# The Language of Chemical Ecology

✦

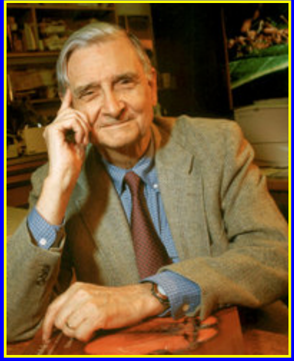
# Chemical Ecology Memories

25th Annual Meeting of
The International Society of Chemical Ecology

David L. Wood
Department of Environmental Science, Policy and Management
University of California
Berkeley, CA 94720

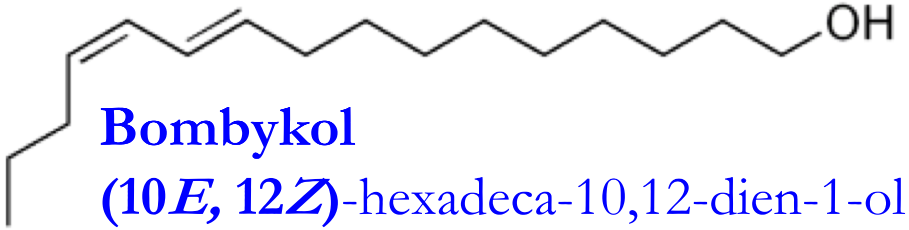
Chemical communication systems play a major role in the survival of all organisms, from bacteria to primates.
They have been described from the following phyla:

| | | | |
|---|---|---|---|
| bacteria | blue-green algae | slime molds | true fungi |
| nematodes & rotifers | annelids | mollusks | arthropods |
| chordates | protozoans | | |



Wilson, E. O. 1970. Chemical communication within animal species, pp. 133-135,
*in* E. Sondheimer and J. B. Simeone (eds.).
Chemical Ecology. Academic Press, New York.

The identification of the silkworm moth sex attractant by Adolf Butenandt & colleagues in 1959 is often cited as the founding study in Chemical Ecology.




**Bombykol**
**(10*E*, 12*Z*)**-hexadeca-10,12-dien-1-ol

Silkworm moth, ***Bombyx mori***

Butenandt, A., Beckmann, R., Stamm, D., & Hecker, E. 1959. Uber den Sexual-lockstoff des Seidenspinners *Bombyx mori* Reindarstellung und Konstitution. *Z. Naturforsch* 14b:283–284.

**The Language of Chemical Ecology**:

Highlights of discoveries made from these organisms during this "early period" of chemical ecology leading up to the founding of ***The Journal of Chemical Ecology*** in 1975.

PHEROMONES

Karlson, P., & Lüscher, M. 1959. Pheromones:
A new term for a class of biologically active substances. *Nature* 183:55–56.

RELEASERS & PRIMERS

Wilson, E. O., & Bossert, W. H. 1963. Chemical communication among animals. *Recent Progr. Hormone Res.* 19:673–716.

KAIROMONES & ALLOMONES

Brown, W., Jr., Eisner, T., & Whittaker, R. 1970. Allomones and kairomones: *trans*-specific chemical messengers. *Bioscience* 20:21–22.

**The Language of Chemical Ecology**:
Highlights of discoveries made from these organisms during this "early period" of chemical ecology leading up to the founding of ***The Journal of Chemical Ecology*** in 1975.

ALLELOCHEMICAL INTERACTIONS & SEMIOCHEMICALS

Whittaker, R. H., & Feeny, P. P. 1971. Allelochemics: Chemical interactions between species. *Science* 171:557–770.

Law, J. H., & Regnier, F. E. 1971. Pheromones. *Ann. Rev. Biochem.* 40:533–548.


*The Journal of Chemical Ecology* was first published in 1975 and is devoted to promoting an ecological understanding of the origin, function, and significance of natural chemicals that mediate interactions within and between organisms.

In the period leading up to the first issue of the *Journal of Chemical Ecology*,


biologically active compounds were identified from many organisms in diverse taxa such as:

water mold   slime mold   honeybee   bark and ambrosia beetles

carpet beetle   boll weevil   ground beetle   cabbage looper moth

red-banded leaf roller moth   Indian meal moth   pink bollworm moth

European corn borer   monarch butterfly   leaf-cutting ant   housefly

millipede   whip scorpion   minnow   boar   black-tailed deer

pronghorn antelope   rhesus monkey   and many more

Also during this period many new behavioral chemical or "semiochemical" phenomena were discovered, e.g.:

multi-component chemical stimuli

synergism among components

interruption/disruption

structural and enantiomeric specificity

interspecific interactions

releaser and primer effects

and many others

At the same time an amazing diversity of new biologically active chemicals was discovered.

These studies on semiochemical phenomena and biologically active compounds were summarized in more than ten books during this period:

Hall, S. A. (ed.). 1963. *New Approaches to Pest Control and Eradication,* Advances in Chemistry: Series 41. American Chemical Society, Washington, D. C., 74 pp.

Jacobson, M. (ed.). 1965. *Insect Sex Attractants*. John Wiley and Sons, Inc., New York, 154 pp.

Crosby, D. G. (ed.). 1966. *Natural Pest Control Agents*, Advances in Chemistry: Series 53. American Chemical Society, Washington, D. C., 24 pp.

Pfaffmann, C. (ed.). 1969. *Olfaction and Taste*. Proceedings of the Third International Symposium. Rockefeller Univ. Press, New York, 648 pp.

Wood, D. L., Silverstein, R. M. & Nakajima, M. (eds.). 1970. *Control of Insect Behavior by Natural Products*. Academic Press, New York, 345 pp.

Sondheimer, E., & Simeone, J. B. (eds.). 1970. *Chemical Ecology*. Academic Press, New York, 336 pp.

Johnston, J. W., Jr., Moulton, D. G., & Turk, A. (eds.). 1970. *Communication by Chemical Signals*. Appleton-Century-Crofts, New York, 412 pp.

M. Beroza (ed.). 1970. *Chemicals Controlling Insect Behavior*. Academic Press, New York, 170 pp.

Tahori, A. (ed.). 1971. *Chemical Releasers in Insects*. Gordon and Breach, New York. 227 pp.

Jacobson, M. 1972. *Insect sex pheromones*. Academic Press, New York, 382 pp.

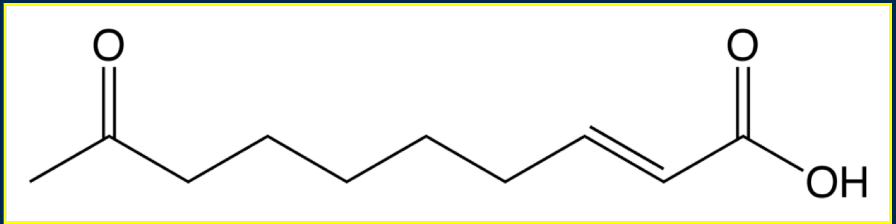
H. F. van Emden (ed.). 1972. *Insect/Plant Relationships*. Blackwell Scientific Publications, Oxford, England. 215 pp.

M. C. Birch (ed.). 1974. *Pheromones*. North-Holland Publishing Co., Amsterdam, Holland. 495 pp.

PRIMER

Following identification of the silkworm moth sex pheromone, Callow and Johnston (1960) & Barbier and Lederer (1960) identified the "queen substance" in the mandibular gland secretion of the queen honeybee, which inhibits queen cell construction.

Queen bee, *Apis mellifera*



9-oxo-2-decenoic acid (9-ODA)

Callow, R. K., & Johnston, N. C. 1960. The chemical constitution and synthesis of queen substance of honeybees, *Apis mellifera*. *Bee World* 41:152–153.

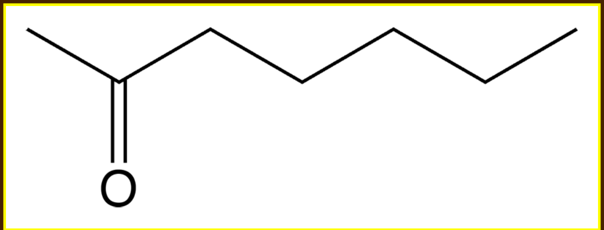
Barbier, J., & Lederer, J. 1960. Structure chimique de la substance royale de la reine d'abeille *Apis mellifera* L. *C. R. Acad. Sci. Paris* 250:4467–4469.

