

CURRICULUM VITAE

Mark A. Willis

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Education:

University of California, Riverside, Ph.D. in Entomology, 1986
University of California, Davis, M.S. in Entomology, 1982
University of California, Riverside, B.S. in Entomology, 1978
College of Marin, Kentfield, California, 1973-1976

Professional Employment:

2001-present **Associate Professor**, Department of Biology, Case Western Reserve University, Cleveland.
1992-present **Assistant Research Scientist**, Arizona Research Laboratories, Division of Neurobiology (ARLDN), University of Arizona, Tucson.
1991-1992 **Postdoctoral Research Associate**, ARLDN, University of Arizona, Tucson.
1989-1991 **N.I.H. Postdoctoral Fellow**, Training Program in Motor Control Neurobiology and the ARLDN, University of Arizona, Tucson.
1986-1989 **Postdoctoral Research Associate**, Department of Entomology, University of Massachusetts, Amherst.
1982-1986 **Research Assistant**, Division of Toxicology and Physiology, Department of Entomology, University of California, Riverside.
1979-1981 **Teaching Assistant**, Department of Entomology, University of California, Davis.
1979-1981 **Research Assistant**, Department of Entomology, University of California, Davis.
1978 **Laboratory Assistant**, Division of Economic Entomology, Department of Entomology, University of California, Riverside.

Awards and Honors:

N.I.H. Postdoctoral Training Fellowship, Training Program in Motor Control Neurobiology and the ARLDN, University of Arizona, Tucson, (1988).
Graduate Student Association Mini-Grant for Travel (U.C. Riverside) (1983 and 1985).
Entomology Graduate Student Research/Travel Grant (U.C. Davis) (1980-1982).
Edmund C. Jaeger Award (U.C. Riverside Life Sciences Department) (1978).

Grants:
(Extramural)

NSF "Adaptive Control of Pheromone-guided Locomotion" (Co-PI with E.A. Arbas)- Entire period of grant 11/15/92-9/30/95. Annual direct costs for yr 1: \$51,976. Total cost: \$234,758.

NSF - successful competitive renewal of "Adaptive Control of Pheromone-guided Locomotion" (PI) Entire period of grant 9/1/95 - 8/31/98. Annual direct costs for yr 1: \$82,499. Total cost: \$283,251.

NSF "A Video-based Motion Analysis Facility for Neuroethological Research on Insects" (PI)-Amount received from NSF \$69,307, Univ. of Arizona matching funds \$29,703, Total funds for motion analysis facility: \$99,010.

DARPA: Program Grant for "Olfactory control of insect flight behavior: Strategic exploitation of a controlled biological system". Entire period of grant 7/1/98 - 6/31/02. J.G. Hildebrand overall P.I. Total direct costs: \$2,957,530. M.A. Willis P.I. for Task 3, "Sensory-motor control of pheromone-guided flight behavior", total direct costs for Task 3: \$724,888.

DARPA/ONR "Biologically-inspired search algorithms for locating unseen odor sources" (PI) Entire period of grant 7/15/98 - 1/31/01. Annual direct costs for yr 1: \$184,922. Total costs: \$436,865.

DARPA white paper on Chemical Plume Tracking using Unmanned Aerial Vehicles: A Trade Study. with W. Jouse of Raytheon Missile Systems Co.- (Jouse has zero-time appointment in Aerospace and Mechanical Engineering at U. of A.). 3/01-3/02 Total budget: \$260,257. Total costs to Willis: \$50,000.

ONR MURI "Using Silicon Electronics to Study the Control of Insect Flight". 5/01 - 5/04. C. Diorio (Computer Science and Engineering, Univ. of Washington) overall P.I., Co-P.I.s - T. Daniel (Zoology, Univ. of Washington), M. Tu (Zoology, Univ. of Washington), M. Dickinson (Integrative Biology, U.C. Berkeley), M. Willis (Neurobiology, Univ. of Arizona). Total direct costs: \$2,852,930. Total direct costs for Case Western Reserve University subcontract to Willis: \$431,730.

Ongoing Collaborations:

Funded by DARPA/ONR grant, "Biologically-inspired search algorithms for locating unseen odor sources."

Dr. Jim Belanger, Louisiana State University, Baton Rouge, LA. Simulation modeling of pheromone-guided locomotion in flying moths.

Dr. Danny Grünbaum, Department of Oceanography, University of Washington, Seattle. Analytical modeling of odor-guided locomotion and fluid dynamics of plumes.

