Programme

27th Meeting of the International Society of Chemical Ecology

July 24 – 28, 2011

On the Burnaby Campus of Simon Fraser University

General Index

Conference Overview

Day	Symposia & Activities
Sunday July 24	Public Events, Opening Ceremony & BBQ (Halpern Centre)
Monday July 25	Symposium 1 Symposium 3 Symposium 7, part I Posters/Evening social
Tuesday July 26	Symposium 4 Symposium 8 Symposium 5, parts I and II Symposium 6
Wednesday July 27	Symposium 7, part II Symposium 9, part I Symposium 5, part III Posters/Evening social
Thursday July 28	Symposium 2 Symposium 9, part II Gala Dinner (Diamond Alumni Club, DAC)

Symposia:

1. Efficient synthesis and new methods for the identification of semiochemicals and natural products (organizers: B. Torto and J. Bergmann)
2. Chemical ecology and natural products of marine organisms (organizer: K. VanAlstyne)
3. Multimodal communication (integration of olfaction, taste, vision, acoustics and mechanoreception) in arthropods (organizers: G. Gries, J. Millar)
4. Chemical ecology of microorganisms, including symbionts and pathogens of plants and animals; soil microorganisms (organizer: S. Schulz)
5. Social insects (organizers: Y. LeConte, R. Van der Meer)
6. Neural function and modulation underlying chemosensory driven behavior (organizers:B. Hansson, M. Ozaki)
7. Chemical ecology in forest ecosystems (organizers: C. Keeling, D. Huber, B. Aukema)
8. Genomics and chemical ecology (organizers: C. Keeling, D. Huber)
9. Plant natural products and chemical ecology (organizers: T. Hartmann, M. Heil)

Business Meetings:

ISCE Executive Committee Meeting: Sunday July 24, 1:00 – 4:00 PM, SSB 7172
J. Chem. Ecol. Meeting (J. Romeo): Wednesday July 27, 12:30 – 2:00 PM, SSB 7172
On-site student competition jury meeting: Thursday July 28, 3:00 – 4:00 PM, SSB 7172

Welcome to the 27th ISCE Meeting in Burnaby

It is a great pleasure and honor to welcome you to this year's meeting of the International Society of Chemical Ecology and to the Burnaby campus of Simon Fraser University. The Chemical Ecology Research Group (CERG) at SFU was founded in 1981 by several researchers and faculty members who were also contributors to the foundation (in 1965) and expansion of SFU itself. Chemical ecology at SFU is now in its second generation, and we are excited to celebrate chemical ecology with our colleagues from around the world.
Our campus is located on top of Burnaby Mountain, with Burrard Inlet and the Coast Mountains to the North/North East, Mount Baker (USA) to the South East, the Fraser Valley to the South and the City of Vancouver to the West. SFU has two other campuses: one in Surrey (South of the Fraser River) and one in Downtown Vancouver. I thank you for participating in the 27th ISCE Meeting and hope that you will enjoy your stay in Burnaby.

Erika Plettner

Conference Hostess

Acknowledgments

This conference would not have been possible without the help and dedication of Mr. Justin Ankenmann (SFU Meeting Event & Conference Services) and Mrs. Angie Zhang (webmaster). I thank Dr. Ken Haynes, ISCE Treasurer, Dr. Monika Hilker, ISCE President, Dr. Anna-Karin Borg-Karlsson, ISCE secretary, and the symposium organizers: Dr. Kathy Van Alstyne (USA), Dr. Brian Aukema (USA), Dr. Jan Bergmann (Chile), Dr. Gerhard Gries (Canada), Dr. Bill Hansson (Germany), Dr. Thomas Hartmann (Germany), Dr. Martin Heil (Mexico), Dr. Dezene Huber (Canada), Dr. Christopher Keeling (Canada), Dr. Sophie Lavieri (Canada), Dr. Yves LeConte (France), Dr. Jocelyn Millar (USA), Dr. Mamiko Ozaki (Japan), Dr. Stefan Schulz (Germany), Dr. Baldwyn Torto (Kenya) and Dr. Robert Van der Meer (USA).

Thank you also to the Student Travel Award Committee: Dr. Tetsu Ando (Japan), Dr. Manfred Ayasse (Germany), Dr. Anne-Geneviève Bagnères (France), Dr. Tom Baker (USA), Dr. Jan Bergmann (Chile), Dr. Wilhelm Boland (Germany), Dr. Stefano Colazza (Italy), Dr. Gerhard Gries (Canada), Dr. Dezene Huber (Canada), Dr. Christopher Keeling (Canada), Dr. Caroline Müller (Germany), Dr. Erika Plettner (Canada), Dr. Anke Steppuhn (Germany), Dr. Baldwyn Torto (Kenya), Dr. Nicole Van Dam (Netherlands), Dr. Robert Van der Meer (USA) and Dr. Aijun Zhang (USA).

Thank you to our on-site volunteers: Dr. Carlos Castillo, Dr. Hao Chen, Mrs. Parisa Ebrahimi, Mr. Lothario Lau, Mr. Derrick Mah, Mr. Jason Nardella, Mrs. Brinda Prasad and Dr. Yang Yu.

We thank our international volunteers: Mr. Simon Atsbaha Zebelo (Italy), Ms. Claudia Dussabat (France), Ms. Elisabeth Eilers (Germany), Mr. Ezra Schwarzberg (USA), Mr. Mohammed Shabab (Germany) and the Science in Action at SFU team.

Conference Sponsors

We thank the following organizations and individuals for their sponsorship of the 27th ISCE Meeting:

Gold

- ChemTica International
- Gesellschaft Deutscher Chemiker (Student Travel Awards)
- Suterra LLC (Silver Medal)

Silver

- SFU (VP Academic's Conference Fund)
- Springer (Silverstein-Simeone Awards)
- Syntech
- Trécé (Student Travel Awards)

Bronze

- BASF
- Science in Action

In-kind contributions

Dr. Wilhelm Boland (Max-Planck Institute of Chemical Ecology, Jena)
Dr. Wittko Francke (Professor emeritus, Hamburg)
Dr. Gerhard Gries (SFU)
Dr. Erika Plettner (SFU)

ISCE Award Winners

Prof. Coby Schal. Award Lecture: Monday July 25, 9:20–10:00, Images T.

Professor Schal works at North Carolina State University in Raleigh, NC. His interests range from urban entomology to insect physiology and chemical ecology. He obtained his B.Sc. at the State University of New York at Albany in Biology in 1976 and his Ph.D. at the University of Kansas, Lawrence, in Entomology, in 1983. After a two year postdoctoral training at the University of Massachusetts, Amherst, in Entomology (with Ring Cardé), he became first (in 1984) Assistant Professor of Entomology and later (in 1988) Associate Professor at Rutgers University, NJ. In 1993, he was appointed Blanton J. Whitmire Distinguished Professor of Structural Pest Management at North Carolina State University.

Prof. Ken Raffa. Award Lecture: Wednesday July 27, 9:20-10:00, Images T.

Professor Raffa works at the Department of Entomology, at the University of Wisconsin in Madison. His interests range from forest entomology and plant-insect interactions to insect chemical ecology. He obtained his B. Sc. at St. Joseph's College in 1972, followed by his M. Sc. in Entomology at the University of Delaware in 1976 and his Ph. D. Washington State University in 1981. He worked at the US Forest service 1973-1974 and at E.I. DuPont de Nemours & Co., Biochemicals Dept. 1981-1985. In 1985 he joined the faculty at the University of Wisconsin.

Prof. Paul Feeny. Award Lecture: Thursday July 28, 12:00-12:40, Images T.

Paul Feeny is Professor Emeritus of the Department of Ecology and Evolutionary Biology and Department of Entomology at Cornell University, NY. His research interests include insect – plant interactions, chemical ecology, plant defense mechanisms and evolution. He obtained his B.Sc. in Chemistry, his B.A. in Zoology and his D.Phil. (= Ph.D.) from Oxford University in the UK. After his D.Phil. studies, he started as Assistant Professor of Entomology at Cornell University, NY. In 1972, he continued his professor career first as Associate Professor (1972) at Cornell University where he was appointed Professor in 1978.

Chemical Ecologists Honored and Remembered

Prof. Wittko Francke. Symposium 1 (July 25 in Images Theatre and Keynote lecture by Prof. Robert Britton July 28 in Images Theatre)

Prof. Ken Raffa. Symposium 7 (July 25, part I in Blusson Hall 10011 and July 27, part II in SWH10081)

Prof. Thomas Eisner (1929-2011). Remembrance Lecture by Prof. Hummel (July 28 at 2:20 in SWH10081)

Thomas Eisner was born on June 25, 1929, in Berlin, Germany. His family moved to Spain and later to Uruguay. In 1947 the family moved to the USA. He obtained his B. Sc. and Ph. D. at Harvard. In 1957 he joined the faculty in entomology at Cornell, where he worked until recently. He passed away March 25, 2011. Professor Hummel will give an overview of Dr. Eisner's many contributions to the field of chemical ecology.

July 24 (Sunday)

12:00 (noon) – 18:00 Registration

13:00-16:00 Executive Committee meeting in room SSB 7172

13:00 – 16:00 Public events: Chemical Ecology and Climate Change
16:30 – 18:00 Opening ceremony with a public lecture by Dr. Jeremy McNeil (17:00-18:00) The public lecture will be open (and free) to members of the public.

19:00 – 21:00 Welcome cocktail / BBQ

July 25 (Monday)

Time	**Activities**		
8:15 – 9:00	***Breakfast*** (outside of Images Theatre)		
9:00	Opening (Images Theatre)		
9:20 – 10:00	Silverstein-Simeone Lecture No. 1 Coby Schal (Images)		
10:00 – 10:30	***Coffee Break***		
	Images Theatre	**Saywell Hall Theatre SWH 10081**	**Blusson Hall room 10011**
10:40 – 11:20	**Symposium 1** inv. T. Hooper	**Symposium 3** inv. T. Baker	**Symposium 7 part I** (no pres)
11:20 – 11:40	B. Kang	J. Millar	M. Hilker
11:40 – 12:00	A. Tetsu	E. Rowland	B. Brodie
12:00 – 12:20	Y. Yu	E. Eilers	A. M. Ray
12:30 – 2:00	***Lunch at the DAC***		
2:00 – 2:40	Conference keynote lecture (symp 3) Bert Hölldobler (Images)		
2:40 – 3:20	Conference keynote lecture (symp 3) Stefan Schulz (Images)		
3:20 – 3:40	***Coffee break***		
3:40 – 4:00	A. Khrimian	S. Vibert	R. M. Borges
4:00 – 4:20	P. Zarbin	K. Ablard	A. Najar
4:20 – 4:40	D. Wakarchuk	G. Gries	C. Schiebe
4:40 – 5:00	T. Turlings	C. Oehlschlager	
5:00 – 5:20		S. McCann	
5:20 – 7:00	***Dinner break***		
7:00 – 10: 00	Posters and evening social (7:00-8:30: poster judging of student & PDF submissions for symposia 1, 3, 4 and 8)		

July 26 (Tuesday)

Time	Activities		
8:00 – 8:30	***Breakfast*** (outside of Images Theatre)		
8:30	Opening/Announcements (Images Theatre)		
8:40 – 9:20	Conference keynote lecture (symp 8 & 5) Christina Grozinger (Images)		
9:20 – 10:00	Conference keynote lecture (symp 4) Jon Clardy (Images)		
10:00 – 10:30	***Coffee Break***		
	Images Theatre	**Saywell Hall Theatre SWH 10081**	**Bluson Hall 10011**
10:40 – 11:20	Conference keynote lecture (symp. 4) Rensen Zeng (Images)		
	Symposium 4	**Symposium 8**	**Symposium 5**
11:20 – 11:40	H. Alborn	R. Mitchell	D. Orona-Tamayo
11:40 – 12:00	B. Prasad	K. Wanner	M. Greene
12:00 – 12:20	H. Fadamiro	J. Gress	C. Dussaubat
12:30 – 2:00	***Lunch at the DAC***		
2:00 – 2:20	F. Verheggen	P. C. Constabel	C. Castillo
2:20 – 2:40	I. Khallaf	S. Christensen	T. Schmit
2:40 – 3:00	N. Woodbury	R. Bodeman	J. Anderson
3:00 – 3:20	M. Heil	C. I. Keeling	
3:20 – 3:40	***Coffee break***		
3:40 – 4:20	Conference keynote lecture (symp 6) Dr. Ryohei Kanzaki (Images)		
4:20 – 5:00	**Symposium 6** invited lecture: M. Knaden	**Symposium 5** invited lecture: R. Crewe	
5:00 – 5:20	K. Hillier	M. Ozaki	quiet room
5:20 – 5:40	*Coffee break*		
5:40 – 6:00	J. Chin	**Symposium 5** inv. (Ayasse)	quiet room
6:00 – 6:20	A. Saveer		quiet room
6:20 – 6:40	A. Reinecke	R. Kather	quiet room
	evening off		

Foyer (all day): posters

July 27 (Wednesday)

Time	**Activities**		
800 – 8:30	***Breakfast*** (outside of Images Theatre)		
8:30	Opening/Announcements (Images Theatre)		
8:40 – 9:20	Conference keynote lecture (symp. 9 & 7) Jonathan Gershenzon (Images)		
9:20 – 10:00	Silverstein-Simeone Lecture 2: Ken Raffa (Images)		
10: 00 – 10:30	***Coffee Break***		
	Images Theatre	**Saywell Hall Theatre SWH 10081**	**Halpern Centre 126**
10:40 – 11:20	**Symposium 9** inv. D. Ober	**Symposium 7** inv. N. Erbilgin	**Symposium 5** (no pres.)
11:20 – 11:40	A. Weinhold	D. Pureswaran	P. Lhomme
11:40 – 12:00	P. Girón-Calva	F. Schlyter	H. Fadamiro
12:00 – 12:20	C. Orians	B. Aukema	D. Durieux
12:30 – 2:00	***Lunch at the DAC & J. Chem. Ecol. Meeting (SSB7172)***		
2:00 – 2:40	Conference keynote lecture (symp 9 & 4) Soledade Pedras (Images)		
2:40 – 3:00	E. Schwartzberg	C. Tittiger	quiet room
3:00 – 3:20	L. Jeffares	R. D. Figueroa-Teran	quiet room
3:20 – 3:40	H. E. Hummel (res.)	I. Lusebrink	quiet room
afternoon	***Time off***		
7:00 – 10:00	Posters and evening social (7:00-8:30: poster judging of student & PDF submissions for symposia 2, 5, 6, 7 and 9)		

Foyer (all day): posters

July 28 (Thursday)

Time	Activities		
8:00 – 8:30	***Breakfast*** (outside of Images Theatre)		
8:30	Opening/Announcements (Images Theatre)		
	Images Theatre		**Saywell Hall Theatre**
	Symposium 2		**Symposium 9, part II**
8:40 – 9:00			E. Yaya
9:00 – 9:20	G. Caulier		A. Najar
9:20 – 9:40	U. Röse		A. Strauss
9:40 – 10:00	J. Kubanek		M. Shabab
10:00 – 10:30	***Coffee break***		
10:40 – 11:20	Conference keynote lecture (symp 2) Gabi Nevitt		
11:20 – 12:00	Conference keynote lecture (symp 1 & 2) Rob Britton		
12:00 – 12:40	Silver Medal Lecture: Paul Feeny (Images)		
12:40-2:20	***Lunch at the DAC***		
2:20 – 2:40	K. Van Alstyne		H.E. Hummel (T. Eisner remembrance)
2:40 – 3:00	C. Amsler		R. Ferrieri
3:00 – 3:20	D. L. Smee	Jury meeting SSB 7172	A. Burse
3:20 – 3:40			
3:40 – 4:00	***Coffee break***		
4:00 – 5:30	(Images) Annual General Meeting (at 4:00 PM winners of travel awards and the poster/oral competition will be announced)		
7:00	***Gala dinner at the Diamond Alumni Club***		

Poster presenters: please remove your posters before 5:00 PM.
3:00 – 4:00 Student poster & oral comp. jury meeting

Keynote and Award Lectures

Opening Public Lecture:
Eavesdropping on Mother Nature: How Chemical Ecology Provides Alternatives to Synthetic Insecticides

Jeremy McNeil
University of Western Ontario, Department of Biology, 3066 B and G Building, London ON, N6A 5B7, Canada. e-mai: jmcneil2@uwo.ca

The over-reliance on synthetic pesticides to control insects, diseases and weeds has a number of undesirable side effects and so it is essential that we develop more ecologically, socially and economically acceptable management programs to control pests. Research in chemical ecology examines how naturally occurring chemicals may be used to modulate interactions within and between species. In my presentation I will give examples of how understanding the basic nature of such ecological interactions has provided effective alternatives to synthetic pesticides.

Silverstein-Simenone Award Lecture 1:

Chemoreception in the German cockroach: A potpourri of novel semiochemistry, behavior and adaptive evolution

Schal, Coby; Wada-Katsumata, Ayako
Department of Entomology and W.M. Keck Center for Behavioral Biology, North Carolina State University, Raleigh, NC 27695, USA, coby@ncsu.edu.

This presentation will cover three aspects of chemoreception in the German cockroach. The first is a volatile sex pheromone emitted by the female cockroach and detected by the male's olfactory system. The coupled GC-EAD was used in combination with a highly efficient preparative GC technique to obtain small amounts of pure sample for NMR analysis. The second involves a multi-component female contact sex pheromone that elicits courtship behavior in males and has served as an excellent model for unravelling the biosynthetic pathways and endocrine regulation of these contact pheromones. Finally, we investigated a strain of this cockroach that is behaviorally deterred from eating glucose. We first showed that the paraglossae alone were sufficient for maximum sensitivity to both phagostimulants and deterrents, including glucose as a deterrent in the glucose-averse strain. Single-sensillum electrophysiological results indicate that in the glucose-averse cockroach, glucose and bitter compounds elicit similar sensory neuronal responses. Our results suggest that changes in ligand-receptor interactions at the gustatory neurons — likely mis-expression of glucose receptors on bitter neurons — are responsible for the glucose-averse trait.

Keynote Lecture, Symposium 3:

Multimodal Signals in Ant Communication

Bert Hölldobler
Arizona State University, Tempe, and University of Würzburg, Germany

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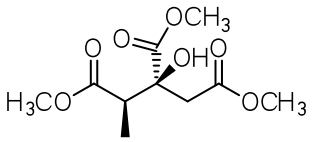
It is well known, and studied in several vertebrate groups, that communication can work through several sensory channels; that is, a signal can be composed of distinct physical components, transmitted simultaneously or in tightly paced sequence. Such cross-modal perception of composite signals has been investigated particularly well in humans and non-human primates and in birds, and, in fact, already was recognized by Darwin in his book "The expressions of the emotions in man and animals" (1872) where he noted that the power of communication by language is much enhanced by "the expressive movements of the face and body." We have learned that communication in social insects and particularly in ants is mainly based on multi-component chemical signals. Such signals can be further combined with signals from other sensory modalities, such as vibrational or tactile stimuli. These kinds of accessory signals usually serve in modulatory communication, lowering the response threshold in the recipient for the actual releasing stimulus, or they may serve as referential signals. Comparative studies suggest that such signals may have evolved through ritualization from actions originally not directly related to the same behavioral context.

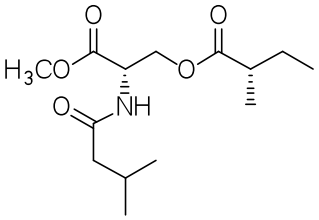
Keynote Lecture, Symposium 3:

Pheromones of Spiders

Schulz, Stefan
Technische Universität Braunschweig, Institute of Organic Chemistry, Hagenring 30, 38106 Braunschweig, Germany, stefan.schulz@tu-bs.de

In the presentation an overview of the chemistry of spider pheromones will be given. Compared to insects, not many spider pheromones have been identified. This might be related to their lower economic importance, but may also be due to practical difficulties in rearing and bioassay design as well as in electrophysiology. Many of the identified pheromones are unique to spiders and are not found as pheromonal components of other taxa. Especially noteworthy is the use of citric acid derivatives in *Cupiennius salei* and *Argiope bruennichi* as well as an amino acid related pheromone in *Latrodectus hasselti*. The identification and biological function of the pheromones in various species will be discussed.





Keynote Lecture, Symposium 8 (cross ref. to Symp. 5):

Genomics of pheromone communication in honey bees.

Grozinger, Christina M.
Department of Entomology, Center for Pollinator Research, Penn State University
University Park, PA 16803 cmgrozinger@psu.edu

Chemical communication is critical for regulating behavior and colony organization in social insects. Pheromone production and response are highly variable, and can be altered by physiological state, behavioral state, or the environmental context. How modulation of pheromone signaling is orchestrated at the molecular level and the role it plays in regulating individual behavior and colony organization remain largely uncharacterized. To address these questions, we are studying the pheromones that regulate queen-worker and worker-worker interactions in honey bees. Queen pheromone production is strongly linked to the reproductive state of the queen, and has consequences on worker-queen interactions, worker physiology, and queen longevity. Worker responses to queen pheromone are also highly variable, and are associated with worker physiology, reproductive potential, and brain gene expression patterns. Additionally, the chemical signals that mediate worker-worker interactions can be modulated by social context and physiological state, and may play a role in disease transmission. We are now extending these studies to other social insect species, to begin to elucidate the molecular mechanisms underlying the evolution of pheromonal regulation of social behavior.