RELEASER

Gary, N. E. 1962. Chemical mating attractants in the queen honey bee. *Science* 136:773–774.

The following year, Blum and colleagues (1963) identified methyl-*n*-amyl ketone as the alarm pheromone of the ant, *Iridomyrmex pruinosus*.

*Iridomyrmex pruinosus* (Roger)



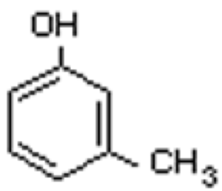

Methyl-*n*-amyl ketone

Murray Blum

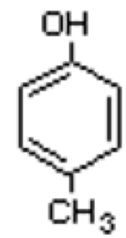
Silver Medal, 1989

Blum, M. S., Warter, S. L., Monroe, R. S., & Chidester, J. C. 1963. Chemical releasers of social behavior. I. Methyl *n*-amyl ketone in *Iridomyrmex pruinosus* (Roger) (Formicidae: Dolichoderinae). *J. Insect Physiol.* 9:881–885.

Eisner, Hurst, & Meinwald (1963) identified phenolic glandular defense secretions of a carabid beetle, *Chlaenius cordicollis* Kirby, and the chordeumoid millipede, *Abacion magnum* (Loomis).




*m*-methylphenol
(*m*-cresol)
*Chlaenius cordicollis* Kirby




*p*-methylphenol
(*p*-cresol)
*Abacion magnum* (Loomis)

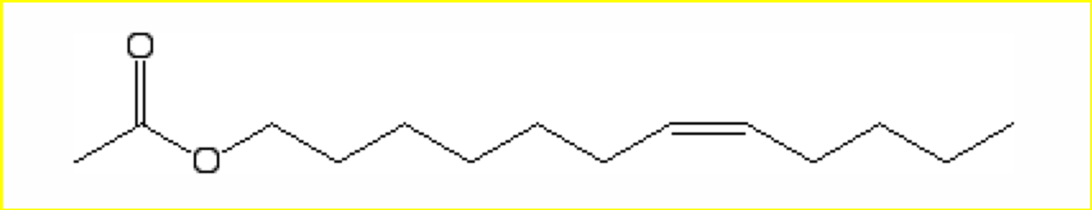
Jerrold Meinwald  Thomas Eisner

Co-Silver Medal, 1991

Eisner, T., Hurst, J. J., & Meinwald, J. 1963. Defense mechanisms of arthropods XI. The structure, function and phenolic secretions of the glands of a chordeumoid millipede and a carabid beetle. *Psyche* 70:94–116.

# Berger identified the sex pheromone of the cabbage looper, *Trichoplusia ni*, in 1966.

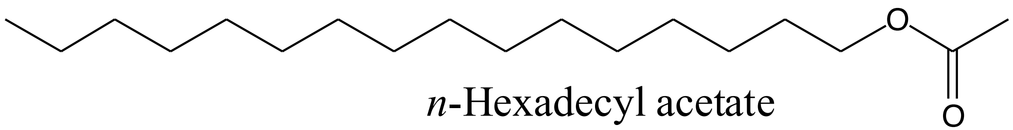
Cabbage looper moth, *Trichoplusia ni*



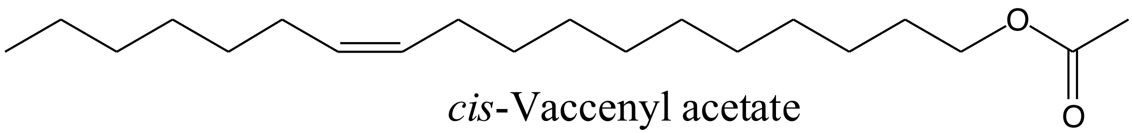

(*Z*)-7-dodecenyl acetate


Berger, R. S. 1966. Isolation, identification, and synthesis of the sex attractant of the cabbage looper, *Trichoplusia ni*. *Ann. Entomol. Soc. Amer.* 59:767–771.

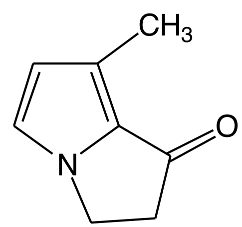
Meinwald & colleagues (1966) identified 3 major components of the "hair-pencilling" secretion of the male danaid butterfly, *Lycorea ceres ceres*. These compounds, termed aphrodisiacs, are essential for successful courtship resulting in mating.



*n*-Hexadecyl acetate



*cis*-Vaccenyl acetate



2,3-Dihydro-7-methyl-1*H*-pyrrolizin-1-one

Male danaid butterfly, *Lycorea ceres ceres*

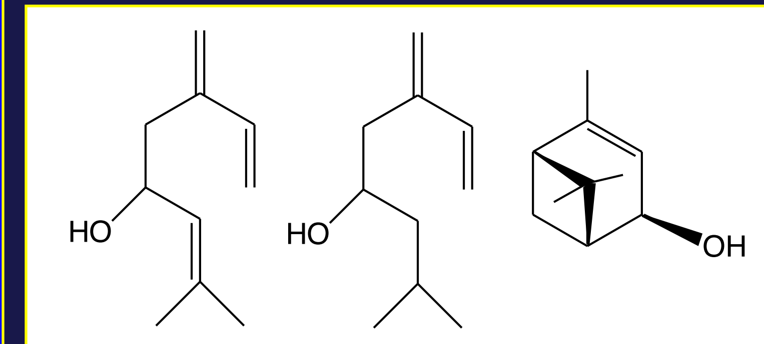
Meinwald, J., Meinwald, Y. C., Wheeler, J. W., Eisner, T., & Brower, L. P. 1966. Major components in the exocrine secretion of a male butterfly (*Lycorea*). *Science* 151:583–585.

In 1966, Silverstein and colleagues identified three monoterpene alcohols that elicit mass aggregation of male and female engraver beetles (*Ips paraconfusus*) during host colonization.

Milt Silverstein
Silver Medal, 1986

David Wood
Silver Medal, 2001

California fivespined ips,
*Ips paraconfusus*




Ipsdienol Ipsenol *cis*-Verbenol

None of these pheromone components was active alone and all were required for maximum activity, thus demonstrating synergism among the components.

Silverstein, R. M., Rodin, J. O., & Wood, D. L. 1966. Sex attractants in frass produced by male *Ips confusus* in ponderosa pine. *Science* 154:509–510.

Bark beetle aggregation behavior can result in the death of living trees, often over vast forested areas.

Tree damage caused by mountain pine beetle in B.C.
(The largest recorded North American outbreak, 1995-the present)

Interactions between two co-colonizing species were also discovered:

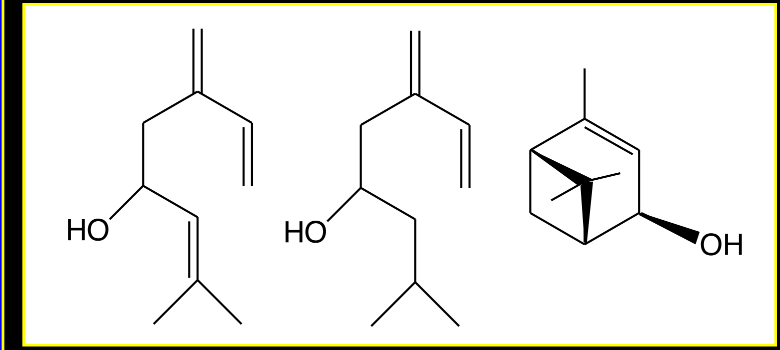
Ipsenol + *cis*-Verbenol attracted *Ips latidens*

Ipsenol + *cis*- Verbenol + Ipsdienol attracted *Ips paraconfusus*

Ipsdienol is an allomone for *Ips paraconfusus*

Western pine engraver
*Ips latidens*

Calif. fivespined ips
*Ips paraconfusus*




Ipsdienol Ipsenol *cis*-Verbenol

This study demonstrated that bark beetle pheromones also function as allomones to reduce competition between species.