Dr. Wayne Jouse, Department of Aerospace and Mechanical Engineering, University of Arizona. Biomimetic navigation and motor control of mobile robots.

Funded by DARPA grant, "Sensory-motor control of pheromone-guided flight behavior."

Drs. Selden Crary and Khalil Najafi, Department of Electrical Engineering and Computer Sciences, University of Michigan. Design and use of light-weight telemetry systems with insects, and parallel neural recording using multi-channel silicon probe electrodes.

Dr. Michael Dickinson, Department of Integrative Biology, University of California, Berkeley. Measurements of flight forces generated by freely flying insects.

Funded by previous NSF grant (and still ongoing), "Adaptive Control of Pheromone-guided Locomotion."

Dr. Ryohei Kanzaki, Department of Biological Sciences, University of Tsukuba, Japan.

Telemetric measurements of electromyograms from freely moving insects.

Dr. Robert Raguso, Department of Biological Sciences, University of South Carolina. Odor-modulated behavior of hawkmoths and pollination of night-blooming flowers.

Professional Societies:

American Association for the Advancement of Science
Entomological Society of America
International Society for Neuroethology
Society for Neuroscience
Society for Integrative and Comparative Biology
Sigma Xi

Publications:

Submitted:

Raguso, R. and M. Willis. Behavioral responses of wild hawkmoths to visual and olfactory floral stimuli. (Submitted to Animal Behavior).

Publications:

In Press:

Raguso, R. and M. Willis. Synergy between visual and olfactory cues in nectar feeding by naïve hawkmoths. (Animal Behavior In press).

Raguso, R. and M. Willis. 2000. The importance of olfactory and visual cues in nectar foraging by nocturnal hawkmoths. in: Watt, W., Boggs, C. and Ehrlich, P., eds. "Proceedings of the Third International Congress on Butterfly Ecology and Evolution", Univ. of Chicago Press. In press.

Publications:

Published :

Murlis, J., Willis, M.A. and Cardé, R.T. (2000) Spatial and temporal structure of pheromone plumes in fields and forests. Physiological Entomology 25: 211-222.

Raguso, R. and M. A. Willis. (2000) Chapter on Moths for "A Naturalist's Guide to the Sonoran Desert", S. Phillips, ed., University of California Press, Berkeley, CA.

- Isaacs, R., Willis, M.A., and Byrne, D.N. (1999) Modulation of take-off and flight orientation of whiteflies by wind speed and visual cues. Physiological Entomology, 24: 311-318.
- Belanger, J.H. and Willis, M.A. (1998) Biologically-inspired search algorithms for locating unseen odor sources. Proceedings of special session on Biomimetic Robotics in the 1998 joint meeting of the IEEE International Symposium on Intelligent Control, International Symposium on Computational Intelligence in Robotics and Automation, and Intelligent Systems and Semiotics.
- Willis, M.A. and Arbas, E.A. (1998) Variability in odor-modulated flight by moths. Journal of Comparative Physiology A 182:191-202.
- Willis, M.A. and Arbas, E.A. (1997) Active behavior and reflexive responses: Another perspective on odor-modulated locomotion. In: Pheromone research: New directions, eds. R.T. Cardé and A.K. Minks, Chapman & Hall, pp. 304-319.
- Willis, M.A. and Arbas, E.A. (1997) Active behavior and the adaptive control of oriented locomotion. In: Neurons, Networks and Motor Behavior, eds. P. Stein, D. Stuart, S. Grillner and A. Selverston, MIT Press.
- Belanger, J.H. and Willis, M.A. (1996) Centrally-generated and reflexive control strategies in the adaptive behavior of real and simulated animals. In: From animals to animats 4: Proceedings of the fourth international conference on the simulation of adaptive behavior, eds. P. Maes, M. Mataric, J.-A. Meyer, J. Pollack, and S.W. Wilson, MIT Press/Bradford Books, Cambridge, Massachusetts, pp. 155-162.
- Belanger, J.H. and Willis, M.A. (1996) Adaptive control of odor-guided locomotion: Behavioral flexibility as an antidote to environmental unpredictability. Adaptive Behavior 4:217-253.
- Willis, M.A., Butler, M.A., and Tolbert L.P. (1995) Normal glomerular organization of the antennal lobes is not necessary for odor-modulated flight in female moths Journal of Comparative Physiology A. 176:205-216.
- Willis, M.A., David, C.T., Murlis, J. and Cardé, R.T. (1994) Effects of pheromone plume structure and visual stimuli on the pheromone-modulated upwind flight of male gypsy moths (*Lymantria dispar* L.), in a forest. Journal of Insect Behavior. 7:385-409.
- Willis, M.A. and Baker, T.C. (1994) Behaviour of oriental fruit moth males during approach to sex pheromone sources. Physiological Entomology. 19:61-69.
- Kaiser, L., Willis, M.A., and Cardé, R.T. (1994) Flight manoeuvres used by a specialist parasitoid, *Cotesia rubecula* (Hym.:Braconidae) to locate odour sources. Entomologia Experimentalis et Applicata. 70:285-294.
- Arbas, E.A., Willis, M.A., and Kanzaki, R. (1993) Organization of goal-oriented locomotion: Pheromone-modulated flight behavior of moths. in, Biological Neural Networks in Invertebrate Neuroethology and Robotics, eds. R. Beer, R. Ritzmann, and I. McKenna.