Keynote Lecture, Symposium 4:

Bacterial Conversations

Clardy, Jon;[1] Seyedsayamdost, Mo;[1] Case, Rebecca;[2] Traxler, Matt;[2] Kolter, R.[2]
[1]Harvard Medical School, Department of Biological Chemistry and Molecular Pharmacology, Boston, MA 02115 [2]Harvard Medical School, Department of Microbiology and Molecular Genetics, Boston, MA 02115.
Email: jon_clardy@hms.harvard.edu

This talk will deal with some of the ways that bacteria sense and respond to their changing environment with small molecules. Two cases will be examined carefully. The first deals with a relatively simple exchange between two actinomycetes – *Amycolatopsis sp.* AA4, a 'rare' actinomycete with multiple drug resistance genes; and *Streptomyces coelicolor*, the model organism for a highly productive group of bacteria. The interaction between the two is mediated by amychelin, which dramatically influences *S. coelicolor's* development. The second case will be a more complicated exchange between members of the Roseobacter clade, a large group of metabolically versatile and ecologically important Alphaproteobacteria found in a variety of marine environments, and the microphytoplankton with which they have an intermittent symbiosis.

Keynote Lecture, Symposium 4:

Allelochemical-mediated interactions between plants and mycorrhizal Fungi

Zeng, Rensen [1,2]*; Song, Yuanyuan [1,2]; Ye, Mao [1,2]; Wang Ruilong [1,2]
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Mycorrhizas are ubiquitous plant-fungus symbiosis in terrestrial ecosystems. We demonstrated that mycorrhizas enhanced host plant defense against both soil-borne fungal pathogen of corn as well as foliar pathogen of tomato. Pre-inoculation with arbuscular mycorrhizal fungi (AMF) reduced disease incidence and disease severity of corn sheath blight caused by *Rhizoctonia solani* and of tomato early blight caused by *Alternaria solani.* AMF inoculation led to significant increase in allelochemical accumulation and transcripts of defense-related genes in the leaves of corn. Mycorrhizal colonization led to increases in activities of the putative defensive enzymes, as well as in transcripts of six defence-related genes in both leaves and roots of tomato, suggesting that mycorrhizal infection induces systemic defense responses. Common mycorrhizal networks (CMNs) mediated plant-plant underground communication between healthy plants and pathogen-infected tomato plants. We also demonstrated that the root exudates of eight species of Brassicaceae strongly stimulated the hyphal growth of several ectomycorrhizal fungi. Our study indicates that allelochemicals mediate interactions between plants and mycorrhizal fungi that are beneficial to both partners.

Keynote Lecture, Symposium 6:

Insect-robot hybrid system for understanding the neural basis of odor-source localization

Kanzaki Ryohei
Research Center for Advanced Science and Technology, The University of Tokyo
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Insects display a surprising diversity of sophisticated behaviors adapted to the environments they populate, generate by information processing in relatively simple nervous systems. Once released from their source, odor molecules float through the air in complex spatial and temporal patterns. Even under such adverse conditions, insects can trace and orient toward the pheromone of a mating partner. In order to understand the neural bases of adaptive behavior, we employ a strategy that tackles the question a multiple levels, from genes, single cells of the neural system to the actual behavior. To examine the neural basis of the behavior, we implemented a model of the neural circuit, and integrated it with a mobile robot. Moreover, in order to understand the dynamics of the neural circuitry, we have developed an "insect-robot hybrid system" in which the insect or an isolated insect brain controls a robot. By comparison between the hybrid system and the model of the neural circuit of the insect, we can continuously improve the insect-brain model until we obtain a full emulation and complete understanding of the mechanisms of adaptability in the insect brain.

Keynote Lecture, Symposium 9 (cross ref. to Symp. 7):

Exploring new roles for volatile terpenes emitted from plants

Gershenzon, Jonathan;[1] Assefa Fantaye, Chalie;[1] Degenhardt, Jörg;[2] Fontana, Anna;[1] Huang, Mengsu;[1,3] Kigathi, Rose;[1,4] Tholl, Dorothea;[3] Unsicker, Sybille;[1] Weisser, Wolfgang;[4]
[1]Max Planck Institute of Chemical Ecology, Jena, Germany, gershenzon@ice.mpg.de; [2]Martin Luther University, Institute of Pharmacy, Halle, Germany; [3]Virginia Tech, Dept of Biological Sciences, Blacksburg, VA, USA; [4]Friedrich-Schiller University, Institute of Ecology, Jena, Germany

For chemical ecologists, interest in plant volatiles has been anything but volatile. Over the last two decades, there has been a steady increase in published research on this subject, with a focus on the induction of volatiles by herbivores and their possible roles in plant defense. However, herbivore-induced volatiles have also been implicated in other functions, about which much less is known.
To investigate a broad range of functions of volatile terpenes, the largest group of plant volatiles, we have employed genes encoding terpene biosynthetic enzymes to create transgenic lines of Arabidopsis and maize with altered volatile composition. Experiments with these transformants have explored several less-studied roles of volatile terpenes. For example, these compounds appear to function in direct defense not only against herbivores, but also against microbial pathogens. Volatile terpenes also act as internal signals priming the induction of non-volatile anti-herbivore defenses, as well as having the potential to protect plants against oxidative stresses. Finally, the interactions of a plant with its neighbors can dramatically alter volatile emission profiles.

Silverstein-Simenone Award Lecture 2:

Terpenes Tell Different Tales at Different Scales: The Chemical Ecology Of Conifer - Bark Beetle -Microbial Interactions

Raffa, Kenneth
University of Wisconsin-Madison, Department of Entomology, Madison, Wisconsin, USA raffa@entomology.wisc.edu

Terpenes pose formidable barriers to host colonization by tree - killing bark beetles. Mechanisms by which these highly inducible compounds repel attack, kill adults and brood, and inhibit symbiotic fungi are well documented. Yet the extent to which tree defenses affect beetle population dynamics, particularly the transition from low-densities to landscape-scale outbreaks, is poorly understood. We propose that this understanding can be improved by placing particular emphasis on cross-scale interactions and thresholds that separate negative from positive feedbacks. This talk, in honor of chemical ecology pioneers Milt Silverstein and John Simeone, describes recent work at three scales of this interface: a) Interactions among conifer terpenes, bacteria associated with bark beetles, and symbiotic fungi; b) Factors affecting whether various negative or positive feedback predominate in the field; c) Comparison of defense chemistry between coevolved hosts and naïve hosts that are becoming accessible due to changing climate. We highlight examples of direct interactions at each scale. We also illustrate how signatures of important drivers can be confounded once critical thresholds are surpassed, and likewise how not all lower-scale processes exert effects at higher scales. Together, these relationships highlight the need to integrate pattern and process in understanding the roles of chemical signals in complex environments.

Keynote Lecture, Symposium 9 (cross ref. to Symp. 4)

The "arms race" between crucifers and their fungal pathogens: Learning to inhibit pathogen invasion from Nature

Pedras, M. Soledade C.
University of Saskatchewan, Department of Chemistry, 110 Science Place, Saskatoon, SK, s.pedras@usask.ca.

The "arms race" between plants and their microbial invaders has led to historical famines and continues to be a critical agricultural issue. Although fungicides and pesticides are used to prevent crop losses, these agricultural practices are not sustainable and must be changed. To devise sustainable methods to prevent and deter cruciferous pathogens, their molecular interaction with crucifers, both cultivated and wild species, is under intense investigation. Cruciferous plants (e.g. canola, mustard, cauliflower, broccoli, turnip) produce complex blends of secondary metabolites with diverse ecological roles, which include self-protection against microbial pathogens, pests and other sorts of stress, whereas their fungal pathogens produce phytotoxic metabolites and macromolecules that facilitate plant invasion. Although many of the natural products involved in crucifer defense reactions are detoxified by fungal pathogens, these fungal detoxifications can be stopped. That is, inhibitors (**paldoxins**) of these transformations could protect plants by boosting their natural chemical defenses and prevent pathogen growth. The fundamental aspects and challenges of this strategy to treat plant fungal diseases will be presented.

Keynote Lecture, symposium 2:

The road less traveled: Investigations into avian chemical ecology using tube-nosed seabirds as a model system.

Nevitt, Gabrielle A. and Prada, Paola.
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The sense of smell in birds has been enigmatic, in part due to our limited understanding of the naturally-occurring compounds birds detect and produce, as well as a paucity of behavioral research in this area in natural contexts. Our laboratory has studied this problem using procellariiform seabirds as a model group. These birds have unusually large olfactory bulbs, and we and collaborators have shown that olfaction is critical to a range of behaviors, including foraging, individual recognition and homing. This presentation will provide a brief overview of our work, and will emphasize recent investigations into the genetic and chemical basis for individual odor recognition in a common burrow nesting species, the Leach's storm-petrel (*Oceanodroma leucorhoa).*

Keynote Lecture, Symposium 1:

Chlorohydrins: Versatile Intermediates for the Asymmetric Synthesis of Natural Products

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The formation of 1,2-*anti*-chlorohydrins via the addition of Gignard reagents to α-chloroaldehydes was first reported in 1959. That very little has been done to exploit this reaction since this time may largely be attributed to the perceived instability of chlorohydrins, their preparation as diastereomeric mixtures (d.r. ≤ 4:1), and lack of practical methods to access these compounds in optically pure form. Recently, we re-investigated the addition of organometallic reagents to optically active α-chloroaldehydes (generated via organocatalytic asymmetric α-chlorination) and found excellent diastereomeric ratios (d.r. >20:1) could be obtained through use of organolithium reagents. These findings now enable rapid access to variously functionalized and enantiomerically enriched heterocycles, including: epoxides, tetrahydrofurans, pyrrolidines, pipiridines, and spiroacetals. A survey of these methods as well recent examples of their application to the rapid synthesis of heterocyclic natural products and insect sex pheromones will be presented.

Silver Medal Lecture:

Fifty years of exploration and adventure as a chemical ecologist

Feeny, Paul
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At a time when the boundaries between academic disciplines in England were quite rigid, I was particularly fortunate to have the opportunity to combine my interests in chemistry and natural history. My first project, as a final-year chemistry student in 1960/61, was to build a gas chromatograph and use it to try (unsuccessfully) to identify volatile "sex attractants" and supposedly defensive odors from various moths. For my doctoral work in the Department of Zoology at Oxford University, I switched to studying the effects of seasonal changes in the chemistry of oak leaves on the ecology of associated herbivorous insects. I moved to Cornell University in 1967 and chemical interactions between plants and insects have remained my primary interest ever since. Here I plan to outline briefly the main themes of my research and to discuss some of the projects that I have found most rewarding.

ORAL PRESENTATIONS
MONDAY 25 JULY
SYMPOSIUM 1
Images Theatre

Time	Activity
8:15 – 9:00	***Breakfast*** (outside of Images Theatre)
9:00	Opening (Images Theatre)
9:20 – 10:00	Silverstein-Simeone Lecture No. 1 Coby Schal (Images)
10:00 - 10:30	***Coffee Break***
10:40 – 11:20	**Symposium 1** **inv. T. Hooper**
11:20 – 11:40	**B. Kang**
11:40 – 12:00	**A. Tetsu**
12:00 – 12:20	**Y. Yu**
12:30 – 2:00	***Lunch break***
2:00 – 2:40	Conference keynote lecture (symp 3) Bert Hölldobler (Images)
2:40 – 3:20	Conference keynote lecture (symp 3) Stefan Schulz (Images)
3:20 – 3:40	***Coffee break***
3:40 – 4:00	**A. Khrimian**
4:00 – 4:20	**P. Zarbin**
4:20 – 4:40	**D. Wakarchuk**
4:40 – 5:00	**T. Turlings**
5:00 – 5:20	
5:20 – 7:00	***Dinner break***
7:00 – 10: 00	Posters and evening social (7:00-8:30: poster judging of student & PDF submissions for symposia 1, 3, 4 and 8)

Will Allelopathy Drive Chemists Underground? *C*-Glycosylflavonoid Chemistry in Plants.

Hamilton, Mary;[1] Kuate, Serge;[2] Brazier-Hicks, Melissa;[3] Lis, Karolina;[4] Torto, Baldwyn;[2] Edwards, Rob;[3] Pickett, John;[1] Timko, Mike;[4] Hooper Tony.[1]

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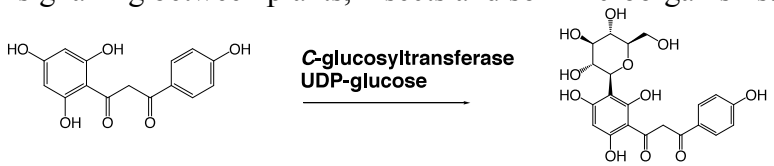
In East Africa, the parasitic weed *Striga hermonothica* can devastate maize yields but intercropping with the legume *Desmodium uncinatum* protects the cereal from parasitism by an allelopathic mechanism. A compound involved is the di-*C*-glycosylflavone isoschaftoside, a member of the *C*-glycosylflavonoid (CGF) class of natural products which have roles beyond this example in signalling between plants, insects and soil microorganisms.



We have studied CGF chemical synthesis and its biosynthesis in *D. uncinatum* (figure). Purification of *C*-glycosyltransferases and the associated genes responsible for CGF biosynthesis in this plant, and from rice, allows introduction of the pathway into other suitable crop plants such as cowpea. We can also generate a range of novel CGFs using synthetic substrates and recombinant enzymes to test products for other biological activities.

A Non-Racemic Synthetic Route to *trans*-Epoxides: A Concise Synthesis of *trans*-Epoxide Containing Insect Sex Pheromones

Kang, Bal;[1] Britton, Robert[1]

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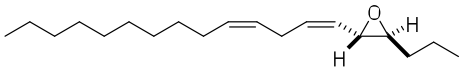
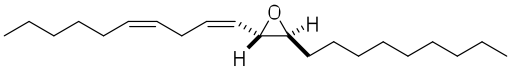
Throughout Europe, the pine looper moth *Bupalus pinarius* has become a serious threat to the Scots Pine forests, the most widespread conifers in the world. Currently there are no effective means to monitor the *B. pinarius* populations resulting in extensive defoliation which incurs great economic losses to the forest industry. Recently, *trans*-epoxide **(A)** has been identified as an attractant pheromone for *B. pinarius* and we have developed a high yielding and concise synthesis for this substance. Our synthetic approach to the pheromone exploits advances in organocatalysis and represents a general and concise route to non-racemic *trans*-epoxides. This aforementioned methodology has also been applied to the concise synthesis of the sex pheromone **B** isolated from the tussock moth *Orgyia postica*, which is a concern for litchi and mango production in Asia and the only other *trans*-epoxide containing insect pheromone.



A: (6Z,9Z,4S,5S)-4,5-epoxynonadeca-6,9-diene



Characterization of Epoxytrienes Derived from (3*Z*,6*Z*,9*Z*)-1,3,6,9-Tetraenes, Sex Pheromone Components of Arctiid Moths and Related Compounds

Ando, Tetsu; Yamakawa, Rei; Takubo Yoshiko
Graduate School of Bio-Applications and Systems Engineering (BASE), Tokyo University of Agriculture and Technology, Koganei, Tokyo 184-8588, Japan. antetsu@cc.tuat.ac.jp

9,10-Epoxy-(3*Z*,6*Z*)-1,3,6-henicosatriene has been identified from female moths of *Hyphantria cunea*. Since diversity of lepidopteran species suggests that some species utilize the positional isomers for their mating communication, we systematically synthesize and characterized the epoxytrienes with a C_{19}–C_{21} chain. While 1,2-epoxy-3,6,9-trienes were not yielded, MCPBA oxidation of (3*Z*,6*Z*,9*Z*)-1,3,6,9-tetraenes produced mixtures of three epoxides, 3,4-epoxy-1,6,9-trienes (**1**), 6,7-epoxy-1,3,9-trienes (**2**), and 9,10-epoxy-1,3,6-trienes (**3**), which were separable by GC and LC. Detailed inspection of their mass spectra indicated the following diagnostic ions for determining the chemical structures; *m/z* 128, 167, M-87, and M-85 for **1**, *m/z* 111, M-125, and M-69 for **2**, and *m/z* M-125 and M-139 for **3**. Resolution of two enantiomeres of each epoxytriene was achieved by HPLC equipped with a chiral column. The elution order of the enantiomers was the same as that of the corresponding epoxydiene derived from a (3*Z*,6*Z*,9*Z*)-3,6,9-triene. Chiral HPLC analysis of the pheromone extracted from virgin females of *H. cunea* revealed 9*S*,10*R* configuration of the natural epoxytrine.

Synthesis and interaction studies of (+)-disparlure analogs with gypsy moth pheromone binding proteins

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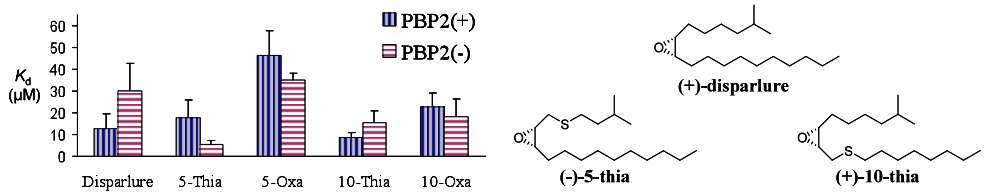
Pheromone binding proteins (PBPs) bind specifically to (+)-disparlure and activate the olfactory system, although PBPs have been shown to bind various ligands. In order to find agonists or antagonists of disparlure and to decipher the PBP-ligand interactions, we chemoenzymetically synthesized racemic and enantiopure disparlures as well as 5- and 10- oxa or thia analogs. All analogs showed binding activity to PBPs. PBP1 showed enantioselective binding to oxa analogs whereas PBP2 bound enantioselectively to thia analogs. Several promising PBP-ligand complex crystallization conditions were found through preliminary screens, and the PBP-ligand complex crystallography study is underway.



Synthetic studies toward 7-*epi*-sesquithujene, bicyclic sesquiterpene antennally active to emerald ash borer

Khrimian, Ashot;[1] Cossé, Allard A.[2]
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Emerald ash borer, *Agrilus planipennis*, is an invasive beetle that has been causing extensive mortality of ash trees since arriving in North America in 2002. 7-*epi*-Sesquithujene is produced by stressed ash and elicits a strong EAD response on the emerald ash borer antennae. In the course of making a synthetic 7-*epi*-sesquithujene for field studies, we found that this compound was drawn in literature incorrectly and ultimately determined its absolute configuration as 2*S*,6*S*,7*R*. We synthesized 7-*epi*-sesquithujene as well as other diastereomers from commercially available (*R*)- and (*S*)-citronellals. The synthesis was conducted in a straightforward approach, circumventing expensive chiral catalysts and reagents. Even tough it produced 7-*epi*-sesquithujene in a mixture, the three accompanying diastereomers were found inactive in GC-EAD studies. While conducting L-Selectride reduction of intermediate bicyclic ketones, we discovered an unusual stereochemistry that remarkably helped to make individual diastereomers and develop a chiral GC method for separation of all four.

Identification, synthesis and biological activity of the sex pheromone of *Edessa meditabunda* (Fabricius, 1794) (Heteroptera, Pentatomidae)

Zarbin, Paulo H. G.; Vidal, Diogo M.; Fávaro, Carla F.; Rodrigues, Mauro M. A. C.
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pzarbin@ufpr.br

Edessa meditabunda occurs in soybean crops in Brazil as a secondary pest. The behavioral responses of males and females to conspecifics aeration extracts suggested the presence of a male-specific sex pheromone. The extracts were analyzed by GC-EAD revealing the presence of two male-specific EAD-active compounds. Analysis of GC-MS and GC-FTIR suggested a methyl branched long chain methyl ester for both compounds. The chemical structures were proposed based on the mass spectra (EI) of the respective hydrocarbons, obtained by microderivatizations, as being methyl 4,8,12-trimethylpentadecanoate (major) and methyl 4,8,12-trimethyltetradecanoate (minor). The synthetic standards, which were undistinguishable from natural compounds, were obtained from ciclopropyl methyl ketone and were employed on Y-olfactometer assays, showing strongly attractiveness to females.