Wood, D. L., Stark, R. W., Silverstein, R. M., & Rodin, J. O. 1967. Unique synergistic effects produced by the principal sex attractant compounds of *Ips confusus* (LeConte) (Coleoptera: Scolytidae). *Nature* 215:206.

Shorey & colleagues (1967) and Gaston & colleagues (1967) demonstrated disruption of pheromone communication in the cabbage looper as a method of population control.

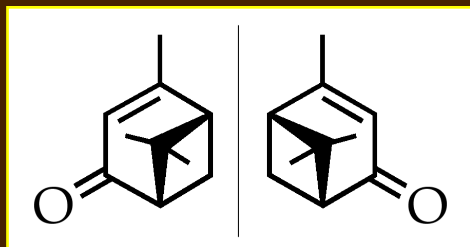
Cabbage looper moth, *Trichoplusia ni*

Harry Shorey

Shorey, H. H., Gaston, L. K., & Saario, C. A. 1967. Sex pheromones of noctuid moths. XI. Feasibility of behavioral control by disrupting pheromone communication in cabbage loopers. *J. Econ. Entomol.* 60:1541–1545.

Gaston, L. K., Shorey, H. H., & Saario, C. A. 1967. Insect population control by the use of sex pheromone to inhibit orientation between the sexes. *Nature* 213:1155.

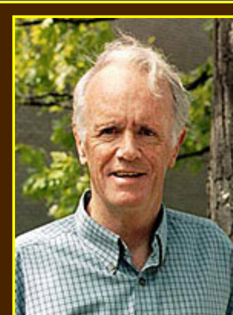
Renwick (1967) identified verbenone from the volatiles of extracted hindguts of male *Dendroctonus* species, but no biological activity was known at that time.



enantiomers of Verbenone


*D. brevicomis*


*D. frontalis*


Alan Renwick

Silverstein/Simeone Lecture Award, 1999

Renwick, J. A. A. 1967. Identification of two oxygenated terpenes from the bark beetles *Dendroctonus frontalis* and *Dendroctonus brevicomis*. *Contrib. Boyce Thompson Instit.* 23:355–360.

1998: Phero Tech verbenone pouches registered by EPA for control of southern pine beetle

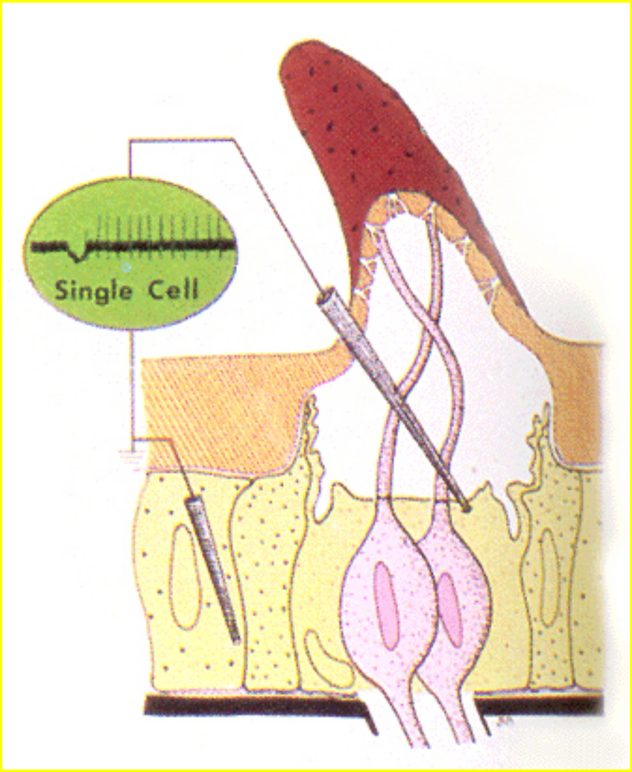
2008: Hercon laminated flakes with verbenone registered by EPA for control of mountain pine beetle

Flakes on ground following application (Water bottle shown for scale)

Gillette, N. E., Erbilgin, N., Webster, J. N., Pederson, Mori, S. R., Stein, J. D., Owen, D. R., Bischel, K. M., & Wood, D. L. 2008. Aerially applied verbenone-releasing flakes protect *Pinus contorta* stands from attack by *Dendroctonus ponderosae* in California and Idaho. *For. Ecol. Manage.* In Review.

# Pheromone identification by using electroantennograms (EAG) and laboratory and field behavioral responses.

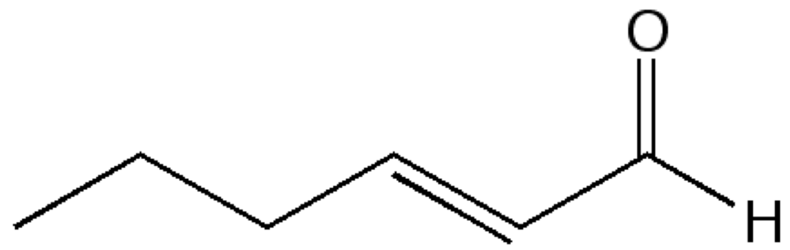
Dietrich Schneider
Silver Medal, 1990




Schneider, D. 1967. Insect olfaction: deciphering system for chemical messages. *Science* 163:1031–1038.

Riddiford (1967) identified the volatile compound *trans*-2-hexenal from oak leaves that stimulates the female polyphemus moth (*Antheraea polyphemus*) to release her sex pheromone.

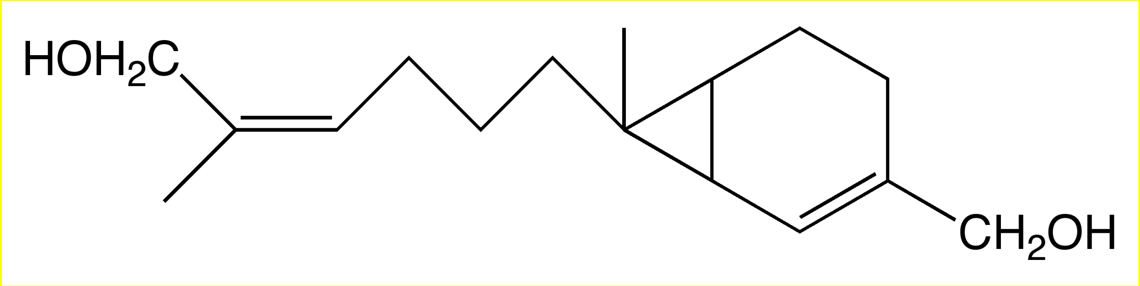
Polyphemus moth, *Antheraea polyphemus*




*trans*-**2-Hexenal**

Riddiford, L. M. 1967. *trans*-2-Hexenal: Mating stimulant for polyphemus moths. *Science* 158:139–141.

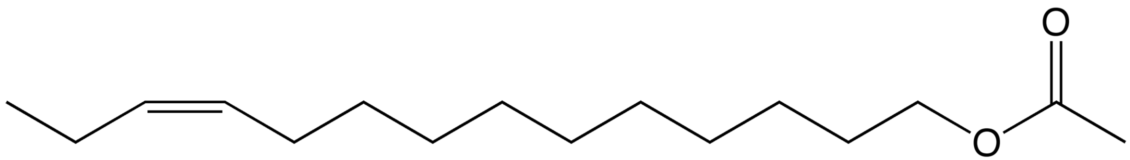
In 1968, Machlis & colleagues published the structure of sirenin, which was isolated from a water mold, *Allomyces* sp.
This compound functions as a female plant "sex hormone," which attracts the highly motile male gametes.




Sirenin

Machlis, L., Nutting, W. H., & Rapoport, H. 1968. The structure of sirenin. *J. Am. Chem. Soc.* 90:1674–1676.

Roelofs & Arn (1968) identified the sex attractant for the redbanded leafroller moth.



*cis*-11-tetradecenyl acetate

Wendell Roelofs

Silver Medal, 1990

Red-banded leafroller moth, *Argyrotaenia velutinana* (Walker)


Roelofs, W.L., & H. Arn. 1968. Sex attractant of the red-banded leafroller moth. *Nature* 219:513.