Publications: (cont.)

Willis, M.A. and Arbas, E.A. (1991) Odor-modulated upwind flight in *Manduca sexta*. (Journal of Comparative Physiology A. 169:427-440.

Willis, M.A., Murlis, J. and Cardé, R.T. (1991) Pheromone-modulated upwind flight of male gypsy moths, *Lymantria dispar*, in a forest. Physiological Entomology. 16:507-521.

Murlis, J., Willis, M.A. and Cardé, R.T. 1990. Odor signals: patterns in time and space. In, Proceedings of the X International Symposium on Olfaction and Taste. (K. Doving, ed.), Oslo.

Willis, M.A. and Cardé, R.T. (1990) Pheromone-modulated optomotor response in male gypsy moths, *Lymantria dispar* L.: Upwind flight in a pheromone plume in different wind velocities. Journal of Comparative Physiology A. 167:699-706.

Olberg, R.M. and Willis, M.A. (1990) Pheromone-modulated optomotor response in male gypsy moths, *Lymantria dispar* L.: Directionally selective visual interneurons in the ventral nerve cord. Journal of Comparative Physiology A. 167:707-714.

Cardé, R.T., Willis, M.A. and Charlton, R.E. (1989) Mate-finding behaviors and chemical communication in the Lymantriidae. In, Proceedings, Lymantriidae: a comparison of features of new and old world tussock moths. Wallner, W.E. and McManus, K.A., (eds.). Gen. Tech. Report NE-123, USDA Forest Service. pp. 133-141.

Willis, M.A. and Baker, T.C. (1988) Effects of varying pheromone component ratios on the zigzagging flight movements of *Grapholita molesta*. Journal of Insect Behavior. 1:357-371.

Willis, M.A. and Baker, T.C. (1987) Comparison of manoeuvres used by walking vs. flying *Grapholita molesta* males during pheromone-mediated upwind movement. Journal of Insect Physiology. 33: 875-883.

Baker, T.C., Willis, M.A., Haynes, K.F. and Phelan, P.L. (1985) A pulsed cloud of pheromone elicits upwind flight in male moths. Physiological Entomology. 10:257-265.

Baker, T.C., Willis, M.A. and Phelan, P.L. (1984) Optomotor anemotaxis polarizes self-steered zigzagging in flying moths. Physiological Entomology. 9:365-376.

Willis, M.A. and Baker, T.C. (1984) Effects of intermittent and continuous pheromone stimulation on the flight behavior of the oriental fruit moth, *Grapholita molesta*. Physiological Entomology. 9:341-358.

Page, R.E. and Willis, M.A. (1983) Sexual dimorphism in ventral abdominal setae in *Scolytus multistriatus* (Coleoptera:Scolytidae): possible role in courtship behavior. Annals of the Entomological Society of America 76:78-82.

Willis, M.A. and Birch, M.C. (1982) Male lek formation and female calling in a population of the arctiid moth, *Estigmene acrea*. Science. 218: 168-170.

Publications:

In Preparation:

Willis, M.A. and Arbas, E.A. Motor patterns underlying maneuvers performed during pheromone-modulated flight in moths. (in preparation for Journal of Comparative Physiology A).

Willis, M.A., Floyd, J.D., Kellar, R.S. and Tolbert, L.P. Effects of abnormal development on the glomerular organization of the olfactory processing center of moth brains. (In preparation for Journal of Comparative Neurology).