An Oxidized Monoterpene Library Used to Probe Bark Beetle Host Chemoreception

Wakarchuk, David[1] , Rattray, Peter,[2] Sullivan, Brian [3,] and Shepherd,William[4]
[1] Synergy Semiochemicals Corp., david@semiochemical.com; [2] Synergy Semiochemicals Corp., peter@semiochemical.com, [3] USDA Forest Service briansullivan@fs.fed.us; [4] USDA Forest Service williamshepherd@fs.fed.us

Monoterpenes are hydrocarbons produced by trees which play an important role in host recognition in conifer infesting bark beetles. Monoterpenes are toxic at certain concentrations, bark beetles and other organisms are capable of detoxifying monoterpenes via oxidative processes. Several known oxidized terpene semiochemicals were initially isolated from live insects via volatile trapping or dissection and extraction, both tedious processes. We developed a novel approach to facilitate discovery of new bioactive monoterpenoids. Eight of the most commonly occurring conifer monoterpenes were used as oxidation substrates to prepare a synthetic library of several hundred oxidized monoterpenes products. The library simulates an array of terpene metabolism products and was screened using coupled gas chromatography electro antenneagram detection (GC-EAD) with both the Mountain Pine Beetle (MPB) and Douglas-Fir Beetle (DFB). Most of the library compounds displayed no antennal activity. Among the group of active compounds there are those with known structures as well as novel structures. The library of compounds can be used to map the specificity of MPB and DFB terpenoid receptors. Work is underway to characterize the novel compounds.

Smelly birds: foul smelling cuckoo chicks turn brood parasitism into mutualism

Canestrari, Daniella[1]; Bolopo, Diana[1]; Turlings, Ted C. J.[2]; Röder, Gregory[2]; Marcos, José M.[1]; Baglione, Vittorio[1]
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Avian brood parasites lay eggs in the nests of interspecific hosts, typically resulting in partial or complete loss of their own brood. However, there may be exceptions, as suggested by years of observing the fate of nests of carrion crows *Corvus corone corone* with or without chicks of the great spotted cuckoo *Clamator glandarius*. These observations lead us to hypothesize that a malodorous secretion that the cuckoo chicks produce upon nest disturbance repels predators and thereby also benefits their hosts. Indeed, parasitized nests had higher chance of success (producing at least one chick) than non-parasitized nests. We confirmed this by transferring cuckoo chicks from parasitized to non-parasitized nests, which were then more successful. The foul smelling secretion that cuckoo chicks produce upon harassment seems to be the most plausible explanation for the higher nest success. We used four different volatile trapping techniques and subsequent GC-MS analyses to identify the volatile compounds emitted from the secretion and found that they were dominated by repugnant acids, indoles, phenols and several sulfur containing compounds. By producing these highly caustic and extremely repulsive compounds the cuckoo chicks seems to have turned a parasitic interaction into mutualism.

ORAL PRESENTATIONS
MONDAY 25 JULY
SYMPOSIUM 3
Saywell Hall SWH 10081

Time	Activity
8:15 – 9:00	*Breakfast* (outside of Images Theatre)
9:00	Opening (Images Theatre)
9:20 – 10:00	Silverstein-Simeone Lecture No. 1 Coby Schal (Images)
10-10:30	*Coffee Break*
10:40 – 11:20	**Symposium 3** **invited lecture: T. Baker**
11:20 – 11:40	**J. Millar**
11:40 – 12:00	**E. Rowland**
12:00 – 12:20	**E. Eilers**
12:30-2:00	*Lunch break*
2:00 – 2:40	**Conference keynote lecture (symp 3) Bert Hölldobler (Images)**
2:40 – 3:20	**Conference keynote lecture (symp 3) Stefan Schulz (Images)**
3:20 – 3:40	*Coffee break*
3:40 – 4:00	**S. Vibert**
4:00 – 4:20	**K. Ablard**
4:20 – 4:40	**G. Gries**
4:40 – 5:00	**C. Oehlschlager**
5:00 – 5:20	**S. McCann**
5:20 – 7:00	*Dinner break*
7:00 – 10: 00	Posters and evening social (7:00-8:30: poster judging of student & PDF submissions for symposia 1, 3, 4 and 8)

The Interactive Roles of Chemical and Visual Stimuli in the Mate-Finding and Mate Selection Behaviors of the Emerald Ash Borer, *Agrilus planipennis*

Baker, T.C.[1], M.J. Domingue[1], A.J. Myrick[1], and J.P. Lelito[2]
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Emerald ash borer males have been shown to visually locate their mates by flying over a female basking on an ash leaflet and rapidly descending onto her from ca. a 1-m height in what has been aptly termed a "paratrooper copulation" [1]. We used a super-continuum (white) laser to capture the reflected light scattered from these beetles' elytra and now have shown that the greenish reflections form a complex series of "strands" of colored light interspersed with bands of lower intensity emissions that will create motion across a flying male's ommatidia and induce him to locate the female and hover over her. Evidence shows that plant volatiles emitted from strong point source dispensers, not necessarily from the trap itself, can significantly increase the trap-catch of males when they are emitted from a tree in which visual-lure traps are deployed [2]. When the male lands on the female, two contact sex pheromone components extractable from the cuticle contribute to mate selection and copulatory behavior [3,4]. References: Lelito, J.P. 2009, PhD Dissertation, Penn State University; Lelito et al. 2007; J. Insect Behav. 20:537-552; Lelito et al. 2009, J. Chem. Ecol. 35:104-110; Silk et al., 2009; Naturwiss.96:601-608. We acknowledge the generous support for this work by grants from the USDA/APHIS PPQ

Interplay of Pheromonal and Acoustic Signals in Intraspecific Communication in Stink Bugs

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[2] Dept. of Entomology, National Institute of Biology, Ljubljana, Slovenia. Andrej.Cokl@nib.si;
[3] Dept. of Entomology, WSU Tree Fruit Research and Extension Center, Wenatchee WA 98801, USA. jfb@wsu.edu.

Pheromonal and substrate-borne vibrational signals were first characterized from phytophagous stink bugs more than two decades ago, but the roles and interplay of these different signal modalities were not at first fully appreciated. Over the past few years, pheromones and acoustic signals have been identified from a number of stink bug species, and bioassays have helped to elucidate the roles of these different signal types. Thus, pheromonal signals probably serve as longer range signals to attract conspecifics from a distance. Over shorter distances, i.e., on the same plant, individuals of both sexes produce vibrational signals which are transmitted through the plant stem. The sexes find each other by simply following the vibrational signals to their sources. A number of these pheromones and the corresponding acoustic signals will be described. We will also discuss some biological questions that remain unclear, such as why nymphs as well as adults are attracted, and the attraction of species to the pheromones of heterospecifics. We will also discuss recent attempts to circumvent the shorter range acoustic signals by using high release rates of pheromones.

Not just pheromone! Acoustic communication and functionality of the tympanate ear of the European gypsy moth, *Lymantria dispar dispar* (L.) (Lepidoptera: Noctuidae: Lymantriinae)

Rowland, Eloise[1]; Belton, Peter[1]; Schaefer, Paul[2]; Gries, Gerhard[1]
[1] Simon Fraser University, Department of Biological Sciences, Burnaby, British Columbia, Canada, erowland@sfu.ca; [2] Research Lepidopterist (Retired), 4 Dare Drive, Elkton, Maryland 21921, USA.

Pheromonal communication in lymantriine moths is well documented but little is known about acoustic communication in these moths. Tympanate ears of female European gypsy moth, *Lymantria dispar dispar*, are reportedly more sensitive than the ears of conspecific males to sounds below 20 kHz. We tested the hypothesis that this differential sensitivity is due to sex-specific roles of sound during sexual communication, with males sending and females receiving sound signals. Acoustic signals of *L. d. dispar* were recorded, analyzed and tested for their role in mate location or courtship behaviour. Exposure of females to playback sounds of flying conspecific, but not heterospecific (*L. fumida)*, males elicited wing raising, fluttering and walking, generating distinctive visual signals that may be used by mate-seeking males at close range. Laser interferometry revealed that the female tympanum is tuned to frequencies in the range produced by flying conspecific males. Sexual communication in *L. d. dispar* appears to proceed as follows: (1) females emit sex pheromone that attracts males; (2) males fly toward calling females; and (3) sound signals from flying males at close range induce movement in females which, in turn, provides visual signals that could orient males toward females.

Picky larvae – below ground host plant discrimination in *Melolontha melolontha* (Coleoptera: Scarabaeidae)

Eilers, Elisabeth J.[1,2]; Reinecke, Andreas[1]; Hansson, Bill S.[1]; Hilker, Monika[2]
[1] Max Planck Institute for Chemical Ecology, Department of Evolutionary Neuroethology, Hans-Knöll-Straße 8, D-07745 Jena.
[2] Freie Universität Berlin, Department of Applied Zoology / Animal Ecology, Haderslebener Str. 9, D-12163 Berlin, Germany, eeilers@ice.mpg.de

Melolontha melolontha larvae have been described as polyphagous, and CO_2 was the only identified attractant known so far. However, the larvae show clear host plant preferences, particularly for dandelion (*Taraxacum officinale*) and can even detect intraspecific differences in the plant. Larval attraction to undamaged host plants depended on plant vigor, altered by plant age, substrate type, light regime and mycorrhizal symbionts. We analyzed volatile and water-soluble substances of dandelion root exudates from plants grown under different abiotic (e.g. light regime) and biotic factors (mycorrhizal symbionts). To identify which of the substances other than CO_2 are involved in larval host plant finding, we conducted electrophysiological and behavioral analyses. We found that the larvae are able to sense carboxylic acids of which most are deterrent, and mono- and disaccharides attracting the larvae. Furthermore, mono- and sesquiterpenes present in root exudates may be important cues. The finding that both taste and olfactory cues are involved in orientation of larvae to host plant roots is supported by our ultrastructural studies of larval sensory organs, which revealed the presence of contact chemosensilla and olfactory sensilla on larval antennae and maxillary palps.

Non-redundant multi-modal signalling in the hobo spider *Tegenaria agrestis*

Samantha Vibert[1], Gerhard Gries[2]
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[2] Simon Fraser University, Department of Biological Sciences, Burnaby, British Columbia V5A 1S6, Canada, e-mail: gries@sfu.ca

Multimodal signals may be redundant or carry a different information content. In the hobo spider *Tegenaria agrestis* we tested whether the modalities involved played a separate role. In this species, males use vibratory and silk-associated chemical signals during courtship. Once a male steps onto a female web, he produces continuous vibrations and lays down silk. The female is often placed into a quiescent state prior to copulation. In our experiment males were prevented from either depositing silk, transmitting vibrations to the female, or both. We noted female aggressive behaviours, latency to quiescence, and latency to copulation. Our results show that the chemical signal associated with male silk plays an important role in quiescence induction. Furthermore, we observed a positive interaction between vibratory and chemical signals in terms of latency to copulation. We conclude that the modalities are not redundant and that the chemical signal may serve to reduce female aggressiveness.

Functions and fitness consequences of pheromone-tagging, and pre- and post-copulatory rituals of the parasitoid wasp *Ooencyrtus kuvanae* (Encyrtidae)

Ablard, Kelly[1], Sarah Fairhurst[1], Gillian Andersen[1], Kevin Simonetto[1], Bernard Crespi[1], Paul W. Schaefer[2], Gerhard Gries[1]
[1]Department of Biological Sciences, Simon Fraser University, 8888 University Drive, Burnaby, BC Canada, gries@sfu.ca; [2] United States Department of Agriculture, Agricultural Research Service, Beneficial Insects Introduction Research, Elkton, Maryland, USA.

The parasitoid wasp *Ooencyrtus kuvanae* (Hymenoptera: Encyrtidae) emerges *en masse* from gypsy moth, *Lymantria dispar*, host egg masses. Males pheromone-tag virgins for their harem prior to engaging them in a pre-copulatory ritual, mating, and a post-copulatory ritual. We investigated the functions and fitness consequences of their courtship behaviour using high-speed cinematography, gas chromatographic-mass spectrometric analyses of body washes, behavioural bioassays, and DNA microsatellite analysis. During pheromone-tagging, a specimen-specific pheromone is transferred which serves in mate recognition and assessment. During the pre-copulatory ritual, the male repeatedly strikes a female's antennae with his forelegs, which puts her into a receptive and trance-like state that persists after copulation. In-trance females may be mated by more than one male, with both males possibly siring offspring, as confirmed by paternity testing. The post-copulatory ritual functions as a form of mate guarding in that the initial male accelerates awakening of the in-trance female, which then rejects mating attempts by other males, ensuring his paternity.

Multimodal foraging cues and communication signals in Western conifer seed bugs and German cockroaches

Zahradnik, Tracy[1]; Wijenberg, Rosanna[1]; Takács, Stephen[1]; Hayden, Michael[2]; Gries, Gerhard[1]
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Resin semiochemicals are known to attract conophagous insects. We show that the Western conifer seed bug, *Leptoglossus occidentalis*, also responds to cone-derived electromagnetic wavelengths (EW) in the visual and infrared (IR) range, and that it discriminates between IR radiation from sources well within (40 °C) and just outside (60 °C) the cone temperature range. Laboratory experiments with females revealed a synergistic effect between visible light and IR radiation from a 40 °C heat source. These data support the conclusion that the central nervous system of *L. occidentalis* is capable of integrating information from two types of EW receptors, compound eyes on the head which are tuned to visual light, and IR receptors on the ventral abdomen which are tuned to IR radiation. Such integration was previously known only in snakes. German cockroaches, *Blattella germanica,* are well known to respond to airborne or contact aggregation and sex pheromones, and to sound signals. We present evidence that electrostatic pulses may be part of their complex communication system. We recorded such pulses from females and assayed the response of males to reproduced pulses. Virgin but not mated males responded with (increased) mate-seeking and courtship behaviour.

Mass Trapping as a Control Strategy for Coleopteran and Lepidopteran Pests

Oehlschlager, Cam[1], Gonzalez, Lilliana[1], Lobos, Enrique A.[2]
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Pheromone-based mass trapping is established as an economical method of management for Coleoptera such as palm weevils, banana weevils, coconut rhinoceros beetles and bark beetles. This strategy is presumed to be successful because these insects produce and respond to aggregation pheromones making it possible to remove both sexes from a crop. Pheromone-based mating disruption is usually the preferred method of used in management of Lepidopteran pests. This presentation will give examples of operational pheromone-based mass trapping of Coleoptera, a proposal that mass trapping of Lepidopteran pests should be more economical than mating disruption, and an example of mass trapping of a Lepidopteran pest of tomatos, *Tuta absoluta* M.

Magic force fields: is the Red-throated Caracara chemically defended from its stinging prey?

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The Red-throated Caracara, *Ibycter americanus* (Falconidae), is unique among Neotropical raptors in that it is a highly social cooperative breeder and a specialist predator of social wasps. It attacks social wasp nests, although these wasps are well defended with venomous stings and coordinated defences that avert most predators. It has been hypothesised that wasps are deterred from counterattacking caracaras because they might be associated with an unknown, powerful chemical repellent. We investigated this hypothesis over four seasons of study at the Nouragues station in Central French Guiana. By video recording chick provisioning behaviour at the caracara nest, we determined that wasp larvae and pupae delivered in wasp nest fragments are indeed the main food source for the chick, and that as many as seven adult birds were involved in providing it. Chemical analyses of samples taken from captured (and subsequently released) birds revealed several candidate repellents However; they failed to demonstrate marked repellence in bioassays with sympatric social wasps. Finally, using camera trapping techniques, we investigated the behaviour of caracaras while attacking social wasp nests, and discovered the birds' behavioural strategies obviate the need for chemical repellents.

ORAL PRESENTATIONS
MONDAY 25 JULY
SYMPOSIUM 7, part I
Blusson Hall, room 10011
11:20-12:20 and 3:40 – 4:40

Time	Activity
9:00	Opening (Images Theatre)
9:20-10:00	Silverstein-Simeone Lecture: C. Schal (Images)
10:00 – 10:30	*Coffee break* (AQ outside of Images)
10:40 - 11:20	Invited lectures: symposia 1 and 3
11:20 – 11:40	**M. Hilker**
11:40 – 12:00	**B. Brodie**
12:00 – 12:20	**A. M. Ray**
12:20 – 2:00	*Lunch break*
2:00 – 2:40	Keynote lecture symposium 3: B. Hölldobler (Images)
2:40 – 3:20	Keynote lecture symposium 3: S. Schulz (Images)
3:20 – 3:40	*Coffee break*
3:40 – 4:00	**R. M. Borges**
4:00 – 4:20	**A. Najar**
4:20 – 4:40	**C. Schiebe**
4:40 – 5:00	Symposia 1 and 3
5:00 – 5:20	Symposium 1
5:20 – 7:00	*Dinner break*
7:00 – 10:00	***Posters and evening social***

Dual effects of insect eggs on plants: Induction of indirect plant defense against eggs and impact on direct defense against larvae

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Insect egg deposition is known to induce indirect defense in several plant species. Here, we studied in a system consisting of Scots pine, herbivorous sawflies and eulophid egg parasitoids (a) the relevance of (non-induced) terpenoid habitat odor for parasitoid attraction and (b) whether eggs warn the plant of future larval feeding and affect direct defense against larvae. The egg parasitoid showed the strongest electrophysiological response to the only oviposition-induced pine terpenoid, i.e. (*E)-β*-farnesene. Behavioral studies revealed that the relevance of (*E)-β*-farnesene for parasitoid attraction was dependent on its ratio to other (non-induced) terpenoids present in the habitat. Studies on the question of a warning effect of eggs showed that sawfly larvae developing on pine foliage with prior eggs performed worse than larvae on egg-free foliage. Transcription of pine sesquiterpene synthases increased after egg deposition and dropped at the onset of larval feeding to a level that was slightly higher than in undamaged controls. Hence, the direction of transcriptional changes (decrease, increase) recorded at the onset of feeding depended on whether the natural sequence (1. eggs, 2. feeding: decrease) or an artificial sequence (1. no eggs, 2.feeding: increase) of plant attack was considered.

Use of olfactory cues by newly metamorphosed wood frogs (*Lithobates sylvaticus*) during emigration

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Juvenile amphibians are capable of long-distance upland movements, yet cues used for orientation during upland movements are poorly understood. We used newly metamorphosed wood frogs (*Lithobates sylvaticus*) to investigate: (1) the existence of innate (i.e., inherited) directionality, and (2) the use of chemical olfactory cues, specifically forested wetland and natal pond cues during emigration. In a circular arena experiment, animals with assumed innate directionality did not show a departure from randomness when deprived of visual and olfactory cues, suggesting that juveniles from two different landscape settings in Maine (USA) most likely rely on proximate cues for orientation. Juvenile wood frogs reared in semi-natural conditions (1500-l cattle tanks) showed a strong avoidance of forested wetland cues in two different experimental settings, although they had not been previously exposed to such cues. This finding is contrary to known habitat use by adult wood frogs during summer. Juvenile wood frogs were indifferent to the chemical signature of natal cattle tank water. Our findings suggest that management strategies for forest amphibians should consider key habitat features that influence the orientation of juveniles during emigration, as well as adult behavior.

(*R*)-Desmolactone, female-produced sex pheromone component of *Desmocerus californicus*, a longhorned beetle in the subfamily Lepturinae

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We report the identification, synthesis, and field bioassays of a female-produced sex attractant pheromone component of the cerambycid beetle *Desmocerus californicus californicus* Horn. Headspace volatiles from females contained a sex-specific compound, (*R*)- desmolactone ((5*R*)-dihydro-5-(5*Z*)-5-dodecen-1-yl-2(3H)-furanone), which elicited strong responses from the antennae of adult males in coupled gas chromatography-electroantennogram analyses. In field bioassays, significant numbers of males were collected in traps baited with this enantiomer, whereas the (*S*)-enantiomer attracted no males. This pheromone represents the first example of a new structural class of cerambycid pheromones, and is only the second pheromone identified for cerambycid species in the subfamily Lepturinae. Interestingly, it is a shorter chain analog of (5*R*)-dihydro-5-(5*Z*)-5-tetradecen-1-yl-2(3H)-furanone, the pheromone of an unrelated species, the currant stem girdler *Janus integer* (Hymenoptera: Cephidae).

Resistance traits in Norway spruce against bark beetle attacks – GC-EAD responses to oxygenated host compounds in *Ips typographus*

Christian Schiebe[1], Almuth Hammerbacher[2], Göran Birgersson[1],Johanna Witzell[6], Peter Brodelius[5], Jonathan Gershenzon[2], Bill Hansson[3], Paal Krokene[4], Fredrik Schlyter[1]
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In an attempt to find possible biomarkers for host acceptance or resistance we compared the bark chemistry of 58 trees that either were successfully attacked by *I. typographus*, resisted attacks, or remained unattacked. No pheromones were used to attract beetles to the experimental trees. Samples from each tree included a constitutive bark sample and a bark sample taken four weeks after local defence induction using methyl jasmonate (MeJ). In addition volatile samples were taken from felled trees before, during and after attack.
Principle component analysis (PCA) revealed no clear differences in the bark chemistry of constitutive samples from trees with different attack status. However, bark that had been locally induced with MeJ four weeks earlier showed clear chemical differences between successfully attacked and resistant trees. Resistant trees had significantly higher amounts of most of the 39 analyzed mono-, sesqui- and diterpenes, and of three of 19 phenolics.
Beetles showed strong responses to several oxygenated host compounds in GC-EAD analyses of volatile samples. Single cell recordings and behavioural field test are ongoing to reveal the role of oxygenated host compounds for the host choice of *I. typographus.*

Diel variation in fig volatiles across syconium development: the right scents at the right time?