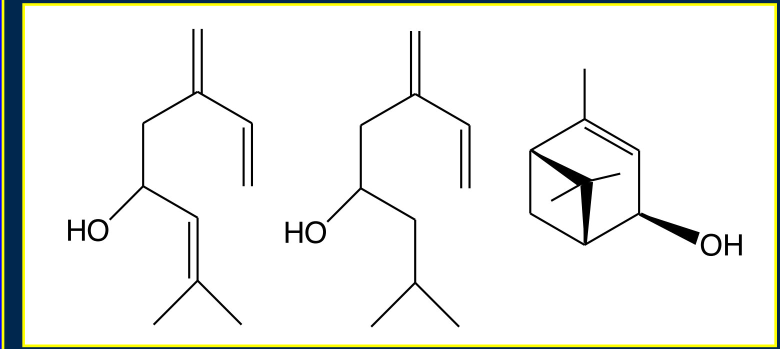
Roelofs, W. L. & A. Comeau. 1971. Sex pheromone perception: Electroantennogram responses of the red-banded leafroller moth. *J. Insect Physiol.* 17:1969–1982.

In field tests, ipsdienol, ipsenol, and *cis*-verbenol also attracted two predaceous beetles that aggregate on the tree under attack.

Wood, D. L., Browne, L. E., Bedard, W. D., Tilden, P. E., Silverstein, R. M., & Rodin, J. O. 1968. Response of *Ips confusus* to synthetic sex pheromones in nature. *Science* 159:1373–1374.

*Enoclerus lecontei*

*Temnochila chlorodia*



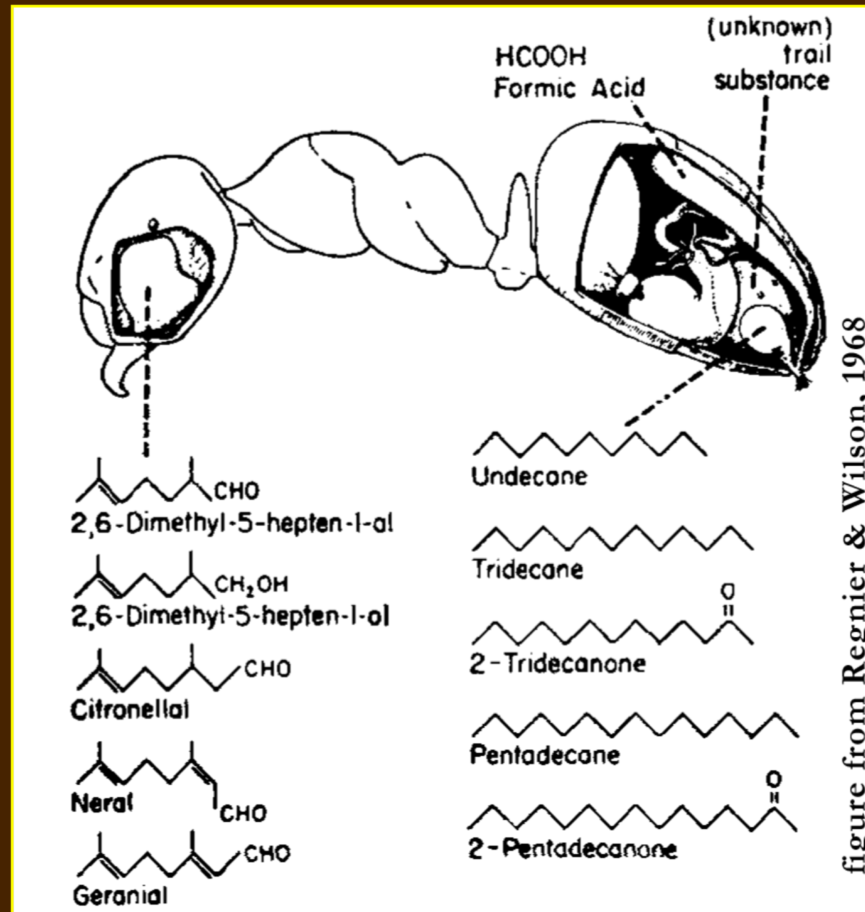

Ipsdienol Ipsenol *cis*-Verbenol

This study demonstrated that bark beetle pheromones also function as kairomones for these predators, directing them to areas with high prey densities

# Regnier and Wilson (1968) identified the volatile substances involved in the alarm-defense system of the ant *Acanthomyops claviger*.

*Acanthomyops claviger*

Regnier, F. E., & Wilson, E. O. 1968. The alarm-defence system of the ant *Acanthomyops claviger*. *J. Insect Physiol.* 14:955–970.




Structural formulas of volatile substances found in various exocrine glands of the ant *Acanthomyops claviger*

# Bergström and Löfqvist (1968) identified the volatile compounds from ant gasters in four formicine ants: slave-keepers *Formica sanguinea* Latr. and *Polyergus rufescens* (Latr.), and slaves *F. fusca* L. and *F. rujibarbis*

Gunnar Bergstrom

Silver Medal, 2008

Bergström, G., & Löfqvist, J. 1968. Odour similarites between the slave-keeping ants *Formica sanguinea* and *Polyergus rufescens* & their slaves *F. fusca* & *F. rufabarbis*. *J. Ins. Physiol.* 14: 995–1011.

Formicine ants: multicomponent & multifunctional pheromone secretions

*Formica sanguinea* (slave keeper)

Acetates: C10-ac, C11-ac, C12-ac

Alcohols: C10-ol, C11-ol, C12-ol

Hydrocarbon: Undecane (C11-ane)

*Polyergus rufescens* (slave keeper) *trans, trans*-α-Farnesene

*Formica fusca* (slave)

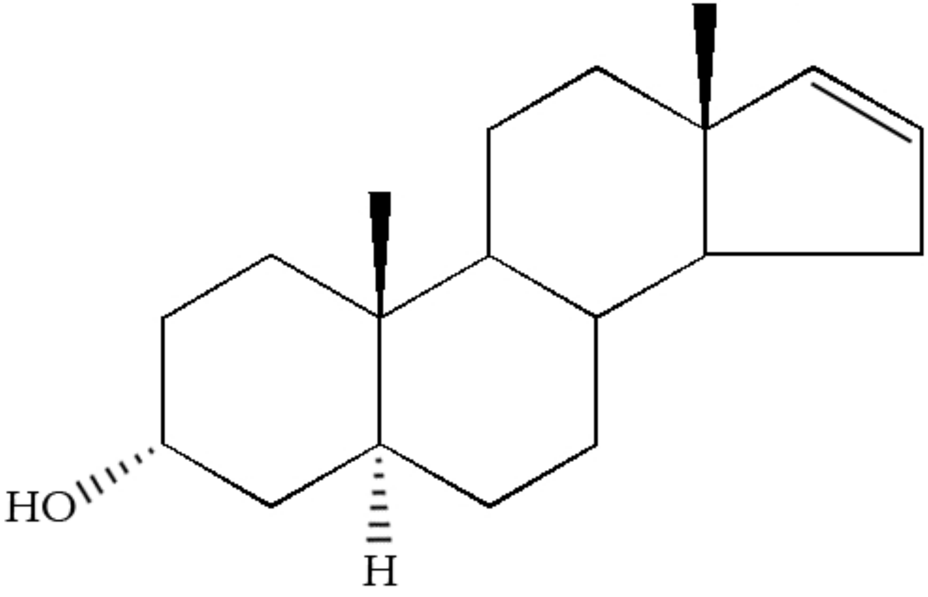
Hydrocarbons: Undecane (C11-ane), Tridecane (C13-ane)

*Formica rufibarbis* (slave)

Acetates: C10-ac, C11-ac, C12-ac

Hydrocarbons: Undecane (C11-ane), Tridecane (C13-ane)

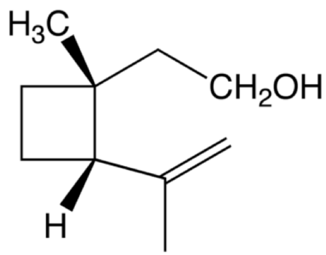
Patterson (1968) identified 3-α-hydroxy-5-α-androst-16-ene as the musk odor component of boar submaxillary salivary glands.



