen-fixing symbiosis: proteome differences between *Sinorhizobium medicae* bacteria and bacteroids. *Mol Plant Microbe Interact*. 2021 Aug 17. doi: 10.1094/MPMI-07-21-0180-R
100. Hagberg KL, Price JP, Yurgel SN, Kahn ML. 2022. The *Sinorhizobium meliloti* Nitrogen Stress Response Changes Radically in the Face of Concurrent Phosphate Stress. *Front Microbiol*. Jan 27;13:800146. doi: 10.3389/fmicb.2022.800146.

#### Theses by GRADUATE STUDENTS UNDER MY DIRECTION AS ADVISOR

- Cloning vehicles for the analysis of gene expression in *Rhizobium meliloti*. Cynthia R. Timblin, M.S. in Bacteriology, 1983.
- Ammonia assimilation of *Rhizobium meliloti*. John E. Somerville, Jr., Ph.D. in Microbiology, 1985.
- Effect of genetic alteration of bacterial metabolism on plant-bacterial interaction. Tom Kerppola, M.S. in Biochemistry, 1985.
- Mechanism and regulation of bacteriophage P4 integration. Leland S. Pierson, III, Ph.D. in Microbiology, 1986.
- Nutrient exchange in the *Rhizobium*-legume symbiosis: Glutamate catabolism by *Rhizobium meliloti*. Jennifer Kraus, Ph.D. in Genetics, 1987.
- Glutamine synthesis in *Rhizobium meliloti*. Robert Shatters, Ph.D. Genetics and Cell Biology 1988.
- Glutamine synthetase III of *Rhizobium meliloti*. Yuan Liu, Ph.D. in Biochemistry, 1992.
- Aspartate Aminotransferases of *Rhizobium meliloti*. James Alfano, Ph.D. in Microbiology, 1993.
- Effect of pH and Organic Acids on Nitrogen Fixation Gene Regulation in *Rhizobium meliloti*, Wei Zhang, M.S. in Microbiology, 1996
- Purification and Characterization of Two *Rhizobial* Aspartate Aminotransferases. Xinxue Bai, M.S. in Microbiology 1996.
- NADP-Dependent Isocitrate Dehydrogenase Isozymes in Legumes. Kyung Soon Park, Ph.D. in Genetics and Cell Biology, 1997
- The Glutamine Synthetase III operon of *Rhizobium meliloti*, Erik L. Powers, M.S. in Genetics and Cell Biology, 1998
- Coenzyme dependence of isocitrate dehydrogenase in *Sinorhizobium meliloti* and its effect on symbiosis. Catherine Tide, M.S. in Plant Physiology, 2000
- The fixABCX operon in *Sinorhizobium meliloti* and *Escherichia coli*. AngeliqueWalt. M.S. in Microbiology 2002.
- Development of a Novel Method of Manipulating the *S. meliloti* Genome to Study the Effects of Denitrification on Symbiotic Nitrogen Fixation, Brent L. House, Ph.D. in Microbiology, 2003

Heritability of Effectiveness in a Nitrogen Fixing Symbiosis, Adriana Parra-Colmenares, Ph.D. thesis in Microbiology, 2003  
Mutagenesis studies of the DctA C4 dicarboxylate permease of *Sinorhizobium meliloti* Maria Anne Ziegler M.S. Biochemistry, 2004.  
*Sinorhizobium meliloti* metabolism of polyols : erythritol catabolic system. John Bovitz M.S. Biochemistry 2006  
Characterization of glutamate catabolism mutants of *Sinorhizobium medicae*. Ryan Rice M.S. Biochemistry 2008  
Coordination of nitrogen and phosphate stress responses in *Sinorhizobium meliloti*. Kelly Lynn Hagberg Ph.D. Microbiology. 2017  
Control of RNA structure by CspA proteins in *Sinorhizobium meliloti*. Jason Peele Price. Ph.D. Molecular Biosciences. 2017  
Rhizobial Genes that Contribute to Effective Symbiosis with Legumes. Katie Adolphsen. Ph.D. Molecular Biosciences. 2018  
Metabolic progression during development of symbiotic nitrogen fixation in the Medicago-*Sinorhizobium* symbiosis and the role of HslUV and ClpXP Protease machinery. Aaron Ogden. Ph.D. Molecular Plant Sciences. 2018.