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Chemical communication, using volatile organic compounds which act as long-range signals, mediates many plant–animal interaction services such as pollination. In brood-site or nursery pollination systems such as the fig–fig wasp interaction system, the modified inflorescence is the nursery for the wasp pollinators, and also hosts a community of parasitic wasps, usually specific to each fig species. Attraction of these pollinators and parasites is mediated by volatiles. However, each of these interactants has a specific diel activity rhythm, being more active during the day or at night. We expected therefore to find diel variation in volatile production patterns both in terms of volatile types and quantities depending on syconium development phase and day/night rhythms. We followed changes in volatile emission profiles of a monoecious fig *Ficus racemosa* (Moraceae) across the syconium developmental cycle through pre-pollination, pollination, and post-pollination stages, and over the diel cycle. Our results reveal diel variation that is dependent on syconium development phase, and may relate to the daily activity rhythms of important interactants such as pollinators.

Aspen's life experience being told by chemistry
How growing conditions are shaping interaction and response to defoliators

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Plant defense has a genetic and environmental component. The interactions between biotic and abiotic stresses in plants infer about strategic allocation of plant resources. We subjected aspen seedlings to different growing conditions then to the forest tent caterpillars (Malacosoma disstria) herbivory to evaluate insect fitness on the light of the feeding experience. Preliminary results showed that the caterpillar consistently fed on aspen seedlings with high carbohydrate and nutrient contents whereas aspens with low resources had little defoliation. Those observations were linked to leaf chemistry; both primary and secondary defensive chemistry explained some of the results observed on insects. The concentration of specific phenolic glucosides known as deterrents of browsing was assessed and turned to be a reliable indicator of plant resistance to deterrence. The results for this year experiment came to confirm our hypothesis, that plants grown in harsher conditions were better defended.
This study highlights the impact of variations in plant growing conditions, and their effects on plant physiology, chemistry and on insect herbivory. The molecular bases for this differential response are being investigated. This is the strongest induced defence ever in Boreal Aspen.

ORAL PRESENTATIONS
TUESDAY 26 JULY
SYMPOSIUM 4
Images Theatre, 11:20 – 3:20

Time	Activities
8:00 – 8:30	*Breakfast* (outside of Images Theatre)
8:30	Opening/Announcements (Images Theatre)
8:40 – 9:20	Conference keynote lecture (symp 8 & 5) Christina Grozinger (Images)
9:20 – 10:00	**Conference keynote lecture (symp 4) Jon Clardy (Images)**
10:00 – 10:30	*Coffee Break*
10:40 – 11:20	**Conference keynote lecture (symp. 4) Rensen Zeng (Images)**
	Symposium 4
11:20 – 11:40	**H. Alborn**
11:40 – 12:00	**B. Prasad**
12:00 – 12:20	**H. Fadamiro**
12:30 – 2:00	*Lunch break*
2:00 – 2:20	**F. Verheggen**
2:20 – 2:40	**I. Khallaf**
2:40 – 3:00	**N. Woodbury**
3:00 – 3:20	**M. Heil**
3:20 – 3:40	*Coffee break*
3:40 – 4:20	Conference keynote lecture (symp 6) Dr. Ryohei Kanzaki (Images)
4:20 – 7:00	Symposium 6
	evening off

Root Zone Chemical Ecology: Semiochemically Mediated Manipulations of Nematode Behavior.

Alborn, Hans[1], Kaplan Fatma[1], Ali, Jared[2], Stelinski, Lukasz[2] and Teal, Peter[1].

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Below ground semiochemically mediated interactions between plants, insects, and nematodes are poorly understood. Volatiles released by citrus root stock in response to damage by root weevils *(Diaprepes abbreviatus)* attract beneficial entomopathogenic nematodes but also attract plant parasitic nematodes, such as root knot nematodes*(Meloidogyne spp*). In addition, root knot nematodes prefer uninfected over nematode infected roots when given a choice. The bacterivorous nematode, *Caenorhabditis elegans,* uses different blends of pheromone components (called ascarosides) to initiate dauer, feeding, and sexual behaviour. Also entomopathogenic (*Steinernema feltiaei*) and root knot nematodes have non-feeding dauer like infectious juvenile stages and utilize pheromone communication to control their behavior. Pheromones and/or host (plant) attractants will trigger dauer/ infectious juveniles movement toward a perceived host and can irreversibly initiate feeding behavior, thus without food the nematodes will die. We will present our progress on isolation and identification of host produced attractants and the nematodes own pheromones and in utilizing them to monitor and manipulate the behavior of beneficial as well as plant pathogenic nematodes.

Ecological Significance of the Reduction Reaction Catalysed by Cytochrome $P450_{cam}$

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Cytochrome $P450_{cam}$ isolated from the soil bacterium *Pseudomonas putida* catalyses the hydroxylation of camphor to 5-*exo*-hydroxy camphor and further to 5-ketocamphor. Unexpectedly, we have also observed the formation of the reduction product, borneol in our enzymatic assays performed under shunt conditions using *m*-CPBA or with the complete P450 system under low O_2 conditions. To test the ecological advantages of camphor and borneol to *P. putida* and *Escherichia coli*, we have performed the toxicity assays. Based on our results, we hypothesized that borneol might be less toxic than camphor to *P. putida*, but more toxic to other bacteria that lack this P450, such as *E. coli*. Experiments with *E. coli* revealed that borneol and camphor were toxic to this species of bacterium (IC_{50} 14.3 - 20 nM and 19 - 42 nM, respectively), whereas the toxicities of camphor and borneol were very low for *P. putida*. We propose a novel reduction mechanism for cytochrome $P450_{cam}$ and discuss the ecological significance of this reaction for *P. putida* and *E. coli*. Our results suggest that the formation of borneol provides an advantage to strains of *P. putida* that can metabolise camphor and compete with other bacteria that do not metabolise camphor, such as *E. coli*.

Effects of on Plant Growth-Promoting Rhizobacteria Induction of Plant Volatiles and Consequences for Insect-Plant Interactions

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Application of plant growth-promoting rhizobacteria (PGPR) to plants is often associated with increased rates of plant growth and the induction of systemic resistance, but little is known about the effects of PGPR on insect-plant interactions mediated by volatile organic compounds (VOCs). Studies were conducted to test the hypothesis that PGPR alters cotton plant VOCs with possible consequences for plant-insect and tritrophic interactions. Three PGPR strains were tested. Strains were applied as spore preparations and headspace volatiles were collected from PGPR-treated and untreated cotton plants four weeks after planting. Results showed quantitative and qualitative differences in headspace volatiles of PGPR treated versus untreated plants. Host acceptance tests with beet armyworm, *Spodoptera exigua* (Lepidoptera: Noctuidae) showed that females prefer to lay eggs on untreated cotton compared to PGPR-treated cotton plants. Four choice olfactometer behavior experiments with *Microplitis croceipes* (a hymenopteran parasitoid of cotton bollworm) revealed that PGPR-treated plants were highly attractive to the parasitoids. These results demonstrate that PGPR alters production of VOCs in cotton, and that herbivores and parasitoids are capable of exploiting these differences in VOCs.

Microorganisms from aphid honeydew attract tending ants and natural enemies

Verheggen, François[1]; Leroy, Pascal[1]; Fischer, Christophe[2]; Sabri, Ahmed[3]; Francis, Frédéric[1]; Heuskin, Stéphanie[2]; Thonart, Philippe[3]; Felton, Gary[4]; Detrain, Claire[5]; Lognay, Georges[2]; Haubruge, Eric[1]
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Aphids are some of the most serious pests of cultivated crops worldwide, causing major yield and economic losses. Previous works have demonstrated ants and natural enemies (including ladybeetles and hoverflies) to be able to use aphid volatile chemicals to locate aphid colonies. Here, we report the first isolation of a bacterium from the pea aphid *Acyrthosiphon pisum* honeydew, *Staphylococcus sciuri*, which produces kairomones used by the aphidophagous hoverfly *Episyrphus balteatus* and the Asian Ladybeetle *Harmonia axyridis* during their search for prey colonies. Some specific semiochemicals produced by *S. sciuri* were identified as attractants and ovipositional stimulants. Similarly, we have shown scouts of the aphid tending ant species, *Lasius niger*, to orientate their foraging behaviour toward an *Aphis fabae* infested plant and we have demonstrated that the odours released by this aphid honeydew were attractive for ant scouts. Again, bacteria were involved in the production of these honeydew semiochemicals. Interestingly, ant scouts were also able to discriminate honeydew odour from *A. fabae* (usually attended by *L. niger*) and *A. pisum* (unattendedby *L. niger*). Comparison of the volatile and bacteria composition of both aphid species honeydew were attended.

Interaction of the fungal phytotoxin destruxin B and sirodesmin PL with crucifer and non-crucifer plants

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Phytotoxins are secondary metabolites produced by plant pathogens to facilitate their invasion and colonization of plant tissues. Host-selective toxins (HST) affect only host plants and non-host selective toxins (non-HST) can damage a much wider range. As a defense strategy, some plants are able to detoxify fungal phytotoxins and/or produce antimicrobial defense metabolites, e.g. phytoalexins. To better understand the interaction of pathogenic fungi with their host-plants, the metabolism of the HST destruxin B (produced by the plant pathogen *Alternaria brassicae*) in crucifers was investigated. Destruxin B was metabolized in turnip rand rutabaga roots, and leaves of salt cress, dog mustard and thale cress via hydroxydestruxin B and β-D-glucosylhydroxydestruxin B. In addition, destruxin B was found to be a strong elicitor of the phytoalexin camalexin in leaves of thale cress and in leaves of all species tested, (phytoalexins wasalexin A and B, 1-methoxyspirobrassinin, erucalexin, spirobrassinin and arvelexin). Unexpectedly, the metabolism of destruxin B into hydroxydestruxin B in non-crucifer plants (oat and wheat leaves) was also detected. Destruxin B was found to be metabolized through formation of new metabolites that were identified based on LC/MS data as dehydrodestruxin B and desmethyldestruxin B. The metabolite profiles of stressed and control plants and their quantitative differences will be presented. In addition, implications of these results on the interaction of the plant species with phytotoxin producing pathogens will be discussed.

Do firebrats deploy microbial symbionts as remote sensors of long-term habitat suitability?

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Most animals gauge the availability and suitability of resources (mates, food, habitat) from direct inspections and snapshot type probes. However, this type of information-gathering strategy is unreliable, if resource characteristics change over time. Insects such as firebrats, *Thermobia domestica*, encounter fluctuating microclimates when they seek hot and humid microhabitats. Here we report that firebrats use microbial symbionts to determine the long-term suitability of habitats. With their feces, firebrats deposit the bacterium *Enterobacter cloacae* and the fungus *Mycotypha microspora.* Like their insect host, both microbes require hot and humid environments and proliferate only in those optimal for their host. Firebrats then aggregate wherever their microbial symbionts thrive. This microbe-based "remote sensing" of habitat suitability ensures conditions are conducive to sustained food supply and offspring survival, it safeguards against potentially lethal habitats, and it designates rendezvous places for male and female firebrats that lack any form of pheromonal communication. Firebrats appear to recognize their microbial symbionts based on polysaccharides present in the bacterial glycocalyx and fungal cell-wall.

Does bacterial nitrogen fixation play a major role in the alimentation of arboreal ants?

Heil, Martin[1] , Bartram, Stefan[2] and Eilmus, Sascha[3]

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Nitrogen fixation by endosymbiotic bacteria in insects could be a major source of organic nitrogen in many ecosystems and a driving force in the evolution of specific feeding modes of insects, such as herbivorous ants. We investigated N fixation in workers and larvae of three arboreal *Pseudomyrmex* species (an obligate plant-ant, an exploiter and a free living generalist). We detected seven taxa of potentially N-fixing organisms, of which *Pantoea*, *Burkholderia* and *Serratia* were confirmed by cultivation and 16S sequencing. The presence of *nifH* in cultivated bacterial strains was confirmed with PCR, and living ants of two species gave a positive result in the acetylene reduction assay. However, no significant incorporation of gaseous ^{15}N into the ant body mass could be detected. Symbiotic bacteria stop nitrogen fixation under inadequate conditions and alternative hypotheses for the lack of an incorporation of N into the host comprise (i) the lack of adequate resorption mechanisms, (ii) low abundances of N fixing bacteria in the ants and (iii) changes in the metabolic activities of the bacteria, for example from N-fixation to N-recycling. Direct, isotope-based experiments are required to prove for a net assimilation of atmospheric nitrogen into the body mass of insects.

ORAL PRESENTATIONS
TUESDAY 26 JULY
SYMPOSIUM 8
Saywell Hall Theatre, SWH 10081, 11:20-3:20

Time	Activity
8:30	Opening (Images Theatre)
8:40-9:20	**Keynote lecture (symp. 8 & 5) C. Grozinger (Images)**
9:20-10:00	Keynote lecture (symp. 4) J. Clardy (Images)
10:00 – 10:30	*Coffee break* (AQ outside of Images)
10:40 - 11:20	Keynote lecture (symp. 4) R. Zeng (Images)
11:20 – 11:40	**R. Mitchell**
11:40 – 12:00	**K. Wanner**
12:00 – 12:20	**J. Gress**
12:20 – 2:00	*Lunch break*
2:00 – 2:20	**P. C. Constabel**
2:20 – 2:40	**S. Christensen**
2:40 – 3:00	**R. Bodeman**
3:00 – 3:20	**C. I. Keeling**
3:20 – 3:40	*Coffee break*
3:40 – 4:20	Keynote lecture (symp. 6) R. Kanzaki
4:20 – 5:00	Symposia 5 and 6 invited lectures
5:00 – 5:20	symposia 5 & 6
5:20 – 5:40	*Coffee break*
5:40 – 7:00	symposia 5 & 6

Sequencing and characterizing the olfactory receptors of *Megacyllene caryae* (Coleoptera: Cerambycidae)

Mitchell, Robert;[1] Hughes, David;[2] Luetje, Charles;[2] Millar, Jocelyn;[3] Robertson, Hugh;[1] Hanks, Lawrence[1].

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Many species of longhorned beetles (Cerambycidae) rely on volatile sex and aggregation pheromones to locate mates. The chemical structures of pheromones vary across subfamilies, but within these groups many species produce similar or identical compounds. In the subfamily Cerambycinae, the chemicals 3-hydroxyhexan-2-one and 2,3-hexanediol have been described as pheromones of over twenty different species. We are describing the pheromone receptors of the Cerambycinae to better understand the evolution of this unusual parsimony in pheromone structure. We sequenced an antennal transcriptome of the longhorned beetle *Megacyllene caryae* (Gahan), which produces in its pheromone blend the common cerambycine pheromones 2,3-hexanediol and 2-methyl-1-butanol. From these data we constructed models of 69 transcripts of putative olfactory receptors (Ors), and we characterized Ors by expressing them in vivo and measuring the response to chemicals in a voltage-clamp system. Through this method we have identified the receptor for 2-methyl-1-butanol, and we now are sequencing orthologs in other beetles that produce 2-methyl-1-butanol to trace the evolution of both receptor and pheromone in the Cerambycinae.

Evolution of Sex Pheromone Detection in *Ostrinia* Moths

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Sex pheromone communication in the Lepidoptera may contribute to speciation by acting as a barrier to mating. Several closely related moth species in the genus *Ostrinia* use varying ratios of E11- and Z11-tetradecenyl acetate as their main sex pheromone (E11- and Z11-14:OAc), including the European corn borer (ECB). The Asian corn borer (ACB) has evolved to use E12- and Z12-tetradecenyl acetate (E12- and Z12-14:OAc), a unique sex pheromone in the genus and in the Lepidoptera. Using a variety of functional genomic approaches (transcriptome analysis, BAC sequencing, tests of molecular evolution and *in vitro* function) we have identified an ACB odorant receptor (Or) that has evolved specificity to the E12 and Z12 pheromones. Using branch-specific models the nonsynonymous to synonymous nucleotide substitution ratio (ω) of the branch leading to ACB Or3 produced evidence of positive selection (ω=2.9). Expressed in *Xenopus* oocytes, ECB and ACB Or3 responded differentially to the four sex pheromones. ECB Or3 responded generally to all four pheromones while ACB Or3 has evolved a stronger response to the E12- and Z12-14:OAc pheromones. Inferences towards the evolution of sex pheromone detection in the Lepidoptera will be discussed.

Identifying Wheat Stem Sawfly Odorant Receptors

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The wheat stem sawfly, *Cephus cinctus*, is considered one of the most important insect pests of wheat in Montana and the northern Great Plains region. In recent years, infestation levels in both winter and spring wheat have approached 100% and annual economic losses in the region are estimated at about $100 million. Little or no molecular biology information is available for this important insect pest. We sequenced its antennal transcriptome using next generation 454 sequencing to identify odorant receptor genes. The antennal transcriptome was searched using published honeybee receptor sequences as tBLASTn queries and 205 odorant receptor sequences were identified of which 29 were full or near full length. Expression of these 29 candidate odorant receptor genes was analysed by qPCR to identify highly expressed and/or sex-biased receptors. In addition we have created an odorant gene receptor Hidden Markov Model based on the *Nasonia vitripennis* odorant receptors that we will use to discover and characterize the remaining odorant receptors from the *C. cinctus* genome. Candidate odorant receptor genes will be used in a "reverse chemical ecology" approach to identify attractive odors that can be used to develop lures and traps for IPM.

Testing the role of foliar condensed tannins against caterpillars with transgenic poplars

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Condensed tannins, also known as proanthocyanidins (PAs), are common constituents of woody plants. These polymeric flavanoids (flavan-3-ols) have broad protein-precipitating and antimicrobial activities, and are often believed act in anti-herbivore defense. In *Populus tremuloides* (trembling aspen), PAs can be induced by herbivory, suggesting they function in defense against pests. However, the extent to which tannins act against insects, and potential mechanisms of such effects, have rarely been tested directly. We recently generated poplar plants genetically engineered to accumulate high levels of PAs via overexpression of the PA regulator, PtMYB134. The high-tannin plants were strongly preferred in choice-tests with forest tent caterpillars (*Malacosoma disstria*), indicating that tannins do not deter these herbivores from feeding. Currently, we are working to establish if the increase in palatability are best explained by PAs acting as a feeding stimulant, or by secondary effects of the genetic manipulation such as leaf hardness, nutritional factors, or alterations in other secondary metabolites including phenolic glycosides. Furthermore, we are testing additional herbivores to determine if these effects are more broadly applicable.

The multi-tasking gene, *ZmLOX10*, regulates GLV, JA, and HIPV production for defense against insect attack.

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Plants have evolved the innate ability to thwart insect attack through the regulation of direct and indirect defense responses including those mediated by jasmonates (JA) and green leaf volatiles (GLVs), the molecular signals produced by the lipoxygenase (LOX) pathway. Knowledge about the interaction between the GLV and JA pathways in defense responses is still fragmentary, partly due to the limited number of genetic studies surveying crosstalk between these two distinct signaling cascades. Here we show that knock-out mutation in the 13-LOX isoform, *ZmLOX10*, completely eliminates GLV biosynthesis in maize. Moreover, we demonstrate that a different 13-LOX isoform, *ZmLOX8* is responsible for wound-induced JA production, and show that LOX8-mediated JA is dependent upon LOX10 derivatives. The elimination of *ZmLOX10* results in a dramatic reduction of herbivore-induced plant volatiles (HIPV), which affects the ecological behavior of parasitoid wasps as evidenced by reduced preference for mutant plants in choice assays. GLV-, JA- and HIPV-deficient *lox10* mutants also display compromised resistance to beet armyworms, providing strong genetic evidence for the central role that *ZmLOX10* plays in insect defense responses.

RNAi-a promising tool for exploration of the defense related secretome in leaf beetle larvae.

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The larvae of the mustard leaf beetle *P. cochleariae* use a defensive secretion to repel predators. Proteins in the secretion convert chemical precursors into biological active deterrents. We have analyzed the secretome by LC-MS/MS. The resulting peptides have been matched to our translated transcriptome data by using BLASTp and we could identify several cDNAs encoding putative proteins. However, very often it is impossible to conclude from sequence similarities to the *in vivo*-activity of the assigned proteins. Therefore, we have tested whether gene-silencing by RNAi is a useful tool for the screening of protein functions in the defensive secretion of *P. cochleariae*. In order to establish the technique, we used as a testRNAi-target a Cu/Zn-superoxide-dismutase that was identified in the secretion. Different amounts of double stranded RNA as well as artificial short interfering RNAs was injected in different life stages of *P. cochleariae*. The effects of the RNAi treatment were monitored on the mRNA level by qPCR and on the protein level by using 1D-PAGE in combination with bioassays. Thus, RNAi turned out to be a powerful tool in secretome analysis and can be used for the functional screening of biosynthetically relevant proteins.