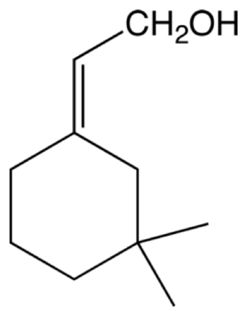

3-α-hydroxy-5-α-androst-16-ene

Patterson, R. L. S. 1968. Identification of 3-alpha-hydroxy-5-alpha-androst-16-ene as the musk odour component of boar submaxillary salivary glands and its identification to the sex odour taint in pork meat. *J. Sci. Fd. Agric.* 19:434–438.

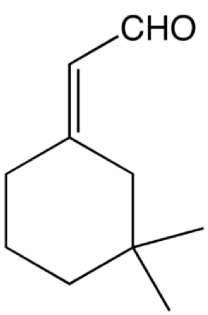
# Tumlinson & colleagues (1969) identified four terpenoids as the aggregation pheromone of the boll weevil. As with bark beetles, these compounds also exhibited synergism.



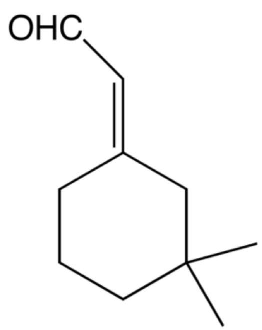

(+)-*cis*-2-isopropenyl-1-methylcyclobutaneethanol




*cis*-3,3-dimethyl-$\Delta^{1,\beta}$ cyclohexaneethanol




*cis*-3,3-dimethyl-$\Delta^{1,\alpha}$ cyclohexaneacetaldehyde




*trans*-3,3-dimethyl-$\Delta^{1,\alpha}$ cyclohexaneacetaldehyde

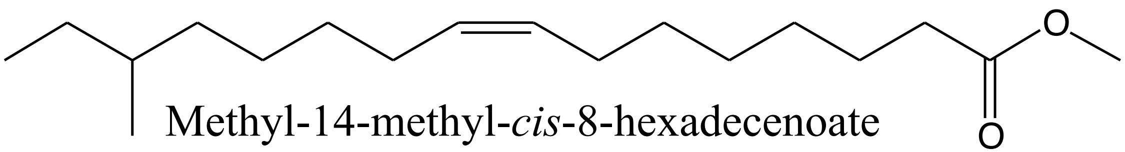
Cotton boll weevil, *Anthonomus grandis*

Jim Tumlinson

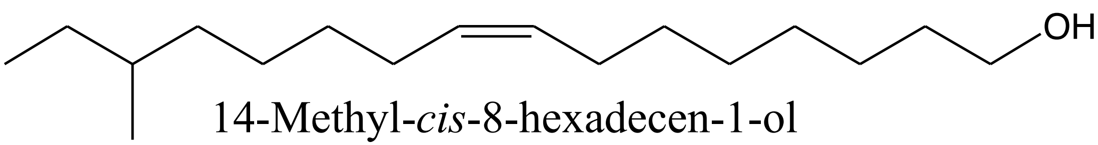
Silver Medal, 2005

Tumlinson, J. H., Hardee, D. D., Gueldner, R. C., Thompson, A. C., Hedin, P. A., & Minyard, J. P. 1969. Sex pheromones produced by male boll weevil: isolation, identification, and synthesis. *Science* 166:1010–1012.

Rodin & colleagues (1969) identified two individually active compounds that account for the attractive response of the male dermestid beetle, *Trogoderma inclusum* Le Conte to females.




Methyl-14-methyl-*cis*-8-hexadecenoate

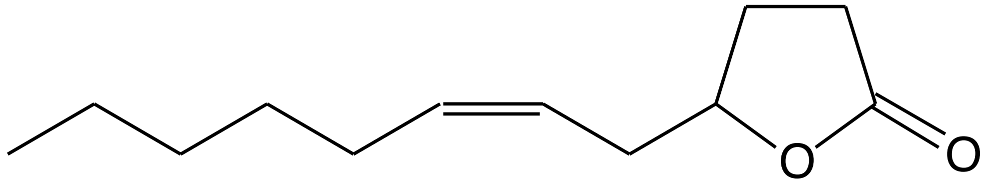



14-Methyl-*cis*-8-hexadecen-1-ol

Dermestid beetle, *Trogoderma inclusum*

Rodin, J. O., Silverstein, R. M., Burkholder, W. E., & Gorman, J. E. 1969. Sex attractant of female dermestid beetle, *Trogoderma inclusum* LeConte. *Science* 165:904–906.

Brownlee & colleagues (1969) identified the "individual recognition" pheromone found in the tarsal secretion of the black-tailed deer, *Odocoileus hemionus columbianus*.

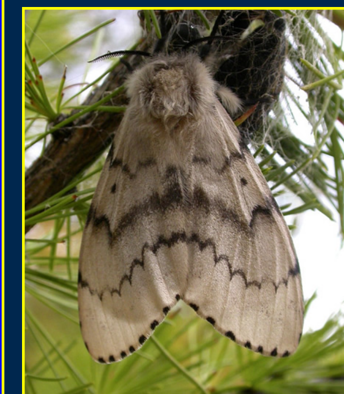



*cis*-4-hydroxydodec-6-enoic acid lactone

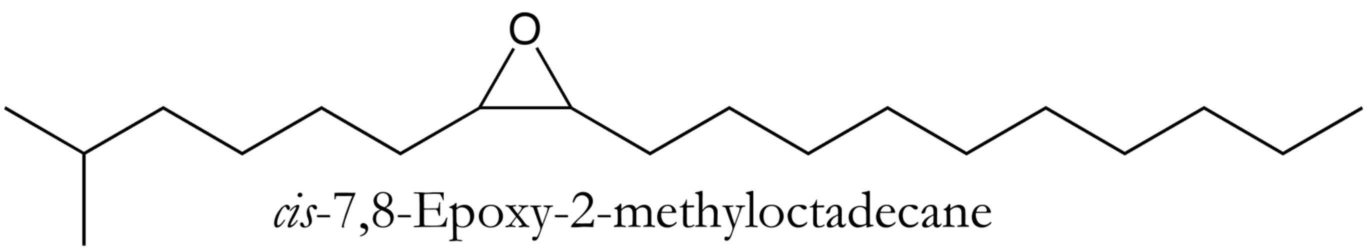
Brownlee, R. G., Silverstein, R. M., Müller-Schwarze, D., & Singer, A. G. 1969. Isolation, identification and function of the chief component of the male tarsal scent in black-tailed deer. *Nature* 221:284–285.

Bierl & colleagues (1970) identified the sex pheromone for the gypsy moth, a destructive forest defoliator.

The Hercon plastic chip formulated with this sex pheromone disrupts mating and is applied widely to "slow the spread" of this pest in North America.



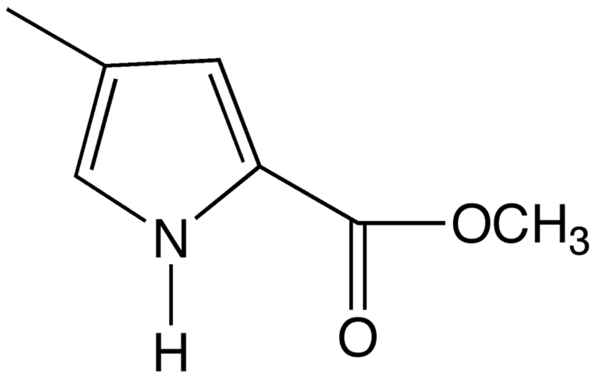
Gypsy moth, *Lymantria dispar*



*cis*-7,8-Epoxy-2-methyloctadecane

Bierl, B. A., Beroza, M., & Collier, C. W. 1970. Potent sex attactant of the gypsy moth: its isolation, identification and synthesis. *Science* 70:87.

The trail-following pheromone of the a leaf-cutter ant was identified by Tumlinson and colleagues (1971).