#### Classroom TEACHING RESPONSIBILITIES:

My major responsibilities have included Introductory Microbiology, Introductory Genetics, Graduate level Molecular Biology, Undergraduate level Microbial Genetics, Protein Biotechnology, Responsible Conduct of Research



RESEARCH GRANTS AWARDED (Individual)

1. Construction of a Cosmid Gene Bank of *Rhizobium meliloti*.  
NSF 7/1/80 - 6/30/82
2. Construction of a Genetic Transfer Agent for *Rhizobium meliloti*.  
USDA/SEA-CRGO 7/1/80 - 6/30/82
3. A Phage Type Coning Vehicle for Gram Negative Bacteria.  
WSU Grant-in-Aid 7/1/80 - 6/30/81
4. Analysis of F Incompatibility. PHS 6/1/80 - 9/15/80
5. Identification of Nodulation Activated Genes in *Rhizobium meliloti*.  
WSU Grant-in-Aid 7/1/82 - 6/30/83
6. Promotion of Host Resistance to Fire Blight  
(With D. Gross & R.A. Spotts) 9/1/82 no-  
Washington Winter Pear Commission term date
7. Genetic Investigation of Gene Expression in *Rhizobium meliloti*.  
USDA/SEA-CRGO 9/1/82 - 8/31/84
8. Regulation of Site Specific Recombination in Bacteriophage P4  
ACS Inst. Grant. 5/31/83 - 6/30/84
9. Genetics of Ammonia Assimilation in *Rhizobium meliloti*.  
USDA-CRGO 9/1/84 - 8/31/86
10. Regulation of Bacteriophage P4 Integration.  
ACS Inst. Grant 7/1/84 - 6/30/84
11. Crop Plant Biotechnology. Washington Technology  
Center (With A. Kleinhofs & P. Lurquin). 7/1/86 - 6/31/87
12. Crop Plant Biotechnology. Washington Technology  
Center (With A. Kleinhofs & P. Lurquin). 7/1/87 - 6/31/88
13. Amino acid metabolism and the *Rhizobium* legume symbiosis.  
USDA-CRGO 8/15/86 - 8/31/88
14. Bacterial amino acid metabolism and the *Rhizobium*-legume symbiosis.  
USDA-CRGO 9/1/88 - 8/31/92
15. Cloning of *Bacillus thuringiensis* gene into *Rhizobium* to control *Sitona* weevil.  
(with Dave Bezdicek and Mark Quinn)  
USAID 5/1/89 - 4/30/92
16. Amino acid metabolism in alfalfa root nodules.  
USDA-CRGO 8/1/90 - 7/31/92
17. *Rhizobium* amino acid metabolism and symbiotic nitrogen fixation.  
USDA-NRI 9/1/92 - 8/31/95
18. Carbon metabolism in symbiotic nitrogen fixation.  
DOE 2 7/16/93 - 7/15/96  
Equipment supplement
19. Carbon metabolism in symbiotic nitrogen fixation.  
DOE 7/16/96 - 7/15/99
20. Dicarboxylate transport in symbiotic nitrogen fixation  
USDA-NRI 11/1/98-10/31/01
21. RUI: Endophytic nitrogen fixation by European Beach grass (*Ammophila arenaria*)  
NSF co-PI with David Dalton (Reed College) 3/1/99 - 2/28/01
22. Surface change and virulence in *Coxiella burnetii*  
NIH-NIAID (orig PI L Mallavia) 6/1/98 - 5/31/00
23. Carbon metabolism in symbiotic nitrogen fixation.  
DOE 7/16/99 - 7/15/02
24. Genetics of Symbiotic Effectiveness in Legumes  
USDA-NRI 11/15/00 - 11/14/03
25. Characterization of the Sugar Kinases of *Sinorhizobium meliloti*  
WSU College of Sciences 5/1/03 – 9/1/03  
Undergraduate Research Award to Sharon Ankrah
26. Changing Substrate Recognition by the *S. meliloti* DctA Transporter.