Mountain pine beetle genomics

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The mountain pine beetle (MPB, *Dendroctonus ponderosae*) is devastating the pines in western North America, particularly in British Columbia, Canada. MPB has now entered new habitats and new hosts on the eastern side of the Rocky Mountains, and Canada's vast boreal forest is now at risk for widespread infestation by this beetle. To understand the interactions between the mountain pine beetle, its associated fungi, and the host pine trees, we have created extensive transcriptome and genome sequence resources for the MPB. These resources have allowed us to begin to examine the various processes of host colonization such as olfaction and pheromone biosynthesis at the molecular level. We have also obtained quantitative transcriptomic and proteomic data from specific tissues to guide the identification and functional characterization of genes such as cytochromes P450 and isoprenoid pathway genes involved in the processes of pheromone biosynthesis, and our progress to date will be described.

ORAL PRESENTATIONS
TUESDAY 26 JULY
SYMPOSIUM 5, part I
Blusson Hall 10011, 11:20 – 3:20

Time	Activities
8:00 – 8:30	*Breakfast* (outside of Images Theatre)
8:30	Opening/Announcements (Images Theatre)
8:40 – 9:20	**Conference keynote lecture (symp 8 & 5) Christina Grozinger (Images)**
9:20 – 10:00	Conference keynote lecture (symp 4) Jon Clardy (Images)
10:00 – 10:30	*Coffee Break*
10:40 – 11:20	Conference keynote lecture (symp. 4) Rensen Zeng (Images)
	Symposium 5
11:20 – 11:40	**D. Orona-Tamayo**
11:40 – 12:00	**M. Green**
12:00 – 12:20	**C. Dussaubat**
12:30 – 2:00	*Lunch break*
2:00 – 2:20	**C. Castillo**
2:20 – 2:40	**T. Schmit**
2:40 – 3:00	**R. Adams**
3:00 – 3:20	
3:20 – 3:40	*Coffee break*
3:40 – 4:20	Conference keynote lecture (symp 6) Dr. Ryohei Kanzaki (Images)

Ethanol Detoxification and Biosynthesis of the Primer Pheromone Ethyl Oleate in Honeybees

Carlos Castillo,[1] Hao Chen,[1] Alban Maisonnasse,[2] Yves Le Conte,[2] and Erika Plettner[1]
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Task allocation in honeybees changes with age, ultimately shifting from nursing to foraging activities approximately 21 days after adult emergence. The presence of old bees, in part, delays the onset of foraging in young bees by producing and releasing a primer pheromone: ethyl oleate (EO). We investigated the metabolism of EO by labelled substrates, gene expression analysis and recombinant protein activity assays. We found that EO can be more efficient biosynthesized from tri-oleyl glyceride than from the free fatty acid, while, *in-situ* imaging revealed candidate genes expressed along the oesophagus, where nectar intake and ethanol exposure take place. We identified one α/β-hydrolase gene responsible for the trans-esterification reaction by *in vitro* activity assays of the recombinant protein. We propose that the metabolism of EO in honeybees serves two functions: ethanol detoxification and pheromone production.

Tropical parabiotic ants: High interspecific tolerance and the evolution of chemical cues and signals

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Aggression between ant colonies is the norm. However, various *Crematogaster* and *Camponotus* species tolerate each other to various degrees and some of these species even live together in a shared nest (parabiosis). To understand the responsible mechanism for this unusual tolerance, we studied the interspecific nestmate recognition in two parabiotic species, *Camponotus rufifemur* and *Crematogaster modiglianii* in the rainforest of Borneo. Both species did not discriminate their partner colony from foreign colonies of the same species. The cuticular hydrocarbon profile of both ant species consists of unusual compounds with considerably higher molecular mass if compared with other *Camponotus* species. Moreover, *Crematogaster* produces high amounts of other cuticular substances. In bioassays, they significantly reduced aggressiveness of *Camponotus*. The interspecific tolerance thus seems to be facilitated by the low volatility of long-chain cuticular hydrocarbons in combination with the compounds that reduce aggression in *Camponotus*. Finally, we conclude that by evolving a shift towards long-chain cuticular hydrocarbons, the parabiotic ant species provides less recognition cues and thus permit unusual interspecific tolerance between these parabiotic species.

Ant proteases and plant protease inhibitors create a lock-key system to protect *Acacia* food bodies from exploitation

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In most mutualism, hosts provide a reward to their partners to obtain a service. Myrmecophytic *Acacia* species live in an obligate protection mutualism with ants of the *Pseudomyrmex* group[1]. We report a mechanism by which *Acacia* food bodies (FBs) appear protected from exploitation by generalist herbivores. We combined two-dimensional gel electrophoresis with nano LC-MS/MS analysis to investigate the proteome of *Acacia* FBs, studied how FBs are digested by the larvae, and used FBs extracts to evaluate their effect on gut proteases extracted from several pest insects that feed on leguminous seeds. The FB proteomes formed more than 200 discrete spots on 2D gels. Their annotation revealed storage proteins being particularly rich in essential amino acids and many Kunitz-type protease inhibitors (PIs): at least 31 in *A. hindsii* versus 14 in *A. cornigera* FBs. These PIs appear highly active, as FB extract reduced protease activity in several seed-feeding beetles. However, the ant larvae express chymotrypsin proteases, which are almost insensitive to the Kutz-type PIs and therefore capable to digest the FBs. *Acacia* FBs seem to be specifically adapted to nourish mutualist larvae, but not potential exploiters.
[1] Heil, M., Orona-Tamayo, D., *et al.* (2010) *Chemoecology* 20, 63-74.

Group size, patterns of interactions, and chemical recognition cues inform the collective organization of pavement ant (*Tetramorium caespitum*) wars.

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The pavement ant (*Tetramorium caespitum*) is a tramp species that is found in disturbed habitats and closely associates with human habitation. It is a structural pest, building its nests under building foundations and sidewalks, a common household pest in urban and suburban areas, and an agricultural pest. The species is well known for its "ant wars" in which hundreds to thousands of workers from different colonies fight in a large group over food or territorial resources. These ant wars self-organize when ants from different colonies interact; additional workers are recruited to the fight. I show here that *T. caespitum* workers discriminate nestmates and non-nestmates by detecting cues coded in the mixture of hydrocarbons and that the cue workers use to recognize non-nestmate ants is coded in the relative abundance of methyl-alkane hydrocarbons in the hydrocarbon profile. The number of ants from two colonies fighting in a group affects the proportion of ants fighting. A lower proportion of ants fight in small groups and a larger proportion of workers fight in larger groups.

Nosema spp. (microsporidia) infection alters pheromone production in workers and queens (*Apis mellifera*)

Dussaubat, Claudia;[1] Maisonnasse, Alban;[1] Alaux, Cédric;[1] Beslay, Dominique;[1] Folschweiller, Morgane;[1] McDonnell, Cynthia;[1] Cousin, Marianne;[2] Brunet, Jean-Luc;[2] Tchamitchan, Sylvie;[2] Plettner, Erika;[3] Belzunces, Luc;[2] and Le Conte, Yves.[1]

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It is well-established that parasites can modify hormone signaling of their host; however less is known about the effect of parasites on pheromone signaling in insect societies. *Nosema apis* and *Nosema ceranae*, parasites of the honey bee (*Apis mellifera*), can infect workers, drones and queens, having the potential to alter chemical communication inside the colony. Thus, we first tested in honey bee workers the effect of *Nosema* spp. on the production of ethyl oleate (EO), the only identified primer pheromone in workers. Then, we analyzed in queens the impact of *N. ceranae* on the production of mandibular pheromones. We show that in workers *Nosema* spp. significantly altered EO production. Moreover, the level of *Nosema* infection was correlated positively with the level of EO production. In queens, infection by *N. ceranae* surprisingly increased the production of mandibular pheromones. Our results suggest that *Nosema* infection in workers and queens have the potential to disturb colony homoeostasis, considering that EO is involved in the regulation of division of labor among workers and that queens play a major role in colony organization by monopolizing the reproduction and regulating the cohesion of the society via pheromones.

ORAL PRESENTATIONS
TUESDAY 26 JULY
SYMPOSIUM 5
Saywell Hall Theatre, 4:20 – 7:00

Time	Activities
3:20 – 3:40	*Coffee break*
3:40 – 4:20	Conference keynote lecture (symp 6) Dr. Ryohei Kanzaki (Images)
4:20 – 5:00	**Symposium 5** **invited lecture: R. Crewe**
5:00 – 5:20	**M. Ozaki**
5:20 – 5:40	*Coffee break*
5:40 – 6:00	**Symposium 5** **invited lecture: M. Ayasse**
6:00 – 6:20	
6:20 – 6:40	**R. Kather**
6:40 – 7:00	**J. Anderson**

ORAL PRESENTATIONS
Wednesday 27 JULY
SYMPOSIUM 5
Halpern Centre, room 126

Time	Activities
800 – 8:30	*Breakfast* (outside of Images Theatre)
8:30	Opening/Announcements (Images Theatre)
8:40 – 9:20	Conference keynote lecture (symp 7 & 9) Jonathan Gershenzon (Images)
9:20 – 10:00	Silverstein-Simeone Lecture 2: Ken Raffa (Images)
10: 00 – 10:30	***Coffee Break***
10:40 – 11:20	**Symposium 5**
	(no pres.)
11:20 – 11:40	**P. Lhomme**
11:40 – 12:00	**H. Fadamiro**
12:00 – 12:20	**D. Durieux**

The Scent of Social Parasitism in Cape Honeybees

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African populations of honeybees have given rise to both to the Africanized honeybees of the Americas and to the emergence of a worker social parasite in the Cape honeybees. The Cape honeybees (*Apis mellifera capensis*) are native to the south western tip of the African continent and have workers with the capacity for thelytokous parthenogenesis. Since these workers can sustain colonies without a queen, they can give rise to social parasites that invade other honeybee colonies and monopolize reproduction.
The mandibular gland chemistry (MGC) of these parasitic workers, their interaction with colonies of their own population, as well as colonies of *Apis mellifera scutellata* will be discussed. The mandibular gland chemistry of these workers mimics that of queens ('The scent of royalty' = 'The Scent of Social Parasitism'), in addition, microsatellite analysis has shown that the social parasitic workers are clones of the original parasitic worker. Microsatellite data has also revealed self social parasitism within apiaries of *capensis*. Finally the genetic basis for the suite of characters (MGC, ovary activation and thelytoky) that gives rise to social parasitism will be discussed.

Chemosensory nestmate recognition in a polygyne ant, *Formica yessensis*

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Formica yessensis is a polygyne ant species that constructs the largest supercolonies, comprising numerous nests, ever found in Japan. Workers from colonies within the supercolony had more similar profiles compared to workers from colonies outside the supercolony. Total response of the active CHC sensilla increased stepwise, suggesting that discrimination of conspecific workers at the peripheral system is limited, in particular among members of the same supercolony, but is fully expressed for conspecific workers. Thus, we illustrate in *Formica yessensis* that the full and the limited nestmate versus non-nestmate discrimination potential of the CHC sensilla, which relies on the intraspecific similarity of the CHC pattern, is one of the important factors for the characteristic aggressiveness and/or tolerance rather than genetic relatedness.
We demonstrate that "chemosensory dullness" i.e., low discrimination sensitivity of the CHC sensilla, limits these ants' ability to recognize the subtle differences in the CHC pattern that typify members of a supercolony. Such dullness is thus an important factor contributing to the characteristic tolerance exhibited by supercolony-forming ants.

The role of semiochemicals in the reproductive biology of bumblebees and cuckoo bumblebees

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In bumblebees and cuckoo bumblebees we investigated in a comparative approach the proximate mechanisms of intraspecific and interspecific chemical communication in interactions between queens and workers and between host workers and parasite females. Using various bioassays and analytical techniques we identified semiochemicals with a function in host nest recognition by parasitic bumblebees as well as odour compounds that are used by host queens and parasite females to regulate worker reproduction. Nest searching parasite females use host trail odour that workers apply at the nest entrance to recognize their hosts. During nest invasion, social parasitic bumblebees use various strategies to overcome the defensive system of their hosts. They produce repellent compounds and adjust their odour bouquet considerably to the existing colony scent. A further aim of our study was to figure out the mode of control that parasite females use to regulate worker reproduction. We were able to show that parasite females use chemical means to control worker reproduction like the queen does in non-parasitized colonies and are able to mimic olfactory fertility signals of the host queen.
We thank the German Science Foundation for financial support.

Cuticular Hydrocarbon Evolution in the Hymenoptera: A Comparison of "Ancient" and "Modern" Species with varying Degrees of Sociality

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Cuticular hydrocarbons (CHCs) play a vital role in insect recognition behaviour, particularly in social insects. CHCs are also increasingly used as taxonomic tool to differentiate between species that are morphologically indistinguishable. Nevertheless, very little is known about the evolution of CHCs. Focusing on the well-studied hymenoptera (ants, bees and wasps), we used data from over 200 species to compare ancient (basal) with modern (peripheral) species and investigate how a solitary or social lifestyle affected the overall CHC profile. We found big differences in the types of CHC's produced between the primitive Chalcidoidea wasps, and the Apoidea bees and Vespoidea wasps/ants. Unexpectedly the most primitive hymenoptera had highly complex CHC profiles, whereas more modern species have become simpler. We discovered a major split between the bees and wasps/ants by specialisation into either the even positional alkenes in bees or the di-methylalkanes in wasps/ants. Social species tended to have more complex CHC profiles compared to their solitary contemporaries. These findings provide us with a deeper understanding of the differential importance of individual compound groups in these different classes of social insects, as well as with a unique insight into CHC evolution.

Evidence against Composition of Cuticular Hydrocarbons as Nestmate Recognition Cues in the Fire Ant Solenopsis invicta -- the Painted Ant and Beyond.

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The pattern of cuticular hydrocarbon (CHC) composition on the surface of ants, shared by members of the colony and changing slowly over time, has long been assumed to function primarily in nestmate recognition, a process allowing instant identification of intruders and protecting valuable shared resources of the superorganism. However, we found direct evidence in fire ants that the composition of hydrocarbons *per se*, although shared by colony members through active allo-grooming and blending (the Gestalt Organ), is not the actual recognition cue. Furthermore, changes in this shared pattern of colony CHCs are definitely related to changes in ambient temperature and the composite melting point of the mixture.

Born, survive and go out of an alien nest : first example of a social parasite's exfiltration strategy

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In social insects, the high energetic costs of brood care have promoted the evolution of social parasites that exploit worker force of conspecifics or heterospecifics. In bumblebees, all the species of the subgenus *Psithyrus* have lost their worker caste and are completely dependent on host workers to produce their offspring. One of the most striking challenges for these social parasites is to avoid the detection and aggression by their hosts. Many studies have shown how socially parasitic queens overcome host recognition systems to enter successfully into host colonies. However, once a social parasite has successfully usurped a host nest, its emerging offspring still face the same challenge of avoiding host recognition. This is especially the case for the young *Psithyrus* males who possess a strong chemical signature because of their early production of species specific sex pheromones. Therefore, host workers might be able to recognize them. We hypothesized that parasitic males should require a strategy to prevent host agonistic behaviors. This study presents how males of the cuckoo bumblebee *Bombus vestalis* fool *Bombus terrestris* workers during their intranidal life. Our results show that parasitic males produce an allomone that repel attacking host workers. This is the first example of an active exfiltration strategy in social parasites.

Response of Parasitic Phorid Flies to Fire Ant Semiochemicals

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Parasitic phorid flies, *Pseudacteon* spp are introduced parasitoids of imported fire ants, *Solenopsis* spp. in the United States. Previous studies by our group demonstrated that attraction of phorid flies to fire ants is mediated by host semiochemicals, specifically fire ant worker venom alkaloids and alarm pheromone. In the present study, we compared the behavioural response of three phorid fly species, *Pseudacteon tricuspis, P. obtusus* and *P. curvatus*, to the venom alkaloids and alarm pheromone of the red imported fire ant, *Solenopsis invicta*. A key hypothesis tested was that fire ant venom alkaloids and alarm pheromone act in tandem or synergistically to attract phorid flies. All three phorid fly species were attracted to physiologically relevant doses of *S. invicta* venom alkaloids or alarm pheromone alone. The flies were significantly more attracted to the mixture of both chemicals (i.e., venom alkaloid + alarm pheromone) than to either chemical alone, however the results suggest only an additive interaction between both chemicals. *P. tricuspis* was more active and responsive to the chemicals than the remaining two species.

Chemical and physical factors involved in the aggregation behaviour of *Harmonia axyridis* Pallas

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In order to survive cold winters, the multicoloured Asian ladybeetle, *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae) forms large aggregates in dwellings to overwinter. The factors involved in this behaviour remain misunderstood, although their comprehension could lead to the development of new control methods of this invasive species. The work presented herein was oriented to the study of the chemical compounds involved in this phenomenon. Chemical and behavioural analyses highlighted that non volatile hydrocarbons lead congeners towards aggregation sites and ensure the cohesion of the aggregate. Secondly, physical factors were investigated. We studied the influence of (1) the density of individuals and (2) the quality of available shelters on *H. axyridis* decision to settle and aggregate under shelters. A binary choice experiment conducted in laboratory showed that the multicoloured Asian ladybeetles present a permanent aggregative behaviour, even during non-wintering conditions. These experiments also highlighted the existence of social interactions between individuals.

ORAL PRESENTATIONS
TUESDAY 26 JULY
SYMPOSIUM 6
Images Theatre, 4:20 – 7:00

Time	Activities
3:40 – 4:20	Conference keynote lecture (symp 6) Dr. Ryohei Kanzaki (Images)
4:20 – 5:00	**Symposium 6** **invited lecture: M. Knaden**
5:00 – 5:20	**K. Hillier**
5:20 – 5:40	*Coffee break*
5:40 – 6:00	**J. Chin**
6:00 – 6:20	**A. Saveer**
6:20 – 6:40	**A. Reinecke**

Spatial representation of odor valence in an insect brain

Knaden, Markus;[1] Antonia Strutz;[1] Jawaid Ahsan;[1] Silke Sachse;[1] Bill S. Hansson[1]
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Brains have to decide whether and how to respond to detected stimuli based on complex sensory input. The fruit fly *Drosophila melanogaster* evaluates food sources based on olfactory cues. Here we performed a behavioural screen using *Drosophila* and established the innate valence of 110 odours. Our analysis of neuronal activation patterns evoked by attractive and aversive odours suggests that the representation of odour valence is formed at the output level of the antennal lobe. The topographical clustering within the antennal lobe of aversive-specific output neurons resembles a corresponding domain in the olfactory bulb of mice. The basal anatomical structure of the olfactory circuit between insects and vertebrates is known to be similar; our study suggests that the representation of odour valence is as well.

Octopamine: Effects on olfactory sensitivity and learning in insects

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Within insect fauna, octopamine (OA) functions as an important neuromodulator, neurotransmitter and neurohormone regulating the function of multiple organ systems, particularly in relation to stress response. OA has an important behavioural role in motivation, sensory sensitivity, as well as in reinforcement of learned behaviours. Results of recent studies on sensory physiology of Heliothine moths will be presented which describe the differential effects of OA on sensory physiology. Furthermore, the effects of OA on olfactory learning and memory are tested in relation to physiological state in relation to recall through a learning assay, the proboscis extension reflex (PER).

Triacylglycerides (TAGs) – A Novel Class of Courtship-related Compounds Found in *Drosophila arizonae* and *D. mojavensis*

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Changes in chemosensory systems may be one of the initial triggers of speciation. In *Drosophila arizonae* and *D. mojavensis*, two recently diverged species, pheromone profiles were previously shown to be qualitatively similar but quantitatively different. However, recent studies using laser desorption/ionization mass spectrometry indicate that males of both species express a novel class of triacylglycerides (TAGs). Amounts of these TAGs are different between the two species. Interestingly, several of these TAGs along with other cuticular compounds are transferred from the males to the females during mating, which leads us to suspect that the compounds are courtship- inhibitory and may prevent other males from courting the mated females. We examined courtship behaviour using flies 'perfumed' with these TAGs in order to determine whether these compounds influence mate choice. *D. arizonae* males exhibit delayed latency to court mated females. In contrast, *D. mojavensis* males show no difference in courtship latency towards virgin females or mated females. Notably, *D. mojavensis* males exhibit increased latency to court when virgin females are 'perfumed' with high amounts of male cuticular pheromone extract. Characterization of the gene(s) underlying production of TAGs might provide insight into the divergence of these two species.

Reproductive state modulates odor-driven behavior: Switching preference from food to host odor

Saveer Ahmed, M;[1*] Kromann, S; [1] Birgerson, G; [1] Bengtsson, M; [1] Lindblom, T; [1] Hansson, BS; [2] Witzgall, P; [1] Becher, PG; [1] Ignell, R[1]
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The sense of smell is generally considered to be crucial for the survival of most animals, including insects. Understanding how insects exhibit innate behaviors in responses to olfactory stimuli, and how such processes are modulated by their physiological state is a current challenge in olfactory research. Here, we show that female cotton leafworm *Spodoptera littoralis* exhibit a marked switch in their behavior following mating. Using a flight tunnel, we demonstrate that before mating female *S. littoralis* show robust upwind flight attraction to nectar rich lilac flowers (*Syringa vulgaris*) whereas, after mating female moths switch their olfactory preference to foliage of larval host plant cotton (*Gossypium hirsutum*). Furthermore, electrophysiological and calcium recordings of the antennal lobe (AL), using behaviorally active odorants revealed differential odor representation across a population of glomeruli. Moreover, the odor activity in the AL is switched in accordance with the behavioral pattern.