Willis, M.A. Altering the visual surround predictably shapes the pheromone-modulated flight performance of moths. (In preparation for Journal of Comparative Physiology A).

Willis, M.A. Individual variability between repeated performances of pheromone-modulated flight in moths. (In preparation for Journal of Comparative Physiology A).

Published Abstracts:

Gray, J.R., and Willis, M.A. (2000) Neural ensemble recording during active locomotion in virtual reality. Society for Neuroscience, Abstracts 26:

Willis, M.A., Johnstone, L., and Costy-Bennett, S.J. (2000) Modulation of locomotory motor patterns in response to increased force requirements. Society for Neuroscience, Abstracts 26:

Willis, M.A., Yamada, M., Takasaki, T., Kuwana, Y., Shimoyama, I., and Kanzaki, R. (1998) Pheromone-modulated flight in *Manduca sexta*: variability in individual performances revealed by radio-telemetry of flight muscle activity. Proceedings of the 5th International Congress of Neuroethology.

Willis, M.A., Chow J., Gee E. (1998) Role of antennae in airspeed control during pheromone-modulated flight. Gottingen Neurobiology Conference.

Wicklein, M., Willis, M.A., Strausfeld, N.J. (1997) Visual interneurons involved in feeding in *Manduca sexta* (Sphingidae:Lepidoptera). Society for Neuroscience, Abstracts 23:613.15

Belanger, J.H. and Willis, M.A. (1997) Using genetic algorithms as tools for computational neuroethology. Society for Neuroscience, Abstracts 23:421.4

Wicklein, M., Willis, M.A. and Strausfeld, N.J. (1997) Characteristics of flower approach, hovering flight and visual interneurons in *Manduca sexta* (Lepidoptera: Sphingidae). Gottingen Neurobiology Conference.

- Willis, M.A. and Raguso, R.A. (1996) Behavioral responses of hawkmoths visiting night-blooming flowers of the sonoran desert. Society for Integrative and Comparative Biology.
- Raguso, R.A. and Willis, M.A. (1996) Floral scent chemistry of hawkmoth-pollinated desert flowers is not tightly convergent. Society for Integrative and Comparative Biology.
- Willis, M.A., Floyd, J.D., Kellar, R.S. and Tolbert, L.P. (1996) Effects of abnormal development on the anatomy of the pheromone processing center of male moth brains and the behavior it supports. Society for Neurosciences, Abstracts. 22:427.13.
- Willis, M.A. and Arbas, E.A. (1995) Altering the visual surround predictably shapes the pheromone-modulated flight performance of moths, *Manduca sexta*. Society for Neurosciences, Abstracts. 21:187.4.
- Willis, M.A. and Arbas, E.A. (1995) Altering the visual surround predictably shapes the pheromone-modulated flight performance of moths, *Manduca sexta*. In: Nervous Systems and Behavior, Proceedings of the 4th International Congress of Neuroethology, eds. M. Burrows, T. Matheson, P.L. Newland and H. Schuppe, Georg Thieme Verlag, Stuttgart.
- Baker, K., Willis, M.A. and Arbas, E.A. (1995) Spontaneous self-generated counterturns during tethered flight of male moths, *Manduca sexta*. In: Nervous Systems and Behavior, Proceedings of the 4th International Congress of Neuroethology, eds. M. Burrows, T. Matheson, P.L. Newland and H. Schuppe, Georg Thieme Verlag, Stuttgart.
- Willis, M.A., Butler, M.A., Kellar, R.S. and Tolbert, L.P. (1995) Behavioral consequences of abnormal glomerular architecture of the antennal lobe of the moth, *Manduca sexta*. In: Nervous Systems and Behavior, Proceedings of the 4th International Congress of Neuroethology, eds. M. Burrows, T. Matheson, P.L. Newland and H. Schuppe, Georg Thieme Verlag, Stuttgart.
- Baker, K., Willis, M.A. and Arbas, E.A. (1994) Spontaneous self-generated counterturns during tethered flight of male moths, *Manduca sexta*. Society for Neurosciences, Abstracts. 20:418.10
- Willis, M.A. and Arbas, E.A. (1993) Motor patterns underlying pheromone-modulated flight in male moths, *Manduca sexta*. 11th International Symposium on Olfaction and Taste, Sapporo, JAPAN.
- Arbas, E.A. and Willis, M.A. (1993) Pheromone-modulated flight behavior of the sphinx moth, *Manduca sexta*. 11th International Symposium on Olfaction and Taste, Sapporo, JAPAN.
- Butler, M.A., Willis, M.A., Tolbert, L.P. and Arbas, E.A. (1992) Behavioral consequences of reducing olfactory input to the brain. Society for Neurosciences, Abstracts. 18:135.17
- Willis, M.A. and Arbas, E.A. (1991) Flight muscle activity underlying pheromone-modulated zigzagging flight in male moths, *Manduca sexta*. Society for Neurosciences, Abstracts. 17:492.15.