- |     |   |                    |
|-----|---|--------------------|
|     | NSF Metabolic Biochemistry<br>RET Supplement  | 2/1/02 - 1/31/06   |
| 27. | Building a Genetic Platform for <i>S. meliloti</i> , a Nitrogen-Fixing Symbiont of Alfalfa<br>Co-PI with Sharon Long, Stanford University<br>NSF Microbial Genetics<br>RET Supplement | 6/1/02 – 5/31/06   |
| 28. | Carbon Metabolism and Electron Flow in Symbiotic Nitrogen Fixation<br>DOE Energy Biosciences  | 7/16/02 - 7/15/06  |
| 29. | Desiccation resistance in <i>Sinorhizobium meliloti</i> .<br>DOE Energy Biosciences   | 7/15/05 - 7/14/08  |
| 30. | Respiration, polymer synthesis and symbiotic nitrogen fixation<br>USDA-NRI (Svetlana Yurgel, co-PI)   | 11/1/05 – 10/31/06 |
| 31. | The Rhizobial Nitrogen Stress Response and Effective Symbiotic Nitrogen Fixation<br>(Svetlana Yurgel, co-PI)<br>DOE Energy Biosciences  | 7/15/08 - 7/14/11  |
| 32. | The Rhizobial Nitrogen Stress Response and Effective Symbiotic Nitrogen Fixation<br>(Svetlana Yurgel, co-PI)<br>DOE Energy Biosciences  | 7/15/11 - 7/14/14  |
| 33. | Unbalancing Symbiotic Nitrogen Fixation: Can We Make Effectiveness More Effective?<br>(Svetlana Yurgel, co-PI)<br>DOE Physical Biosciences  | 7/15/14 - 7/14/19  |
| 34. | Characterizing a Novel <i>Sinorhizobium</i> activity that Increases Legume Nodulation<br>NSF-IOS  | 3/15/17 – 2/28/22  |
| 35. | Increasing Nodulation of Pulse Legume Crops<br>USA Dry Pea and Lentil Council   | 12/17 – 12/20      |
| 36. | Training in Biotechnology" Emphasis in Protein Chemistry<br>NIH-NIGMS   | 7/1/17 - 6/31/19   |
| 36. | Training in Biotechnology" Emphasis in Protein Chemistry<br>NIH-NIGMS   | 7/1/19 - 6/31/20   |
| 36. | Training in Biotechnology" Emphasis in Protein Chemistry<br>NIH-NIGMS   | 7/1/20 - 6/31/24   |
| 37. | Increasing legume nodulation for improved symbiotic N fixation<br>WSU BIOAg   | 7/1/17 – 6/30/19   |
| 38. | Dissecting Beneficial Plant-Microbe Interactions and their Efficacy in the ISS<br>Spaceflight Environment, A Model Study<br>NASA-(Space Biology Program)                              | 1/1/20 – 12/31/23  |

I am the WSU PI of record for Jason Price's USDA predoctoral fellowship 12/2014 – 12/2017.

An additional award that supported work in my laboratory is an NSF predoctoral award to William Andrefsky (Aaron Ogden) for the period 7/15/2013-6/30/2018.

I had a collaboration with Dr. Luying Xun of WSU-TriCities and Battelle Pacific Northwest Laboratories from 1992-4.