Smelling the difference: Sensory correlates to host plant preferences in ovipositing *Manduca sexta*

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We performed a comprehensive analysis of oviposition preferences as well as sensory responses to host plant derived volatiles in gravid *M. sexta* females. Individual *Manduca* larvae devastate *Nicotiana attenuata* plants, while the species is a pollinator to *Datura wrightii*, which tolerates feeding-damage to a certain degree. Feeding-damaged *N.attenuata* plants also attract parasitoids and predators. In our experiments, gravid females correspondingly prefer intact plants as compared to feeding-damaged tobacco plants. At the species level, *D. wrightii* is preferred to *N. attenuata*, and females do not discriminate between damaged and intact *D. wrightii* plants. Behavioural data show that olfactory cues alone suffice to perform the underlying choice. GC analyses of headspace samples combined with single sensillum electrophysiology and principal component analyses of the perceived fraction of volatile blends indicate that compounds from diverse functional classes, including fatty acids emanating from the larval faeces, contribute to the discrimination capacity of the egg-depositing moth. Single sensillum recordings reveal that *N. attenuata* and *D. wrightii* odours elicit species and condition-specific responses to host components – providing a sensory fingerprint conveyed to the brain.

ORAL PRESENTATIONS
WEDNESDAY 27 JULY
SYMPOSIUM 7, part II
Saywell Hall Theatre, SWH 100081

Time	Activity
8:30	Opening (Images Theatre)
8:40 – 9:20	**Kenyote lecture (symposia 7 and 9) J. Gershenzon (Images)**
9:20-10:00	Silverstein-Simeone Lecture: K. Raffa (Images)
10:00 – 10:30	*Coffee break* (AQ outside of Images)
10:40 - 11:20	**Invited lecture: N. Erbilgin**
11:20 – 11:40	**D. Pureswaran**
11:40 – 12:00	**F. Schlyter**
12:00 – 12:20	**B. Aukema**
12:20 – 2:00	*Lunch break*
2:00 – 2:40	Keynote lecture symposia 9 & 4: S. Pedras (Images)
2:40 – 3:20	**C. Tittiger**
3:20 – 3:40	*Coffee break*
3:40 – 4:00	**R. D. Figueroa-Teran**
4:00 – 4:20	**I. Lusebrink**
4:20 – 7:00	*Time off*
7:00 – 10:00	***Posters and evening social***

Chemical ecology: Implications for response to emerging threats to forest ecosystems

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Chemical ecology in forest ecosystem has a long history. Among the short list of prominent chemical ecologists, **Dr. Kenneth Raffa** has not only reshaped our understanding of **tree-insect interactions**, but also has a tremendous influence over the **students** that he taught. I will describe how it is like to be a doctoral student in Dr. Raffa's Lab and how I have utilized my doctoral (and post-doctoral) experience to establish my program in forest entomology, which focuses on **invasion dynamics** of invasive forest insect herbivores. I incorporate indirect (**plant-mediated**) interactions between an invasive insect and native organisms (insects and diseases) to understand the role of plant chemical defenses and native organisms in **invasion success** of invasive species into new environments. I use the current invasion of jack pine boreal forest by the **invasive mountain pine beetle** as my system model. I will provide some results from studies currently conducted in my lab along with other studies investigating plant-insect interaction in other systems.

Evolutionary transitions in bark beetle pheromone system

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Aggregation and mate location in the genus *Dendroctonus* is mediated by a blend of pheromones composed of up to five active components. Members of the genus are closely related and therefore share pheromone components, although the dominant compound, the sex that produces a particular compound and the precise function of each compound might vary. The evolution of pheromone blends in bark beetles has been argued to occur in major "saltational" shifts in response to selection pressures rather than by a gradual series of small changes over time. Major selection pressures on bark beetle populations include 1) changes in population density and 2) shifts in host species or races. *Dendroctonus* spp. attacking living trees require that a critical density of beetles synchronously attack a tree using aggregation pheromones in order for them survive and reproduce. Investigations of pheromone profiles following selection events would enable us to use the most appropriate pheromone blends when implementing management strategies.

Semiochemical diversity reduces herbivory: Experimental evidence for a new functional significance of biodiversity

Schlyter F[1], Jactel H[2], Jakuš R[3], Schiebe, C[1]
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Biodiversity is a positive catch word, but its biological function -apart from species conservation- is less understood. Lack of biodiversity has been implicated as a factor behind herbivore pest insect rise in monocultures. Mechanisms behind such patterns are partly supported, but we propose an important role for the new Semiochemical Diversity Hypothesis (SDH): The non-host volatiles in a biodiverse habitat, like a mixed forest, disturb insect host and mate location. For conifer insects SDH is established and exploited using semiochemicals dispensed creating "artificially mixed" forest with less insect attacks. Two examples, one for a pine moth and one for a bark beetle are given. We propose an important role of non-host plant signals also for insect herbivores in general.

Jactel H, Birgersson G, Andersson S, Schlyter F 2011. Non-host volatiles mediate associational resistance to the pine processionary moth. *Oecologia*. On line 11 Feb.
Schiebe C, Blazenec M, Jakus R, Unelius CR, Schlyter F 2011. Semiochemical diversity diverts bark beetle attacks from Norway spruce edges. *J. Appl. Entomol.* On line 24 Mar.

Host tree selection behaviour reflects outbreak trajectory of mountain pine beetle

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While plant defenses are postulated to play an important role in mediating herbivore populations, quantifying their role across changing insect population levels is hampered, in part by the speed by which rapid transitions can obscure statistical signals. We annually censused all lodgepole pines in five stands for signs of insect colonization , for three to six years. We assayed a subset of trees for chemical attributes that contribute to constitutive and inducible defenses, such as total monoterpenes and monoterpene concentrations. In all of the stands, we captured population eruptions of mountain pine beetle from endemic to outbreak stages. We found that these insects typically colonize weakened trees, often in association with other stem-colonizing insects, during their endemic phase. When sufficient numbers of conspecifics become available, they lessen this discrimination, characterizing the incipient phase, and ultimately preferentially attack the most well-defended trees during the epidemic phase. Our work provides insight into how plant defenses can constrain populations of mountain pine beetle for long periods of time at low levels, but fail to do so when insect populations are at high levels.

Terminal steps in mountain pine beetle (*Dendroctonus ponderosae*) pheromone biosynthesis

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The mountain pine beetle (*Dendroctonus ponderosae*) relies on a multi-component pheromone blend to coordinate the mass attack required to colonize host trees. Three major components are (-)-*trans*-verbenol, *exo*-brevicomin, and frontalin

(-)-*trans*-Verbenol is produced as a direct hydroxylation product from (-)-α-pinene, which is probably ingested from host phloem. CYP6DH1 is a novel cytochrome P450 closely related to CYP6DH2, which accepts (+)-, but not (-)-∀-pinene as a substrate. Expression data and preliminary assays of recombinant CYP6DH1 suggest this enzyme hydroxylates (-)-∀-pinene and therefore may have a pheromone-biosynthetic role.

e*xo*-Brevicomin is predicted to arise from a fatty acid precursor. Tissue incubations confirm that male fat bodies produce *exo*-brevicomin. A novel P450, CYP6CR1, has an expression pattern consistent with *exo*-brevicomin biosynthesis. Functional assays of recombinant CYP6CR1 confirm that CYP6CR1 converts 6-(Z)-nonen-2-one to 6,7-epoxynonen-2-one, the direct precursor to *exo*-brevicomin. Further experiments suggest that an unidentified cyclase probably converts the keto-epoxide to *exo*-brevicomin.

Ipsdienol dehydrogenase (IDOLDH) is important in determining the final pheromone blend in *Ips* spp. beetles

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Enantiomeric blends of ipsdienol (2-methyl-6-methylene-2,7-octadien-4-ol) and ipsenol (2-methyl-6-methylene-7-octen-4-ol) are the major pheromones of *Ips* species (Coleoptera: Scolytidae). A novel ipsdienol dehydrogenase (IDOLDH) from *Ips pini* (Say) has been cloned, expressed, functionally characterized, and cellular localization analyzed. The cDNA encoded a predicted translation product with conserved "classical" SDR family in the Cp2 subfamily motifs. Transcript levels were highest in the fed male anterior midgut, the site of pheromone biosynthesis. The protein was only detected in fed and unfed male midguts with no significant difference between either. GC/MS analysis showed IDOLDH catalyzed the oxidation of racemic ipsdienol and (-)-ipsdienol to form ipsdienone, while (+)-ipsdienol was not a substrate. IDOLDH also reduced the pheromone precursor, ipsenone, to (-)-ipsenol. The K_m and V_{max} for oxidation of (-)-ipsdienol to ipsdienone were 0.6 uM and 17.2 pmol/min/ug, respectively. The results of this study lead to the conclusion that IDOLDH is an enzyme involved in pheromone biosynthesis and to our knowledge is the first identified ipsdienol, ipsdienone, or ipsenone oxidoreducatase.

How drought affects the mountain pine beetle and its host trees

Lusebrink, Inka; [1] **Evenden, Maya L.;** [1] and **Erbilgin, Nadir** [2]
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The mountain pine beetle (MPB) has extended its range from the lodgepole pine forest of British Columbia into Alberta, where it has successfully attacked lodgepole x jack pine hybrids and jack pine trees. To address how different host trees react to drought and plant defense stimulation and how this response will affect the MPB we conducted a field experiment on hybrid trees subjected to either water or water deficit as an environmental treatment and biological treatments including inoculation with *G. clavigera*, a MPB fungal associate. Volatile emission from the tree bole and monoterpene content of the phloem were measured to assess the tree response. Bolts from treated trees were inoculated with MPB to assess beetle response to tree manipulation.
Bole chemical profiles of hybrids trees represent a mixture of both pure species. Fungal inoculation increased VOCs emission. Beetles that emerged from water deficit hybrid bolts had higher fat content than beetles reared in watered trees. Fungal inoculation increased the level of Nitrogen in phloem of hybrid trees.

ORAL PRESENTATIONS
WEDNESDAY JULY 27
SYMPOSIUM 9, part I
Images Theatre, 10:40 - 4:00

Time	Activities
800 – 8:30	*Breakfast* (outside of Images Theatre)
8:30	Opening/Announcements (Images Theatre)
8:40 – 9:20	**Conference keynote lecture (symp 7 & 9) Jonathan Gershenzon (Images)**
9:20 – 10:00	Silverstein-Simeone Lecture 2: Ken Raffa (Images)
10: 00 – 10:30	*Coffee Break*
10:40 – 11:20	**Symposium 9** **inv. D. Ober**
11:20 – 11:40	**A. Weinhold**
11:40 – 12:00	**P. Girón-Calva**
12:00 – 12:20	**C. Orians**
12:30 – 2:00	*Lunch break & J. Chem. Ecol. Meeting (SSB7172)*
2:00 – 2:40	**Conference keynote lecture (symp 9 & 4) Dr. Soledade Pedras (Images)**
2:40 – 3:00	**E. Schwartzberg**
3:00 – 3:20	**L. Jeffares**
3:20 – 3:40	**H. E. Hummel**
afternoon	*Time off*
7:00 – 10:00	Posters and evening social (7:00-8:30: poster judging of student & PDF submissions for symposia 5,6,7 and 9)

Evolution of pathways in plant secondary metabolism

Ober, Dietrich
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Gene duplication followed by functional diversification is assumed to be one of the major mechanisms involved in the creation of enzymes. These new enzymatic activities are a prerequisite for the establishment of new biosynthetic pathways, for example, in plant secondary metabolism. The evolutionary mechanisms behind this process remain unclear. Various models that have been suggested to explain gene evolution by duplication events but are unable to explain convincingly the way that new functions can evolve. Against this background, models will be discussed that do not only explain the origin of individual enzymes, but also the creation of a complex pathway that ensure proper regulation of all biosynthetic steps. Examples will refer to the present knowledge of pyrrolizidine alkaloid biosynthesis.

Studying the plant's first line of defense – How analytics reveal new defensive functions of trichomes

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Modern analytical techniques allow scientists to increasingly untangle the mechanisms responsible for plant defenses. GC is used to understand the importance of plant volatiles and LC is an important tool for the analysis of phytohormone regulation. In addition NMR is utilized to elucidate the structures of a large number of previously unknown defensive compounds. Moreover this tool box provides new insights into well studied topics. For instance, trichomes and glandular hairs in particular are recognized as an important part in the defensive arsenal of plants, e.g. as obstacles to slow down insect movement. However there exist additional defensive traits in these tissues in addition to those apparent to the naked eye. In our studies we demonstrate that O-acyl sugars, secreted by glandular trichomes of *Nicotiana attenuata,* impart a distinct volatile profile to the body and frass of larvae that feed on them. In native habitats a ground-hunting ant uses these volatiles to locate its prey. Additionally ^{1}H NMR studies on individual trichomes revealed the presence of a new metabolite in a *Solanaceous* plant: phaseoloidin, a homogentisic acid glucoside. Artificial diet bioassays with *M. sexta* and *S. littoralis* larvae revealed that phaseoloidin negatively influenced caterpillar performance.

Plant-plant communication: A brief whisper transmits a message! Short-time exposition to low amounts of volatiles primes plant defenses

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Plants in the vicinity around damaged plants perceive the volatile organic compounds (VOCs) that are released in response to attack by herbivores or bacterial pathogens and adjust their own defenses. We search for the active concentration and time of exposition required to prime defenses against pathogens. *Phaseolus lunatus* plants were exposed in closed systems to several concentrations of methyl salicylate (MeSA) and nonanal [1] over different times. After that, plants were infected with the bacterial pathogen *Pseudomonas syringae*. Exposition to nonanal at initial concentrations of 800 μgL^{-1} and 8 mgL^{-1} of box volume for 6 h decreases infection rates measured at 4 days post infection. At higher concentrations (83 mgL^{-1} of box volume) this VOC resulted toxic. Exposition to MeSA at a low concentration (10 μgL^{-1} of box volume) reduced infection at 4 days, but only when exposition time was increased from 6h to 24 h. Low amounts of VOCs suffice to prime resistance to pathogens only when the time of exposition is long enough. We conclude that plant-plant communication depends on mechanisms that might involve the accumulation of VOCs in the receiving plant.

1. Yi et al. *Plant Physiology* 151: 2152-2161 (2009).

From shoots to roots: Herbivore-induced shifts in chemistry

Orians, Colin[1]; Gómez, Sara[1,2], Steinbrenner, Adam [1]; Osorio, Sonia[3]; Fernie, Alisdair[3]; Erkenbrack, Eric[1]; Korpita, Timothy[1], Schueller, Michael[4], Ferrieri, Richard[4]

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Plants can tailor highly specific responses upon feeding by herbivores. Historically the focus has been on changes in secondary metabolism that increase resistance. Recent evidence, however, suggests that rapid changes in primary metabolites might increase plant tolerance to damage. While isotope studies offer a preliminary view of the dynamic changes affecting primary meta-bolites, it only provides information about movement but not about functional roles. Therefore, coupling radio isotope studies with changes in pool sizes provide a powerful tool to better understand the role of whole-plant resource re-allocation. Here, we used tomato (*Solanum lycopersicum*) to examine induced resource reallocation in response to two herbivores. We used radio isotopes to quantify changes at 4hr, and stable isotopes and chemical assays to measure changes in pool sizes after 5 days in five tissue types: locally damaged leaves, mature leaves, shoot apex, stems/ main root, and fine roots. We found evidence both for reallocation of carbon, and sometimes nitrogen, towards storage organs in response to damage, and for changes in pools indicative of induced storage. Overall, responses across the entire tomato plant were rapid, systemic, cue-specific, and potentially important to the response of tomato to different attackers.

Counteracting a plant's defense: Suppression of herbivore-induced plant volatiles and phytohormones by pea aphids

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Plants are able to defend themselves against herbivory through several means including ramping up the production of within plants defense signaling molecules, including Jasmonic Acid (JA), as well as the emission of airborne volatile organic compounds (VOCs), which aid in the attraction of natural enemies of their herbivores. We found that pea aphids have the ability to inhibit the release of VOCs as well as the accumulation of the precursory phytohormone JA. Levels of VOC emission and hormone accumulation are not significantly different between control plants and those fed upon by aphids for up to 5 days. Using a second herbivore, the beet armyworm caterpillar, *Spodoptera exigua,* we demonstrate that expected caterpillar-induced VOCs and phytohormones are suppressed when co-infested with pea aphids. We see an expected increase in both VOC emission and JA accumulation when plants are subject to herbivory by the beet armyworm caterpillar, however this induction is suppressed when pea aphids colonize plants prior to caterpillar feeding. Furthermore, we have identified salicylic acid (SA) within deposited aphid honeydew as a mechanism for this suppression, and will discuss the SA source, content, activity and potential mode of action.

Sexy Semiochemicals*:* A tale of orchid meets wasp. The case of *Drakaea* orchids and their pollinators.

Jeffares, Lynne;[1,2] **Bohman, Björn;**[1,2] **Barrow, Russell;**[1] **Flematti, Gavin;**[3] **Phillips, Ryan;**[2,3] **Menz, Myles**[4] **and Peakall, Rod** [2]

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Orchids are well known for their extraordinary species diversity and for their specialised pollination systems. *Drakaea* orchids, endemic to Western Australia, are pollinated by the sexual deceit of male thynnine wasps through mimicry of the insect pheromones. An investigation into chemical communication between orchids and their pollinators is underway.
Recently, it has been found that pyrazine based compounds are used as semiochemicals by *Drakaea* orchids. Following the successful identification, synthesis and field testing of four compounds in *D. glyptodon* the study has been expanded to include five additional species. We have strong indications that all species are utilising related compounds, including novel oxygenated pyrazines. This talk will outline the methods utilised in the isolation, identification and synthesis of the identified semiochemicals, including solid phase microextraction (SPME), GC/electroantennographic detection (GC/EAD), GC/MS and GC/HRMS. Finally, the implications for our understanding of the role of chemical changes in orchid speciation will be briefly explored.

Chemical ecology and integrated pest management by pheromone disruptants: A novel technical approach using organic nanofibers

Hummel, Hans E.[1,2], Hein, D.F.[1], Breuer, M.[3], Lindner, I.[1], Greiner, A.[4], Wendorff, J.H.[4], Hellmann, C.[4], Dersch, R.[4], Kratt, A. [5], Kleeberg, H.[5], Leithold, G.[1]

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Economic entomologists and application engineers dearly wish they had the "smart, intelligent and ideal dispenser". Commercially available dispensers fall short of meeting all demands. Their field distribution should be mechanizable and be accomplished by one (or very few) application runs. Required dispensers should be biodegradable, biocompatible, sustainably applicable, and they should be based on renewable resources. Here we present first results of a novel organic, electrospun nanofiber dispenser with dimensions in the upper nanometer range. Its load of pheromone can be adjusted to be sufficient for 7 weeks of constant disruptive action in vineyards and can be directed against the European Grape Vine Moth *Lobesia botrana* (Lepidoptera: Tortricidae), whose mating disruption is well studied. Equally, nanofiber production by electrospinning (see Greiner & Wendorff, 2007) is well known and already has numerous applications in filtration technology, air conditioning, and medical wound dressing. The challenge was to bring together and successfully mate these (partly incompatible) technologies via technical tricks. We still must double the lifetime of currently available nanofibers to last for one growing season. Another challenge is the mechanical distribution of the fibers in the vineyards by suitable machinery currently under development. Julius Kühn Institute Berlin kindly monitors in numerous test systems the compatibility of organic nanofibers for their effects on human, animal and environmental health. So far no contraindications have been identified.