Kaiser, L., Willis, M.A. and Cardé, R.T. (1991) Plasticity in-flight orientation to plant and host odours in the specialist parasitoid *Cotesia rubicula*. 6th European workshop on insect parasitoids, REDIA74:303-304.

Willis, M.A. and Arbas, E.A. (1990) Odor-mediated upwind flight behavior of the tobacco hornworm moth, *Manduca sexta*. Society for Neurosciences, Abstracts. 16:313.4.

Willis, M.A. and Olberg, R.M. (1988) Identified descending interneurons in the male gypsy moth respond to combinations of sex-pheromone, visual and wind stimuli. Society for Neurosciences, Abstracts. 14:154.16.

Invited Seminars and Papers Presented:

Selected Invited Seminars:

- 2002 Multi-sensory integration in insect flight navigation, NASA/ONR sponsored workshop entitled, Combating Uncertainty With Fusion, Marine Biological Laboratories, Woods Hole, MA.
- 2002 Odor-modulated navigation in flying insects: plume structure to biorobotics, Society for Integrative and Comparative Biology, Symposium on Neural mechanisms of orientation and navigation, Anaheim, CA.
- 2000 Odor-guided Flight in Moths: Everything from Soup to Nuts, Departmental seminar, Department of Ecology, Evolution and Behavior, University of Minnesota, St. Paul.
- 2000 Sensori-motor Control of Flight in Insects, NASA sponsored workshop entitled, "Invertebrate Sensory Information Processing: Biological Inspiration for Autonomous Systems, Marine Biological Laboratories, Woods Hole, MA.
- 2000 Odor-guided Navigation in Fluid Media, DARPA/ONR sponsored meeting entitled, "Neurotechnology for Biomimetic Robots", Northeastern University, Boston, MA.
- 1999 Orientation to odors by moths: A look from chemical ecology to flight biomechanics, Department seminar, Department of Biological Sciences, California State University, Long Beach.
- 1998 Odor-guided flight in moths: A neuroethological approach, Departmental seminar, Department of Zoology, University of Washington, Seattle.
- 1998 Neuroethology of pheromone-modulate flight in moths, Departmental seminar, Department of Entomology, Mississippi State University, Starkville.
- 1998 Neuroethology of odor-guided locomotion, Departmental seminar, Department of Biological Sciences, Bowling Green State University, Bowling Green Ohio.

- 1998 Radio-telemetry of flight muscle EMGs from freely flying moths. Symposium on Miniaturization in Behavioral Research, Institut für Neurobiologie, Free University, Berlin.
- 1998 Behavioral and physiological mechanisms underlying the control of odor-modulated flight. In: Insect flight: From neuronal circuits to aerodynamics, symposium 12, 26th Gottingen Neurobiology Conference.
- 1998 Behavioral and physiological mechanisms underlying the control of odor-modulated flight. In: Insect flight: From neuronal circuits to aerodynamics, symposium 12, 26th Gottingen Neurobiology Conference.
- 1997 Neuroethology of odor-guided flight in moths. Invited Speaker. BioMicroMachines Workshop, Department of Biological Sciences, University of Tsukuba, Tsukuba, Japan.
- 1996 Behavioral and physiological mechanisms of odor-guided locomotion. Departmental Seminar. Department of Biological Sciences, University of South Carolina. Columbia, South Carolina.
- 1995 Neural bases for odor-modulated behavior in *Manduca sexta*. Departmental Seminar. Laboratoire de Neurobiologie Comparée des Invertébrés, INRA-CNRS, Bures s/Yvette, France.
- 1995 Mechanisms of odor-guided locomotion. Departmental Seminar. Department of Integrative Biology, University of California at Berkeley, Berkeley, California.
- 1994 Multimodal descending input and motor patterns underlying pheromone-modulated flight in male moths. 1st International Symposium on Insect Pheromones, Wageningen International Conference Center, Wageningen, The Netherlands.
- 1993 Organization of goal oriented locomotion: Pheromone-modulated flight in moths. Departmental Seminar. Department of Anatomy and Organismal Biology, The University of Chicago, Chicago, Illinois.
- 1992 Pheromone-modulated flight and orientation in moths: Variation in individual performance and motor strategies. Departmental Seminar. Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.
- 1992 Pheromone-modulated flight behavior in moths: From forest to flight simulator. Departmental Seminar. Department of Entomology, University of Arizona, Tucson, Arizona.
- 1991 Oriented flight in odor plumes: Behavior and motor patterns. Invited speaker, European Symposium on Insect Taste and Olfaction II, Tegernsee, FEDERAL REPUBLIC OF GERMANY.