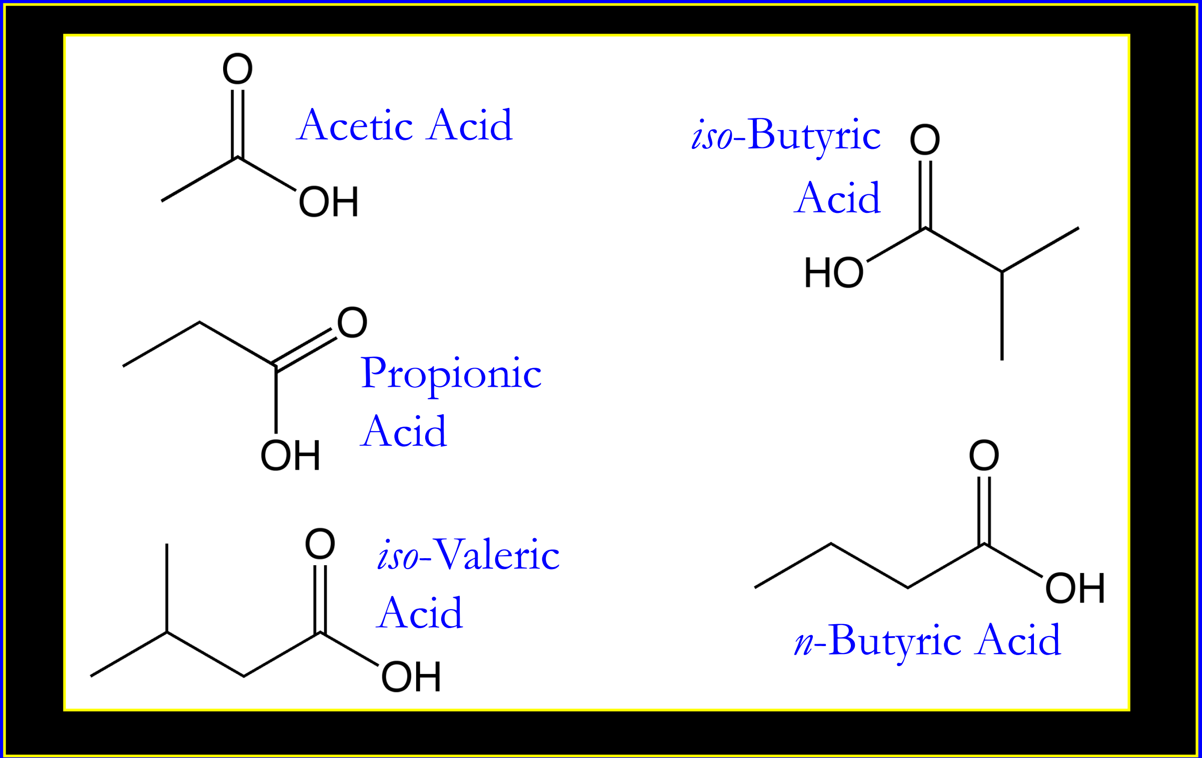


4-Methylpyrrole-2-carboxylate

Leaf-cutter ant, *Atta texana*

Tumlinson, J. H., Silverstein, R. M., Moser, J. C., Brownlee, R. G., & Ruth, J. M. 1971. Identification of the trail pheromone of a leaf-cutting ant, *Atta texana*. *Nature* 234:348–349.

Curtis & colleagues (1971) and Michael & colleagues (1971) identified the sex attractants from vaginal secretions of female rhesus monkeys.




Curtis, R. F., Ballantine, J. A., Keverne, E. B., Bonsall, R. W., & Michael, R.P. 1971. Identification of primate sexual pheromones and the properties of synthetic attractants. *Nature* 232:396–398.

Michael, R. P., Keverne, E. B., & Bonsall, R.W. 1971. Pheromones; Isolation of male sex attractants from a female primate. *Science* 172:964–966.

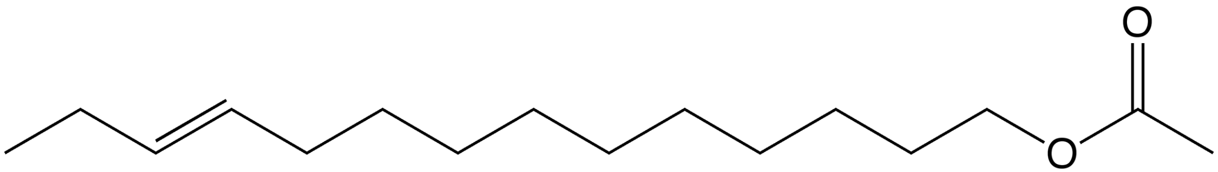
In 1971, Carlson & colleagues identified the house fly, *Musca domestica*, sex pheromone.

**(*Z*)-9-Tricosene**

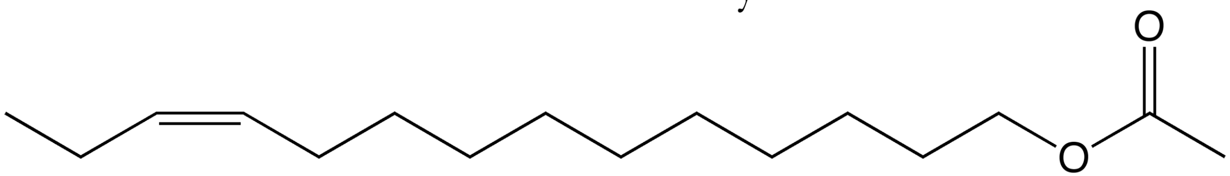
Housefly, *Musca domestica*

Carlson, D. A., Mayer, M. S., Silhacek, D. L., James, J. D., Beroza, M., & Bierl, B. A. 1971. Sex attractant pheromone of the house fly: Isolation, identification and synthesis. *Science* 174:76–78.

Klun & colleagues (1973) showed that maximum attractiveness depended upon a precise mixture of *cis*- and *trans*-isomers in the European corn borer, Iowa strain *Ostrinia nubilalis* (Hübner) and the redbanded leafroller, *Argyrotaenia velutinana* (Walker).



*trans*-11-tetradecenyl acetate



*cis*-11-tetradecenyl acetate

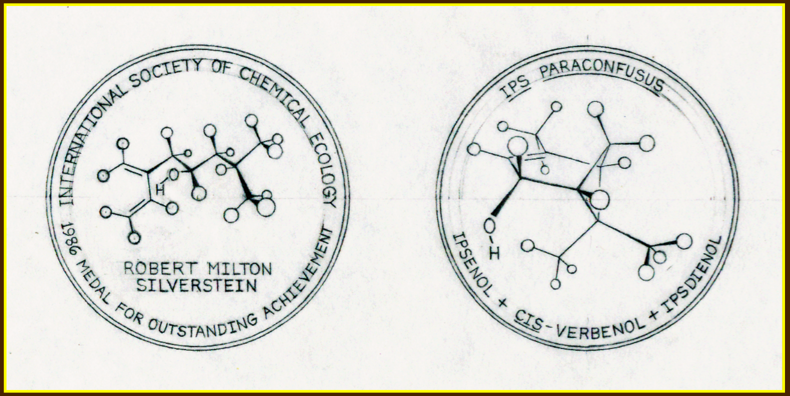
Klun, J. A., Chapman, O. L., Mattes, K. C., Wojtkowski, P. W., Beroza, M. & Sonnet, P. E. 1973. Insect sex pheromones: Minor amount of opposite geometrical isomer critical to attraction. *Science* 181:661–663.

The *International Society of Chemical Ecology* (ISCE) was founded in 1983 and the first annual meeting was held in Austin, TX. Lincoln Brower was the first president.

- The Silver Medal for career achievement in chemical ecology was first awarded in 1986 to Robert M. (Milt) Silverstein in Berkeley, CA.
- Wilhelm Boland received the first Silverstein/Simeone Lecture Award for significant mid-career scientific achievement in 1995 in Los Andes, Chile.