ORAL PRESENTATIONS
THURSDAY JULY 28
SYMPOSIUM 9, Part II
Saywell Hall Theatre, 8:40-9:40; 2:20-3:20

Time	Activity
8:00 – 8:30	*Breakfast* (outside of Images Theatre)
8:30	Opening/Announcements (Images Theatre)
	Symposium 9, part II
8:40 – 9:00	**E. Yaya**
9:00 – 9:20	**A. Najar**
9:20 – 9:40	**A. Strauss**
9:40 – 10:00	**M. Shabab**
10:00 – 10:30	*Coffee break*
10:40 – 11:20	Conference keynote lecture (symp 2) Gabi Nevitt
11:20 – 12:00	Conference keynote lecture (symp 1 & 2) Rob Britton
12:00 – 12:40	**Silver Medal Lecture: Paul Feeney (Images)**
12:40-2:20	*Lunch break*
2:20 – 2:40	**H.E. Hummel**
2:40 – 3:00	**R. Ferrieri**
3:00 – 3:20	**A. Burse**
3:20 – 3:40	Jury meeting 3:00-4:00 in SSB 7172
3:40 – 4:00	*Coffee break*
4:00 – 5:30	(Images) Annual General Meeting (at 4:00 PM winners of travel awards and the poster/oral competition will be announced)
7:00	*Gala dinner at the Diamond Alumni Club*

Biosynthetic studies on rapalexin A, a unique phytoalexin from canola

Estifanos Yaya, Sajjad Hossain and M. S. C. Pedras*
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Plants respond to stress employing defense pathways that involve the biosyntheses of numerous and structurally diverse natural products. Phytoalexins are natural products with antimicrobial activity against plant pathogens and other stresses. Knowledge of the biosynthetic pathways of plant defences will facilitate the identification of plant defence genes and the potential breeding of plants producing more potent antifungal metabolites.
Although several biosynthetic intermediates of cruciferous phytoalexins are common, rapalexin A has a unique structure in that it is the only natural product known with an isothiocynate substituent at C-3 of the indole ring. Although the indole ring is likely derived from tryptophan, no other intermediates or precursors are known. *De novo* incorporation of perdeuterated 3-indolyl derivatives was investigated in rutabaga and turnip tissues stressed under UV light. After suitable incubation periods, tissues were extracted and analysed by LC-DAD-MS for incorporation of deuteria. Results from these feeding experiments showed incorporation of several deuteria into rapalexin A and other rutabaga phytoalexins. Details of this work will be presented and the implications will be discussed.

Aspen's life experience being told by chemistry
How growing conditions are shaping interaction and response to defoliators

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Plant defense has a genetic and environmental component. The interactions between biotic and abiotic stresses in plants infer about strategic allocation of plant resources and plant decision making. We subjected aspen seedlings to different growing conditions then to the forest tent caterpillars (Malacosoma disstria) herbivory to evaluate insect fitness on the light of the feeding experience. Preliminary results showed that the caterpillar consistently fed on aspen seedlings with high carbohydrate and nutrient contents whereas aspens with low resources had little defoliation. Those observations are linked to leaf chemistry; both primary and secondary defensive chemistry explained some of the results observed on insects. The concentration of specific phenolic glucosides known as deterrents of browsing was assessed and turned to be a reliable indicator of plant resistance to deterrence. The results for this year experiment came to confirm our hypothesis, that plants grown in harsher conditions were better defended.
This study highlights the impact of variations in plant growing conditions, and their effects on plant physiology, chemistry and on insect herbivory. The molecular basis for this differential response are being investigated.

Sequestration of plant glucosides by leaf beetle larvae: The ABC in the transporter network

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Leaf beetle larvae of the subtribe Chrysomelina evolved specialized defensive glands in which specific host plant derived glucosides are converted to a toxic chemical cocktail, stored and released in case of attack by predators. Such sequestration processes of glucosides rely on a sophisticated transport system, guiding plant glucosides through the body of chrysomelid larvae, providing an evolutionary flexible defense strategy (1). However, the identification of glucoside transporters has remained elusive, despite their crucial role in respect to host plant adaptation. We identified candidate genes of glucose transporters and ABC-transporters by cDNA library analysis of *Phaedon cochleariae* and *Chrysomela populi,* that show high transcript levels in the glands. The identified gene for an ABCC4like ABC transporter of *C. populi*, is highly conserved among Chrysomelina species. Using HPLC-MS analysis, we measured Salicin transport activity of this transporter, heterologously expressed in *Xenopus laevis* oocytes. Examining the selectivity, tissue distribution, regulation and phylogeny of this transporter by combining different species information could explain leaf beetle defense development in adaptation to their host plant and/or enlighten possible co-evolutionary aspects.

ISOMERIZATION OF THE PHYTOHORMONE PRECURSOR OPDA IN THE INSECT GUT: A MECHANISTIC AND COMPUTATIONAL STUDY

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Plant-derived compounds ingested by a feeding herbivore undergo different metabolic modifications in the herbivore gut. Our analysis of the fate of plant-derived oxylipins in the gut of a feeding Mediterranean climbing cutworm (*Spodoptera littoralis)* revealed an enzyme-assisted isomerization of 12-oxophytodienoic acid (OPDA), the biosynthetic precursor of jasmonic acid, to *iso*-OPDA. The transformation is achieved by a glutathione-*S*-transferase present in the gut epithelium. Experiments with 9-[^{2}H]-*iso*-OPDA demonstrated the complete retention of the deuterium atom in the product 11-[^{2}H]-OPDA consistent with an intramolecular 1,3-hydrogen shift. Homology-modeling based on the X-ray structure of a glutathione S-transferase from *Anopheles gambiae* revealed that the cofactor glutathione does not covalently bind to the substrate, but appears to be involved in the initial deprotonation and enolization of the OPDA. The transformation resembles that of a mammalian GST catalyzed isomerization of Δ^5-3-ketosteroids to Δ^4-3-ketosteroids or the conversion of prostaglandin A_1 to the biologically inactive prostaglandin B_1.

In reverence to the genius of Tom Eisner (1929-2011). Ergograms of his life's work dedicated to chemical ecology and public service

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THOMAS EISNER (1929-2011), when I met him first at Cornell University some 41 years ago, was at the height of his powers. He was a genuinely impressive man with sparkling wit, teeming with ideas, and tempted to do everything simultaneously. Humble in his habitus, he had what, in lieu of a better term, is commonly called a "magnetic personality". So contagious was his curiosity and ingenuity that for a few minutes in March 1970 I considered asking him if I could stay at his lab right away, neglecting the signed post doctoral assistant contract I had in my pocket for joining yet another lab of chemical ecology and insect toxicology, the entomologists around Harry Shorey, Lyle Gaston and Roy Fukuto at UC Riverside.

TOM EISNER, now very unfortunately and forever taken from our midst, can never be replaced. Yet, we might draw comfort from the fact that we could enjoy the few decades of his life during which he did decisively shape our favorite subject area and showed us as a living example what chemical ecology could accomplish. An enlightened character like him is unique and is given to a field of science once, perhaps twice in a century. Even if we do not work ourselves on allomones, biodiversity, nature conservation, and human rights, he may nevertheless serve as a powerful role model and catalyst for better serving our own pursuits in adjacent fields.

Using Carbon-11 to Measure Defense Responses of Maize to the Belowground Specialist Herbivore *Diabrotica virgifera virgifera*

Richard A. Ferrieri[1], Christelle A.M. Robert[2], Benjamin A. Babst[1], Tobias Köllner[3], David L. Alexoff[1], Michael J. Schueller[1], Bruce E. Hibbard[4], Ted C.J. Turlings[2] and Matthias Erb[2,3]
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[4]Plant Genetics Research Unit, 205 Curtis Hall, University of Missouri, Columbia MO 65211-7020, USA.

Diabrotica virgifera virgifera, the western corn rootworm, is an agricultural pest that continues to threaten maize production in the U.S. and in Europe. Novel approaches are warranted to understand and reduce the success of the root-feeding larvae of this coleopteran beetle. We investigated the belowground interaction of *D. virgifera* and maize in the context of what is known about plant defenses from leaf herbivory, and in light of the fact that little is known about what happens when roots come under attack. Using radioactive $^{11}CO_2$ ($t_{1/2}$ 20.4 m) administered to leaves of intact plants, we explored the nature of plant defense responses to root-feeding larvae at the 2nd instar. Measurements were made on $^{11}CO_2$ fixation, tracer export and allocation as ^{11}C-photoassimilates, transport speed and root exudation of ^{11}C-photoassimilates, and root emission of ^{11}C-VOC's comparing controls to 4-day infested plants. Additionally, changes in new carbon partitioning (as ^{11}C) into primary metabolite pools were measured in source leaves and in roots. Results will be discussed in the context of what is known about plant defenses and what new insights come to light in this system. Research was supported by the U.S. Department of Energy through its Office of Biological and Environmental Research, the USDA, the Swiss National Center of Competence in Research "Plant Survival" and the Neuchâtel Doctoral Program in Organismal Biology.

Host plant adaptation of the deterrent biosynthesis in larvae of Chrysomelina beetles

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Leaf beetle larvae of the subtribe Chrysomelina are able to exploit secondary metabolites from their host plants to create their own chemical defence. The metabolites are transferred from the larval gut lumen into the defensive secretion for further conversion into the deterrents. The ability for sequestration is already present in deterrent *de novo*-producing larvae and we demonstrated that exogenous compounds can interfere with the enzymes of the *de novo*-synthesis. In contrast to the *de novo* producers, the sequestering species specialized more and more in their host plants, e.g. salicin sequestration requires feeding on salicaceous plants. But in the course of Chrysomelina evolution host shifts occurred from Salicaceae to Betulaceae especially in the species *Chrysomela lapponica*. These shifts are mirrored in the secretion composition: willow feeders produce manly salicyl aldehyde and birch feeders manly a cocktail of different butyryl and benzoyl esters. By secretom analyses we revealed that the lack of salicyl aldehyde is due to the loss of the functional enzyme salicyl alcohol oxidase (SAO) which catalyzes the oxidation from the alcohol to the aldehyde. A mutation in the SAO gene is responsible for the loss of SAO activity in the secretion of birch feeders.

ORAL PRESENTATIONS
THURSDAY JULY 28
SYMPOSIUM 2
Images Theatre, 8:40-9:40; 2:20-3:20

Time	Activity	
8:00 – 8:30	*Breakfast* (outside of Images Theatre)	
8:30	Opening/Announcements (Images Theatre)	
	Symposium 2	
8:40 – 9:00		
9:00 – 9:20	**G. Caulier**	
9:20 – 9:40	**U. Röse**	
9:40 – 10:00	**J. Kubanek**	
10:00 – 10:30	*Coffee break*	
10:40 – 11:20	**Conference keynote lecture (symp 2) Gabi Nevitt**	
11:20 – 12:00	**Conference keynote lecture (symp 1 & 2) Rob Britton**	
12:00 – 12:40	Silver Medal Lecture: Paul Feeney (Images)	
12:40-2:20	*Lunch break*	
2:20 – 2:40	**K. Van Alstyne**	
2:40 – 3:00	**C. Amsler**	
3:00 – 3:20	**D. L. Smee**	Jury meeting SSB 7172
3:20 – 3:40		
3:40 – 4:00	*Coffee break*	
4:00 – 5:30	(Images) Annual General Meeting (at 4:00 PM winners of travel awards and the poster/oral competition will be announced)	
7:00	*Gala dinner at the Diamond Alumni Club*	

When a repellent becomes an attractant: harmful saponins are kairomones that maintain the symbiosis between the Arlequin crab and their sea cucumber hosts.

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Saponins are secondary metabolites produced by some plants and animals that use them as defensive repellents. They are well known in sea cucumbers in which they function as a chemical protection against predators. Sea cucumbers however house batches of obligate symbiotic organisms for which host selection is generally mediated by chemical signaling. This study is the first to highlight the precise chemical nature of the specific odor involved in the recognition of a sea cucumber by one of its symbionts. Host choice experiments performed using a Y-tube olfactometer demonstrate that saponins secreted by *Bohadschia vitiensis* are specifically recognized by and attracts one of its most common symbionts, the Arlequin Crab *Lissocarcinus orbicularis*. Conversely, saponins emitted by a non-host species of sea cucumber, *Pearsonothuria graeffei*, are not attractive to the crab. The chemical structure of the different saponins was resolved by mass spectrometry analyses. These analyses show that host saponins lack the sulfate group which is characteristic of most non-host saponins. In addition to their traditional defensive role (allomones), saponins, therefore also function as kairomones, maintaining the symbiosis between the Arlequin crab and its sea cucumber host.

Inducible defense compounds in brown macroalgae

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The brown macroalgae algae *Fucus vesiculosus* are very abundant in the intertidal zones of the coast of Maine despite considerable herbivore pressure. This implies that they may contain defense mechanisms that protect them against herbivore and microbial attack. Phenolic compounds, in particular phlorotannins have been suggested to play an important role as antiherbivore compounds in the Fucales to prevent further grazing but were not found to be inducible in *F. vesiculosus*. We investigated the inducebility of defense compounds in the alga *F. vesiculosus* in response to directly applied stressors like mechanical injury and plant signaling compounds methyl jasmonate under field conditions to determine how quickly these defense compounds are synthesized in the algae. Experiments were carried out in the intertidal zone in Biddeford Pool, Maine. We found quantitative and qualitative differences in the inducible compounds in response to mechanical damage and in response to the signaling compound methyl jasmonate within 6 days compared to untreated algae.

Warding off disease on coral reefs: Antifungal chemical cues in tropical seaweeds

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In many cases, they produce small molecules – natural antibiotics – that prevent colonization or infection by pathogens. We have found that seaweeds produce unusual secondary metabolites against pathogen attack, including complex polyketides and terpene-shikimate macrolides not seen in any other organisms. Surprisingly, these defenses are not distributed evenly across algal surfaces; instead they are concentrated at discrete surface patches where they provide bursts of protection at sites that may be especially vulnerable to infection. We applied surface imaging mass spectrometry to intact algal surfaces to show that antifungal defenses are heterogeneously distributed, with compound concentrations high enough at localized patches to block infection. This patchy distribution may represent an optimal defense strategy, in which the most vulnerable parts of the alga are best defended. Chemical defenses of seaweeds may also serve as valuable leads for pharmaceutical development. Members of one group of algal antifungal agents, the bromophycolides, exhibit potent antimalarial activity with an unexpected mechanism of action, inhibiting growth of the malarial parasite at sub-micromolar concentrations.

Chemical Defense and Toxin Production by Bloom-Forming Seaweeds of the South Salish Sea

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Ulvoid seaweeds, commonly known as sea lettuce, can form large blooms in the South Salish Sea of Washington, USA. These blooms have a variety of detrimental effects on co-occurring algae and animals. The mechanisms underlying their formation and harmful effects include overgrowth and shading, seawater oxygen reduction by the algae and their decomposers, and the production of defensive and/or toxic compounds. Two sea lettuce metabolites are particularly noteworthy for their effects on other species. The first is dimethylsulfoniopropionate (DMSP), a sulphur-containing compound that is used as an osmolyte but whose breakdown products can function in the absorbance of reactive oxygen species (ROS) and feeding deterrence towards echinoderm herbivores. The second is dopamine, which is produced in large quantities by *Ulvaria obscura*, a common bloom constituent. In intact *Ulvaria*, dopamine functions as a

Chemical mediation of predator-prey and mutualistic interactions between macroalgae and invertebrates on the Western Antarctic Peninsula

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Macroalgae dominate hard bottom areas along the Western Antarctic Peninsula to depths of up to 40 m or more. Most of the macroalgae are chemically defended from a variety of macro- and mesograzers but harbor very high densities of amphipod mesograzers. The amphipods benefit from living on the large, chemically-defended macroalgae because they gain refuge from fish which are their primary predators. These amphipods do not consume most of the macroalgal species, but are of benefit to the macroalgae by keeping them relatively clean of epiphytic microalgae and filamentous macroalgae. They do, however, appear to have selected for a relatively high incidence of filamentous algal endophytes in some of the larger macroalgae. These endophytes can be, but are not always, detrimental to the hosts. Hence, overall, this represents a community-scale mutualistic relationship between the dominant macroalgal assemblage and the abundant amphipod assemblage that is mediated, at least in part, by the macroalgal chemical defenses.

Hydrodynamics and Chemical Cues Modulate Indirect Predator Effects in Rocky Intertidal Communities

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In marine systems, predatory interactions are often chemically mediated, and the type and delivery of chemical signals can have significant effects on the perceptive abilities of predators and prey, the outcome of predatory interactions, and the degree and type of top-down forcing. Using a tri-trophic rocky intertidal food chain consisting of the invasive green crab (*Carcinus maenus*) as the top predator, the dog whelk (*Nucella lapillus*) as an intermediate consumer, and the barnacle (*Semibalanus balanoides*) as a basal resource, we investigated how indirect predator effects are modulated by the type of chemical cues emitted and the local hydrodynamic environment. Our results suggest that: 1) dogwhelks react to exudates emanating from green crabs and injured conspecifics by reducing their movements and remaining in refuges, 2) dogwhelks react strongly to their most common predators but not to predators they are unlikely to encounter nor do they respond to injured heterospecifics, 3) turbulent flows affect the frequency of dogwhelk reactions to consumers, 4) fast flows impair green crabs' ability to find and consume prey in the lab and field. From these data, we have created a conceptual model illustrating how top-down forcing is influenced by hydrodynamics in this system.

POSTER PRESENTATIONS
SYMPOSIUM 1

Synthesis and Biological Activity of Conformationally Restricted Gypsy Moth Pheromone Mimics: An Effort for the Better Gypsy Moth Control

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The gypsy moth *Lymantria dispar* L. is a defoliator of forest and shade trees. This destructive insect pest has been plaguing the Northeast U.S. and parts of Canada for more than a century. Previously, toxical chemicals such as lead arsenate, chlorinated hydrocarbons, and carbamates were common for the control of the gypsy moth. Other relatively safe products have also been developed since 1970s. The new generation of products includes Dimilin (an insect growth regulator), the soil bacterium *Bacillus theringgensis*, and the nucleopolyhedrosis virus (NPV). Particularly, one of environmentally friendly products called disparlure has played very important role in the gypsy moth control, both to monitor gypsy moth colonies and to disrupt mating. In nature, female gypsy moths emit the sex pheromone disparlure to attract males. In this presentation, the design and synthesis of a series of conformationally constrained mimics of gypsy moth sex pheromone, (+)-disparlure (*7R,8S*)-2-methyl-7,8-epoxyoctadecane, will be described. Their biological activities and potential use for the better control of gypsy moth will also be discussed.

S1. 1

Aggregation pheromone of larvae of *Chilecomadia valdiviana* (Lepidoptera: Cossidae)

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The wood-borer *Chilecomadia valdiviana* is a polyphagous insect native to Chile associated to bushes and trees. The larval stage feeds on the wood of the host species, boring galleries of up to 27 cm length and 1 cm diameter into the stem, weakening the bole. In a previous study we have identified twelve compounds in extracts obtained by maceration the larvae with hexane and fractionation by chromatography on silica gel [1].
In the present study, we analyzed the responses of larvae to live conspecific larvae, crude larval extract and synthetic samples of major compounds present in the extract: Z5,13-14:Ac, Z5-14:Ac, and 12:Ac. The olfactory response to the different stimuli was determined in a Y-tube olfactometer and the results were analyzed using the non-parametric χ^2 test. Our results provide empirical evidence that the larvae are attracted to live insects, crude extract and the synthetic compound Z5,13-14:Ac.

[1]. Bergmann,J.; Lopez, K.; Buono-Core, G.; *Natural Product Research*. Vol. 21, Nº 5, 473-480.**2007**

S1.2

Field screening for potential attractants for oriental fruit moth *Grapholita molesta* Busck (Lepidoptera: Tortricidae) in fruit orchards.

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Oriental fruit moth (OFM) is the most important pest of commercial fruit orchards worldwide. Peach trees, as the primary host-plants for OFM, can be very attractive for mated females for oviposition, where initially larvae damage young shoot tips and later green fruits. The most often damaged parts of the host-plant may indicate the origin of the oviposition attractant and chemicals identified from these parts could be potential candidates for screening as attractants for OFM. More than 20 individual chemicals were known from literature and identified by GS-MS including aliphatic and aromatic esters, aldehydes, monoterpene, homomonoterpene and sesquiterpenes. Initially all known individual chemicals originated from peach trees were tested in OFM infested pear orchards to minimize interference from natural peach odours in the field. Later different doses of best performing chemicals were tested individually and in various combinations in replicated field trials during OFM flights in pear orchards. Moth catches in traps with tested chemicals was compared to that of the standard TA food trap (terpinyl acetate and fermenting brown sugar solution) used for OFM monitoring. The results of the field screening and possible use of identified attractants for OFM monitoring in orchards will be discussed.

S1.3

Pheromones of *Spathius agrili* and *S. floridanus*: Exotic and native parasitoids of the invasive Emerald Ash Borer.

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The Emerald Ash Borer (EAB), *Agrilus planipennis* (Buprestidae) is a serious pest of ash trees (*Fraxinus* spp.) in the US and Canada. Biological control with natural enemies is the only sustainable method for managing EAB at the landscape level in forests, woodlots, and riparian zones. *Spathius agrili* (Braconidae) has been isolated from EAB in China and was approved for US field release in 2007. Recently, a native parasitoid, *S. floridanus* (Braconidae), was identified attacking EAB larvae, suggesting it may also be an effective EAB biocontrol agent. We identified the pheromones of both species as male-produced blends of 7 and 3 compounds for *S. agrili* and *S. floridanus*, respectively. The two species share a lactone, (*E*)-11-tetradecen-4-olide, but of different chirality. We developed a synthesis for the racemic and chiral lactones as well as racemic and enantiomeric forms of a second lactone, 13-tetradecen-4-olide, which is the major compound in the *S. floridanus* pheromone blend. Blends containing racemic materials performed similarly to enantiomeric pure blends in attracting both parasitoid species using flight tunnel experiments and field trapping in large screen cages.