Papers Presented: (since 1990)

- 2001 Gray, J.R. and Willis, M.A. Mult-unit neuronal activity during odour-guided flight of the moth *Manduca sexta*. International Congress of Neuroethology.

- 2001 Belanger, J.H., Willis, M.A. and Jouse, W.C. A combined approach of simulation and robotic studies to the problem of understanding animal orientation to odor plumes. International Congress of Neuroethology.
- 2001 Willis, M.A., Johnstone, L. and Costy-Bennett, S.J. Motor Patterns, Wing Kinematics and Flight Maneuvers of Freely Flying *Manduca sexta* Tracking Odor Plumes. International Congress of Neuroethology.
- 1998 Role of antennae in airspeed control during pheromone-modulated flight. 26th Annual Gottingen Neurobiology Conference, Gottingen, Germany.
- 1997 Effects of abnormal development on the glomerular organization of the olfactory processing center of moth brains. 12th International Symposium on Olfaction and Taste, San Diego, California.
- 1997 Floral scent and its role(s) in hawkmoth attraction. 12th International Symposium on Olfaction and Taste, San Diego, California.
- 1997 Olfactory versus visual cues in hawkmoth attraction to night-blooming flowers. Annual meeting of the Ecological Society of America.
- 1996 Centrally-generated and reflexive control strategies in the adaptive behavior of real and simulated animals. Annual Meeting, Society for Adaptive Behavior, Falmouth, Massachusetts.
- 1995 Altering the visual surround predictably shapes the pheromone-modulated flight performance of moths, *Manduca sexta*. Entomological Society of America, National Meeting, Las Vegas, Nevada.
- 1995 Behavioral strategies underlying pheromone-modulated flight in *Manduca sexta*: Lessons from simulation studies. Entomological Society of America, National Meeting, Las Vegas, Nevada.
- 1993 Locomotory performance of individual moths flying upwind in pheromone plumes. Entomological Society of America, National Meeting, Indianapolis, Indiana.
- 1992 Is glomerular organization of the antennal lobes necessary for odor-modulated upwind flight in moths? Entomological Society of America, National Meeting, Baltimore, Maryland.
- 1992 Locomotory performance of individual moths, *Manduca sexta*, flying upwind in pheromone plumes. International Congress of Neuroethology, Montreal, CANADA.
- 1992 Maneuvers and motor patterns underlying pheromone-modulated flight in male moths, *Manduca sexta*. International Congress of Neuroethology, Montreal, CANADA.
- 1992 Motor patterns underlying pheromone-modulated zigzagging flight in male moths, *Manduca sexta*. Western Nerve Net Meeting, University of California, San Diego.

- 1991 Patterns of flight muscle activity underlying pheromone-modulated zigzagging in freely flying *Manduca sexta* males. Entomological Society of America, National Meeting, Reno, Nevada.
- 1991 Flight muscle activity underlying pheromone-modulated zigzagging flight in male moths, *Manduca sexta*. Society for Neuroscience, Annual Meeting, New Orleans, Louisiana.
- 1991 Pheromone-mediated zigzagging flight and underlying flight muscle activity in unrestrained moths, *Manduca sexta*. Western Nerve Net, Oregon Health Sciences University, Portland, Oregon.
- 1990 Odor-modulated upwind flight response in male and female tobacco hornworm moth, *Manduca sexta*. Entomological Society of America, National Meeting New Orleans, Louisiana.
- 1990 Odor-mediated upwind flight behavior of the tobacco hornworm moth, *Manduca sexta*. Society for Neuroscience, Annual Meeting, St. Louis, Missouri.

References:

Primary References:

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Secondary References:

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