Milt Silverstein

Wilhelm Boland




Initial illustrations of the Silver Award medal awarded to Milt Silverstein

# The 38 Winners of the *ISCE* Silver Medal and Silverstein-Simeone Awards

Silver Medal Awards:

1986 | Robert Silverstein
1989 | Murray Blum & Miriam Rothschild
1990 | Wendell Roelofs & Dietrich Schneider
1991 | Jerrold Meinwald & Thomas Eisner
1993 | Jeffrey Harborne
1994 | Gerald Rosenthal & Dan Janzen
1995 | Wittko Francke
1996 | Kenji Mori & Jacques Pasteels
1997 | William Fenical
1998 | Thomas Hartmann
1999 | Elizabeth Bernays & Reginald Chapman
2000 | William Bowers
2001 | David Wood
2002 | John Pickett
2004 | Jeremy McNeil
2005 | Jim Tumlinson
2006 | John Hildebrand & A.C. Oehlschlager
2007 | Koji Nakanishi
2008 | Gunnar Bergstrom

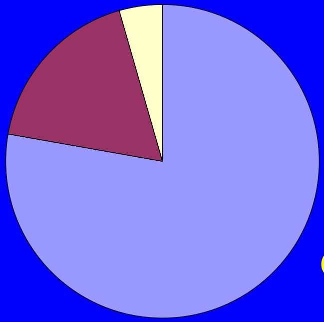
Silverstein-Simeone Lecture Awards

1995 | Wilhelm Boland
1996 | Louise Vet
1997 | Clarence Ryan
1998 | Ian Baldwin
1999 | Alan Renwick
2000 | May Berenbaum
2001 | Glenn Prestwich
2002 | Thomas Baker
2004 | Richard Vogt
2005 | John Carlson
2007 | Walter Leal
2008 | Leslie Vosshall

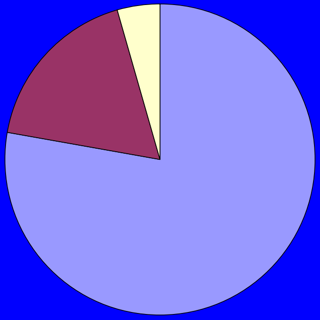
# Analysis of the Contributions of *ISCE* Award Winners

- Chemists/biochemists/molecular biologists were dominant among disciplines (27/38)
- Insects were the most studied organisms (36/38), especially moths/butterflies (15), beetles (8), ants, wasps, & bees (8).

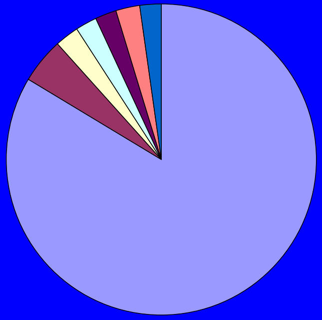
## Discipline



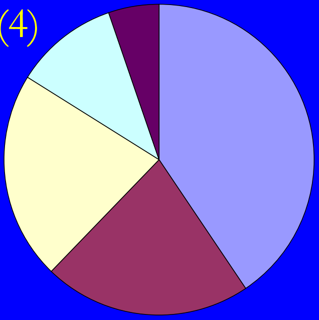

## Ecological Levels




## Organisms Studied

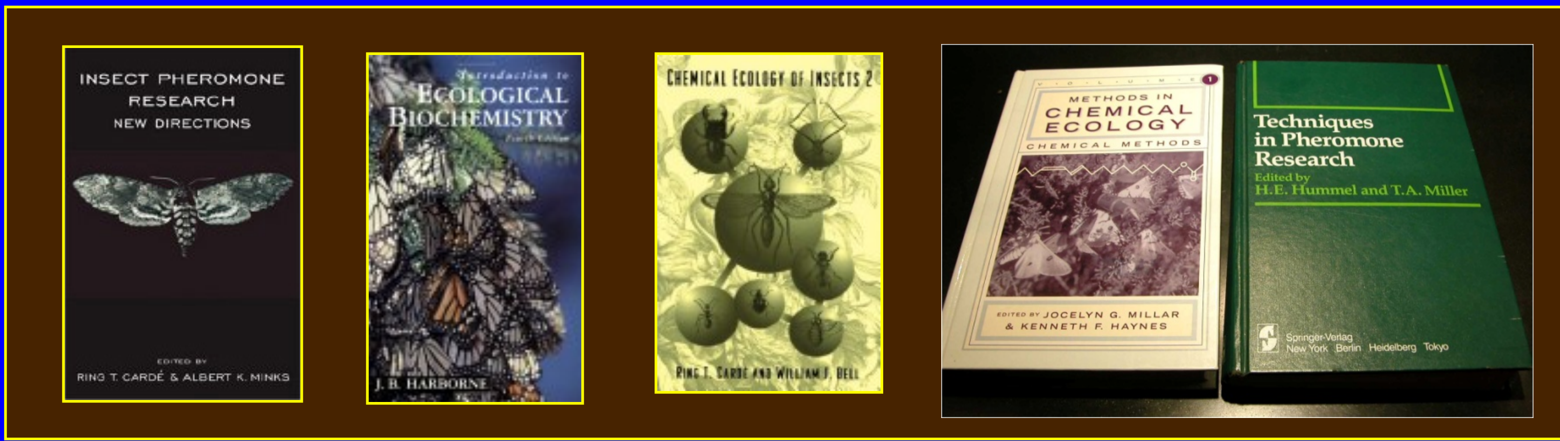



## Insects Studied




* More than one taxon studied by awardee

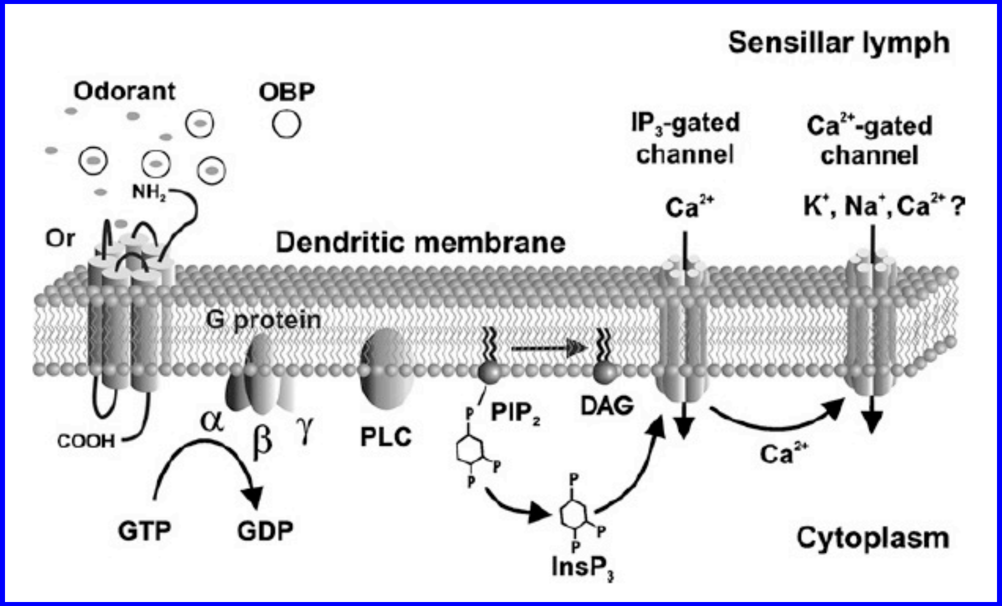
This trend in research may actually be representative of the trend in our society. However, this is a very small and biased sample and there are no statistical analyses to support the obvious conclusions from this sample.
We are a society comprised, in large part, of chemists working on insects that are mostly consumers and herbivores.




Jeffrey Harborne
Silver Medal, 1993

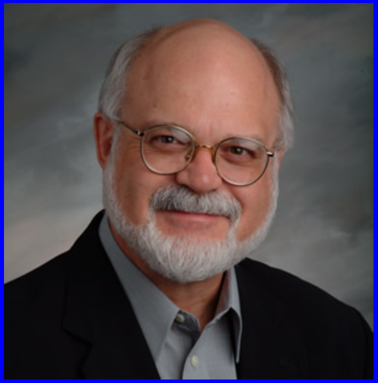
There has been a notable increase in investigations of the physiology & molecular biology of the transduction of chemical signals among organisms.

Vogt & colleagues (1981) provided the first biochemical and molecular evidence for pheromone-binding proteins from the antennae of the male silk moth, *Antheraea polyphemus*




From: Jacquin-Joly and Merlin 2004. *JCE* 30: 2359-2397

**Dick Vogt**
**Silverstein-Simeone Award, 2004**



**John Hildebrand**
**Silver Medal, 2006**

Vogt, R. G., & Riddiford, L. M., 1981. Pheromone binding and inactivation by moth antennae. *Nature* 293:161–163.