#### OTHER GRANTS.

Governmental travel award to Dr. Ricardo Perez-Galdona, Universidad de La Laguna, Canary Islands, Spain, for study in my laboratory, 10/90-7/92

Phosphorus metabolism in *Rhizobium leguminosarum* biovar *phaseoli*  
NSF Postdoctoral Research In Plant Biology Program Award  
to Dr. Timothy McDermott 7/1/92-6/31/94

Governmental travel award to Raquel Martin, Consejo Superior de Investigaciones Cientificas, Madrid, Spain, for study in my laboratory, 10/93-12/93

## GROUP AWARDS

Acquisition of an Ultracentrifuge and HPLC for Plant Biology Research. (IBC group, R. Croteau, PI)	NSF	1988-1989
Plant signaling. McKnight Foundation Training Grant (with 10 others, C.R. Ryan, PI)		1988-1992
NIH Biotechnology Training Grant in Protein Chemistry (with 16 others, G. Hazelbauer, PI)		1989-1994, 1994-1999, 1999-2004, 2004-2009, 2009-2014, 2014-2019) I was the Director of this grant from July 2017-December, 2021
Participant in Hughes Foundation grant supporting science instruction (J. Paznokas, PI).		
Acquisition of plant growth equipment for the proposed C.A. Ryan Plant Growth Facility Complex (IBC group, R. Croteau, PI)	NSF	8/1/92-7/1/94
Interdisciplinary Plant Biochemistry Research and Training Center Triagency Collaborative Research in Plant Biology Program (with 12 others, N. Lewis, R. Croteau, C.A. Ryan, PIs)		1994-1999
Acquisition of centrifuges for plant biochemistry and molecular biology research (Gyn An, PI, with 7 others)	NSF	9/94-8/95
Advanced Plant Biochemistry Summer Course (alternate years) (N. Lewis, M. Kahn, R. Croteau, PIs) Jointly funded by DOE, NSF and USDA		9/96-8/01
An LC/MS Instrument for Biological Research (L. Xun, PI; I am one of three other Co-PIs)	NSF	7/1/00 - 6/30/01
Acquisition of a stable isotope mass spectrometer facility for life science studies (R. Lee, PI; I am one of three other Co-PIs)	NSF	7/1/01 - 6/30/04
Young Investigator Travel Support for the 2004 Symbiotic Nitrogen Fixation Meeting, in Bozeman, Montana, on July 27-July 1, 2004. NSF Integrative Biology		1/1/04- 12/31/04
Capillary Electrophoresis-Mass Spectrometry System (M.L. Kahn, B.M. Lange and N.G. Lewis, co-PIs) Murdock Charitable Trust		12/1/06-11/30/07

## ADMINISTRATIVE GRANTS (When Associate Director of Agriculture Research Center).

Aquaculture ID and WA Kahn, M, D Call, S Chen, R Phillips, Rasco, B, G Thorgaard USDA-CSREES (Special Grants)		8/18/08 – 8/17/11
Aegilops Cylindrica (Jointed Goatgrass) Kahn, ML, I Burke, D Kramer, N Lewis, M Neff, W Pan, R Stevens, J Yenish USDA-CSREES (Special Grants)		10/23/08 – 10/22/11
Aquaculture ID and WA Kahn, M, D Call, J Brunelli, K Patten, R Phillips, Rasco, B, G Thorgaard USDA-CSREES (Special Grants)		9/25/09 – 9/24/12
Aegilops Cylindrica (Jointed Goatgrass) Kahn, ML, I Burke, D Kramer, N Lewis, M Neff, W Pan, J Yenish USDA-CSREES (Special Grants)		11/10/09 – 11/09/12
Aquaculture ID and WA Kahn, M, M Buetel, D Call, P Carter, K Patten, Rasco, B, G Thorgaard USDA-CSREES (Special Grants)		10/5/10 – 10/4/13
Aegilops Cylindrica (Jointed Goatgrass) Kahn, ML, I Burke, D Kramer, N Lewis, M Neff, W Pan, J Yenish USDA-CSREES (Special Grants)		10/12/10 – 10/11/13