Stengl, M. Zufall, F., Hatt, H., & Hildebrand, J. G. 1992. Olfactory receptor neurons from antennae of developing male *Manduca sexta* respond to components of the species-specific sex pheromone *in vitro*. *J. Neurosci*. 12: 2523–2531.

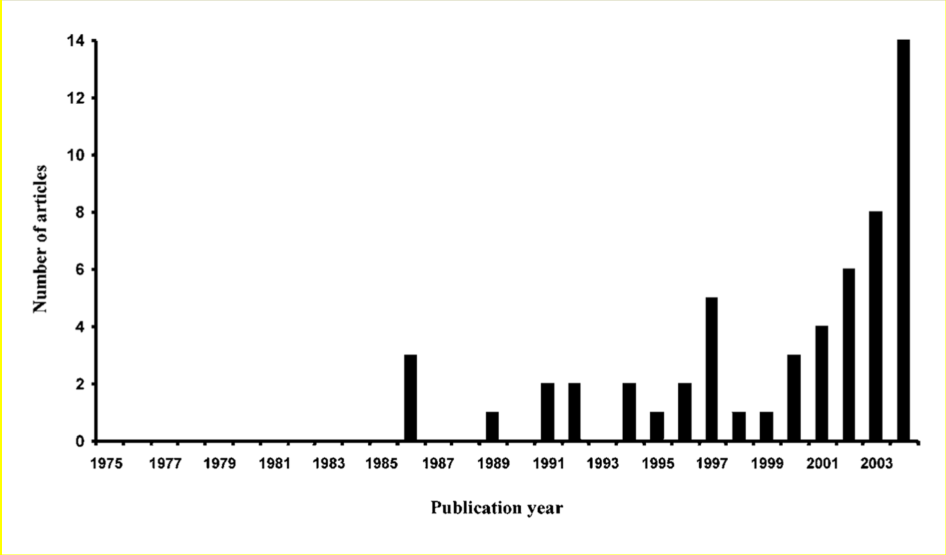
# Trends in Publication in *The Journal of Chemical Ecology*

## Special Topic Issues

Since 2000, *JCE* has produced five special-topic issues

Allelopathy | Sept. 2000
Aquatic Chemical Ecology | Oct. 2002
Molecular Chemical Ecology | Dec. 2004
Mammalian Chemical Ecology | June 2006
Olfactory Ecology | July 2008

## Articles with Molecular Content



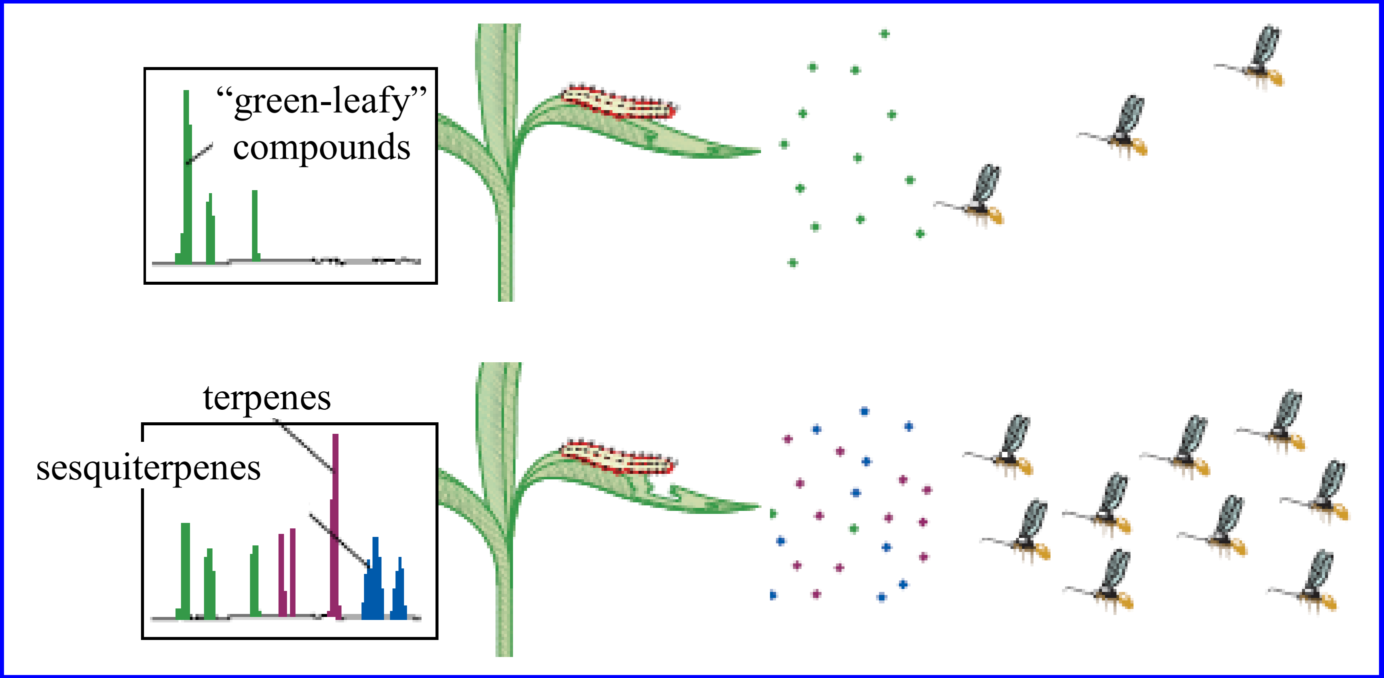

Trends in publication of articles in *The Journal of Chemical Ecology* with molecular content from 1975-2003.

Seybold, S.J. 2004. The eighth day of discovery: Molecular biology comes to chemical ecology. *J. Chem. Ecol.* 30: 2327–2333.

# Looking Forward

✦ Many frontiers for the study of interacting species at the guild, community, and ecosystem levels of biological organization.

✦ The few investigations of tri-trophic interactions among herbivorous insects, parasitoids, and predators, and plants are important steps toward this frontier.




Tumlinson & Colleagues. 1993. How parasitic wasps find their hosts. *Scientific American* 268:100–106.

# Looking Forward

- Recent examples of "chemical ecology" have been noted at the biome and global levels (Gore, A. 2006. "An Inconvenient Truth").
- There are effects of the major "greenhouse" gases ($H_2O$, $CO_2$, $MH_4$ $O_3^-$) on:

  1) increased global temperature;

  2) projected decline in polar bear populations; and

  3) human behavior.
- The link between greenhouse gas emissions and distant observations of impacts on species is difficult for regulators to establish.
- Thus, we see life-threatening ecological impacts of simple compounds produced by respiration and decomposition on our biosphere and ultimately on human survival.

A4 News | The Seattle Times | TUESDAY, AUGUST 12, 2008

NationReport

Species protection in flux

BUSH PROPOSES NEW REGULATIONS

Fewer mandatory reviews by scientists

BY DINA CAPPIELLO
*The Associated Press*

WASHINGTON – Parts of the Endangered Species Act may soon be extinct.

The Bush administration wants federal agencies to decide for themselves whether highways, dams, mines and other construction projects might harm endangered animals and plants.

New regulations, which don't require the approval of Congress, would reduce the mandatory, independent reviews government scientists have been performing for 35 years, according to a draft first obtained by The Associated Press.

Interior Secretary Dirk Kempthorne said late Monday the changes were needed to ensure that the Endangered Species Act would not be used as a "back door" to regulate the gases blamed for global warming.

In May, the polar bear became

*The Seattle Times*, Tuesday August 12, 2008

Meanwhile, we applaud our colleagues in chemical ecology who have discovered many new compounds that may serve to benefit human survival.

**alkaloids** **amino acids** **fatty acid derivatives**

**proteins** **shikimic acid derivatives** **terpenes** **and others**

This theme was developed with the collaboration of
Jim Tumlinson, Steve Seybold, Julie Tillman, & Andrew Graves.