S1.4

Chemical Ecology studies of *Neomegalotomus parvus* (Hemiptera:Alydidae), an important pest of dried beans in Brazil.

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Neomegalotomus parvus (Westwood) is an important pest of dried beans that causes a significant loss in harvesting this valuable agricultural commodity. The use of semiochemicals has a great potential to minimize the costs of the production and pesticides applications. Therefore, the aim of this study was to identify a pheromone that could be used to manage this insect. Volatiles collections and metathoracic gland dissections of male and female adults were carried out and chemical analyses using GC-FID and GC-MS were conducted. The GC profile showed the presence of three female-specific compounds, and the EAG with male and female antennae showed that both genders responded to a blend of five compounds present in the *N. parvus* female extract. The chemical analysis of these compounds suggests that the two chemicals common to both genders are hexyl butyrate and hexyl hexanoate. One of the female-specific compounds was identified as hexyl pentanoate, and the other two (after saponification of the extract) as 4-methylhexyl hexanoate and 4-methylhexyl pentanoate. The syntheses of these two compounds were conducted, confirming that they are produced by *N. parvus* females.

S1.5

Wine and beer? Just give me vodka!
Synergism vs. potency in defense secretions of true bug nymphs

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One of the characteristics of true bugs (Heteroptera) is the presence of abdominal glands in the immature nymphal stages. These glands usually produce defense chemicals that vary among taxa but still maintain levels of similarity in closely related groups. Learning about the compounds and their prevalence in different taxa can help shed light on the evolution of those chemical defenses. We found that within the infraorder Pentatomomorpha, the secretions of nymphs of the Pentatomoid branch usually contain the hydrocarbon tridecane and a long chain keto-aldehyde as the most abundant components. Nymphs of the Coreoid and Lygaeoid branches contain little or no hydrocarbon, and a high prevalence of shorter chain keto-aldehydes. We hypothesized that the long chain keto-aldehyde would be less potent than its shorter homologs, and that bugs that carry the former would benefit from a synergistic effect of tridecane. To test these hypotheses we used three different behavioral assays using ants. The results show a synergistic effect of the combination of tridecane and the long chain keto-aldehyde while short chain keto-aldehydes were highly effective on their own both at deterring predators and paralyzing or debilitating them.

S1.6

Identification of potential aggregation pheromone components from *Forficula auricularia in situ*

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The European earwig (*Forficula auricularia*) is regarded as a pest in many urban and agricultural environments but a beneficial predator in pome fruit crops. Several laboratory studies have demonstrated that earwigs utilise an aggregation pheromone to mediate interactions within the population. However, verification of the active components of the pheromone is yet to be achieved. The aim of this project was to isolate the putative pheromone components from *F. auricularia* field populations *in situ*. This was achieved by (1) lining cardboard rolls traditionally used for earwig monitoring with borosilicate glass filter paper (2) exposing the rolls to a large resident earwig population within an apple orchard for 24 hours (3) proving aggregation to the pre-treated rolls and (4) GC-MS analysis of the filter papers via thermal desorption to identify putative pheromone components. This experiment successfully demonstrated aggregation to the pre-treated rolls and to date has isolated many saturated and unsaturated hydrocarbons, which may prove to be key components of *F. auricularia*'s aggregation pheromone. On-going experiments are being conducted to determine the bioactivity of the major components to *F. auricularia* adults and juveniles.

S1.7

n-Hexyl laurate and fourteen related esters other than benzoquinones from an unidentified *Anaulaciulus* sp. (Julida: Julidae)

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Millipedes (Diplopoda) belonging to the orders Julida, Spirobolida and Spirostreptida are known to possess methyl- and/or methoxy-substituted 1,4-benzoquinones as defensive compounds . However, no other components have been identified from these millipedes.
In this study a total of 15 saturated fatty acid esters were newly identified from an unidentified *Anaulaciulus* sp. (Julida: Julidae). The well-known benzoquinones, such as 2-methyl-1,4-benzoquinone, 2-methoxyl-3-methyl-1,4-benzoquinone, 2-methoxyl-6-methyl-1,4-benzoquinone (tentatively identified), 2,3-dimethoxy-1,4-benzoquinone, and 2,3-dimethoxy-5-methyl-1,4-benzoquinone were also identified. The fatty acid parts of the esters were composed not only of normal chain acids (from C10 to C14) but also of branched chain acids (from iso-C12 to iso-C15 and anteiso-C15). Alcoholic parts were all composed of normal chain alcohols varying from *n*-butanol to *n*-octanol. *n*-Hexyl n-dodecanoate was the most abundant component (64.7%) in the wax esters. The biological functions of the fatty acid esters, other than substituted benzoquinones, which are defensive substances, were obscure for the *Anaulaciulus* sp.

S1. 8

Impacts of biofuel feedstock crops on atmospheric volatile organic composition and potential consequences for global climate change

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Biogenic volatile organic compounds (BVOCs) influence the atmosphere as potential greenhouse gases and precursors of particulate matter. In this study, we compared BVOC emissions from three potential biofuel crops - miscanthus (*Miscanthus x giganteus*), switchgrass (*Panicum virgatum*) and an assemblage of prairie species- and estimated their theoretical impacts on bioenergy agroecosystems. All crops produced higher levels of emissions at the upper canopy level. Miscanthus produced lowest amount of volatiles. The chemical composition of volatiles differed significantly across plant canopies. BVOCs from miscanthus were depleted in terpenoids. The carbon flux via BVOC emissions, calculated using the flux-gradient method, was significantly higher in the prairie assemblage. The BVOC carbon flux was approximately three orders of magnitude lower than the net fluxes of carbon measured over the same fields by eddy covariance systems. Extrapolation of our findings to the landscape scale leads us to suggest that the widespread adoption of biofuel crops can potentially alter the composition of BVOCs in the atmosphere, thereby influencing its warming potential, the formation of atmospheric particulates and interactions between plants and arthropods.

S1.9

POSTER PRESENTATIONS SYMPOSIUM 3

Analysis of courtship behaviour in the western black widow *Latrodectus hesperus*, with insights into vibratory and chemical signals

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Spiders commonly engage in both vibratory and chemical communication. The western black widow, *Latrodectus hesperus,* uses web-borne vibratory signals during courtship, and likely also sex pheromones associated with male and female silk. As females are much larger than males and highly aggressive, courtship can be a challenge for males. Analysis of video recordings revealed the complex sequence of events involved in courtship. Laser Doppler vibrometry was employed to characterize vibrations associated with elements of male courtship behaviour such as “web reduction”. We found that males engage in vibratory communication and deposit silk in both the distal and proximal phases of courtship, and that females must enter a quiescent state before copulation ensues. Males that engaged in web reduction experienced less aggression and induced female quiescence more quickly than males that did not display this element of courtship. Sexual communication in *L. hesperus* likely begins with attraction of males to a female’s web by a volatile pheromone. Contact with pheromone on the web elicits male courtship behaviour, which produces vibratory and possibly chemical signals that lead to female quiescence and ultimately copulation.

S3.1

What's the buzz about? The role of pheromone and sound in the sexual communication of the raspberry crown borer

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The raspberry crown borer, *Pennisetia marginata* (Lepidoptera: Sesiidae), is a day-flying clearwing moth. Newly eclosed females engage in wing fanning behaviour which produces a distinct humming sound. We tested the hypothesis that females produce both sonic and pheromonal signals during sexual communication. In raspberry fields, paired traps baited with synthetic pheromone [(*E*,*Z*)-3,13-octadecadienal] and equipped with speakers playing back either recorded female wing fanning sound (fundamental frequency: 92.9 ± 1.5 Hz) or silence attracted similar number of male moths, indicating no functional role of sound in the context of communication. Instead, wing fanning may facilitate the release of metabolic waste (e.g., meconium) from the pupal stage and/or raise the thoracic temperature in preparation for flight. Attraction of male moths to pheromone increased with increasing pheromone dose (10 µg to 1000 µg). Bait attractiveness decreased within 6 days of aging, likely due to the unstable aldehydic pheromone. This pheromone instability poses challenges in the development of a pheromone-based monitoring or mass trapping program.

S3.2

Host location by the parasitoid, *Nasonia vitripennis* Walker (Hymenoptera : Pteromalidae)

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Successful reproduction for parasitoids encompasses a series of behavioral steps commonly defined as host-habitat location, host location, host acceptance and host regulation. Successful host location, where resources are patchily distributed within the environment, is dependent on the information value of stimuli used in the host location process. Chemical cues produced by either the host itself, products derived from the host play an important role in host location.

This study investigated the role of odorant cues used during host location by the generalist parasitoid, *Nasonia vitripennis* Walker. *N vitripennis* is a common parasitoid of Dipteran pupae found in association with decaying carrion. The biological activity of eight of the volatile molecules constituting the odour of pupae were tested on the searching behavior of parasitoid females through two complementary chemoecological approaches: electronantennography (EAG) and olfactometry bioassays.

S3.3

Semiochemical-mediated early mate detection in the parasitoid wasp *Pimpla disparis* (Hymenoptera: Ichneumonidae)

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Males of the parasitoid wasp *Pimpla disparis* (Hymenoptera: Ichneumonidae) aggregate on parasitized gypsy moth, *Lymantria d. dispar*, host pupae when the emergence of a prospective mate is imminent or under way. We tested the hypothesis that the developing parasitoid ("DePa") inside host pupal cases produces a pheromone that attracts and arrests mate-seeking males. Results obtained in two-choice laboratory experiments with 4- to 7-d-old virgin males as bioassay insects, indicate that (1) DePa-derived chemicals arrest males, (2) the opening of a host pupal case results in a burst release of chemicals and most strongly arrests males, and (3) the arrestment cue emanates from oral fluids secreted by both female and male parasitoids while they chew their way out of host pupal cases. This rather intriguing phenomenon implies that emerging females, which are haplodiploid and can reproduce without mating, do not engage in pheromone signalling to attract males, and that mate-seeking males instead co-opt chemicals involved in the emergence process as a mate-finding cue. Analyses of the oral secretions by flash silica gel fractionation, GC-EAD, GC-MS, and bioassays of silica fractions indicate that a multiple-component blend induces attraction, arrestment and wing-fanning in males.

S3.4

Stimuli involved in foraging behavior of female and male parasitoids, and impact of temperature exposure to the detection of these stimuli.

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When resources are patchily distributed, the Optimal Foraging Theory (OFT) considers that organisms optimize their behavior by being able to estimate the patch quality. We showed in different parasitoid species that (i) females use different cues to estimate patch quality upon arrival in a patch, (ii) they could estimate its quality relatively to previous patches by learning, (iii) they are also able to update their prior estimate. For male parasitoids, we showed that they also used different cues to exploit patches containing females parasitoids, using a decision-making process close to that described for females during host patch exploitation. Exposure to cold or hot temperatures modifies the behavior of male and female parasitoids, probably due to the alteration of perception of cues. In different parasitoid species, we showed that (i) learning capacities were reduced in female parasitoids after a long cold exposure, (ii) antennal sensilla were physically deformed after a long cold exposure, (iii) patch exploitation strategies by female parasitoids were modified according to the rearing temperature, as well as the chemical defensive behavior of the hosts, and (iv) male parasitoids perception of female odor and male mating behavior were disturbed after prolonged cold exposure.

S3.5

Behavioural and chemical investigation of a contact sexual pheromone in the haematophagous bug *Rhodnius prolixus* (Heteroptera: Redudiidae)

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Insect cuticular lipids (CL) are known to be involved in chemical communication as contact pheromones for mate recognition. We studied the role of CL in mate recognition behaviour in *Rhodnius prolixus*, a Chagas disease vector in Central and northern South America. Specifically, we tested whether males distinguish among intact females (dead and alive) and CL-washed females (dichloromethane) that were re-painted with 1 female equivalent of CL from both, adult and immature (5th instar) females and males. The four CL extracts were also analyzed by GC-MS. The results show that male copulatory attempts (N = 10/group) occurred in presence of alive (88%) and, dead females, either intact (70%) or female-painted (50%). Interestingly, no copulatory attempts were observed to females painted with CL extracts from either adult or immature males, while an intermediate copulatory attempts (20%) occurred toward females painted with extracts from immature females. GC-MS analysis of dichloromethane CL extracts showed differences in the hydrocarbon profile between immature and adult insects, but not between males and females. However, non-hydrocarbon CL were different between males and females (adult and immature), which may explain the gender-related behavioural differences.

S3.6

Filling dynamics of Brindley's glands in the Blood-Sucking Bug *Triatoma infestans* (Hemiptera: Reduviidae)

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When *Triatoma infestans* adults are disturbed, both metasternal and Brindley's defensive glands are discharged. During disturbance, it is possible to observe the secretion emitted from Brindley's glands, and to smell the characteristic pungent odour of isobutyric acid, its main component. We studied the filling dynamics of Brindley's glands both qualitatively and quantitatively. Qualitative analysis was done by observing the glands under a stereomicroscope just after insect disturbance, classifying them as full, partially full or empty. The quantitative study was done by dissection of the glands and GC analysis of their isobutyric acid contents. We compared the gland contents of last instar larvae and newly molted adults, both before and after cuticle hardening. We also studied the capacity of adults to reload the glands under two feeding regimes (fed/unfed), and after one or several gland discharges. The results showed that 5th-instar larvae have fully developed but almost empty glands. In the adult, one discharge is not enough to empty the glands, and even unfed bugs can recover the original gland contents within one week. However, three or more discharges significantly reduce gland contents, and in this scenario only fed insects can fully reload their glands, and hence presumably their optimal defensive capacity.

S3.7

Identification and biosynthesis of fatty acid-amino acid conjugates in *Drosophila melanogaster* larvae and adults

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Fatty acid-amino acid conjugates (FACs) are known elicitors of plant volatiles. Since the discovery of volicitin [*N*-(17-hydroxylinolenoyl)-L-glutamine] from oral secretions of *Spodoptera exigua*, related FACs have been identified from 28 lepidopteran species. *N*-Linolenoyl- and *N*-linoleoyl-L-glutamic acid are also reported in two closely related cricket species (Orthoptera: Gryllidae) and in *Drosophila melanogaster* larvae (Diptera). In this study, we demonstrate the identification of FACs in *D. melanogaster* adults but not in pupae and the in vitro biosynthesis of glutamic acid-type FACs by using larval and adult homogenates. When the homogenates were incubated with sodium linolenate and L-[α-^{15}N] glutamic acid, ^{15}N-labeled *N*-linolenoyl-L-glutamic acid was detected by LCMS and LCMSMS. These results suggest that glutamic acid is conjugated with linolenic acid directly. In the case of the crickets, however, it is reported that L-glutamic acid is not incorporated into FACs and L-glutamine is first conjugates with linolenic acid, and then the amide moiety of glutamine in the conjugate is hydrolyzed to yield *N*-linolenoyl-L-glutamic acid. From these results, we conclude that glutamic acid-type FACs are biosynthesized in different metabolic pathways in the crickets and the fruit fly.

S3.8

Host mediation in a mistletoe's phenotype: interaction with pollinators and pollen movement

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Parasitic plants are physically and chemically linked to their hosts, from which they derive water, nutrients, and a wide variety of primary and secondary metabolites; hence, hosts have the capacity to modify the phenotype of their parasites. We have shown that the mistletoe *Tristerix verticillatus* (Loranthaceae) sympatrically growing within a small area (and hence exposed to similar abiotic and biotic conditions) on three different hosts could be discriminated as distinct chemical populations on the basis of their volatile chemical profiles; furthermore, mistletoe individuals parasitizing one of the three host species received more visits by pollinators when compared to individuals on the other two hosts. In the present study, we compare flower morphology and color, and nectar sugar composition, and assess the pattern of pollen movement between the three mistletoe-host associations.
The results revealed that the host had a significant influence on some flower and nectar traits. Furthermore, the mistletoe-host association that was most attractive to pollinators was indeed that which exported and received most pollen, and such pattern was quantitatively affected by floral offer.

S3.9

An arthropod deterrent attracts a specialized bee to its host plants

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Oligolectic bees are specialized on few closely related plant species for pollen foraging. At the beginning of the flight season newly emerged, naïve females have to find and recognize their specific host-plants to reproduce successfully.
To investigate the importance of floral cues for host-plant finding and recognition in oligolectic bees, we chose *Hoplitis adunca* (Megachilidae), a solitary bee species which is highly specialized on the flowers of *Echium* spp. (Boraginaceae). We hypothesized *H. adunca* to use *Echium*-specific signals to recognize their host-plants. To test the hypothesis, we used a combination of chemical (GC-MS) and electrophysiological (GC-EAD) analyses, spectral reflection measurements and bioassays.
Our investigations showed that the interplay between visual and olfactory cues of *Echium* flowers is essential for host-plant finding and recognition by *H. adunca* females. Colour cues of the flowers attract the bees, while the olfactory cues, which are highly specific floral scent compounds only known from the host-plants of *H. adunca* and as arthropod deterrent, are used by the bees to recognise their host plant and discriminate it from non-host plants.

S3.10

Making "scents" of Apple Clearwing Moth attraction to Showy Milkweed flowers

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The apple clearwing moth, *Synanthedon myopaeformis* (Lepidoptera: Sesiidae), is an exotic day-flying insect pest of apple orchards in British Columbia, Canada. Adult moths were observed nectar-feeding on a diverse array of flower species. In choice experiments in the Similkameen Valley of BC, we determined that showy milkweed, *Asclepias speciosa*, is a preferred nectar source. We then tested the hypothesis that the strong odour and the visual conspicuousness of showy milkweed flowers serve as foraging cues for *S. myopaeformis*. In two-choice field experiments, using plants with or without flowers, we first revealed that moths were attracted to flowers rather than foliage. We then assessed the relative importance of olfactory and visual cues by testing paired plants with or without their visual cues (flowers) obscured by dyed cheesecloth bags. Results clearly indicated that flower odour is the primary foraging cue. Volatiles in Porapak Q extract of floral aerations were analyzed by GC-EAD and GC-MS. Moth attraction to synthetic blends of candidate floral semiochemicals will be tested in field experiments using piezo-electric sprayers to disseminate the blends.

S3.11

Remote-sensing for partner finding: Plant volatiles allow founding plant-ant queens to judge on host identity and quality.

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Judging on the quality of the future partner is fundamental in horizontally transmitted mutualisms, because the decision in most cases is taken only once. We used *Pseudomyrmex* ants that live in a protective ant-plant mutualism with *Acacia* to analyze the responses of founding queens towards host volatile organic compounds (VOCs) at the behavioral level and we seek to use GC-EAG to relate the observed responses to the individual VOCs as analyzed by GC-MS. In choice assays (cage and olfactometer), foundresses discriminated between odors of host and non-host species, thus proving able to identify their hosts using only olfactory signals. *Acacia* plants without ants and intact plants were preferred. Thus, the odors transmit sufficient information to choose a future host that is free of competitors and in a good physiological state, likely allowing the production of high amounts of rewards. In the choice between two host species, the ant queens preferred the high-resource host *A. cornigera* over the low-resource species *A. hindsii*, likely because the first one produces higher amounts of rewards. Interestingly, VOC profiles emitted from the high-resource host were the simplest ones. In this ant-plant mutualism, host VOCs are reliable cues for the remote sensing of host quality.

S3.12

A new Rescue® stink bug trap for both consumer and agricultural markets

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The brown marmorated stink bug (BMSB), *Halyomorpha halys*, was introduced from Asia into the mid-Atlantic region, USA, in the mid 1990s. It has been recorded in a total of 33 states. In recent years, the BMSB emerged as a severe pest of fruit and many other crops across the mid-Atlantic region. In addition, this invasive species is a serious nuisance for homeowners and businesses, as it overwinters in residential houses. Recent USDA studies indicated that BMSB are strongly attracted to a known stink bug pheromone, methyl (*E,E,Z*)-2,4,6-decatrienoate. This pheromone will have a great potential for monitoring and mass-trapping of this serious invasive stink bug, if a simple and efficient stink bug trap is commercially available.

In order to fulfil such an urgent need, Sterling International, Inc. developed a pheromone-based outdoor Rescue® stink bug trap for both consumer and agricultural markets. This trap can also be used during fall/winter as a trapping device of our newly developed indoor trap system for the home-owners. Both our outdoor and indoor stink bug traps will be available at all the major US consumer retailers such as Home Deport, Wal-Mart, Costco, ACE hardware, True Values etc. after July 1st and September 1st, 2011, respectively.

S3.13

Sex pheromone analogs for the control of *Cryptoblabes gnidiella* in vineyards

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Cryptoblabes gnidiella (Lepidoptera: Pyralidae) is an exotic pest in Uruguayan vineyards. The larvae feed on the grapes, causing direct and indirect damage. The sex pheromone of *C. gnidiella* is a mixture of (*Z*)-11-hexadecenal and (*Z*)-13-octadecenal, which are chemically unstable for mating disruption. Stable structural analogs are hence potentially useful for the management of this pest. We have reported that the formate analogs are electrophysiologically active and behaviorally inhibitory in wind tunnel and field studies. Here we present a field experiment to test the potential of these compounds as mating disruptants for *C. gnidiella*. One thousand dispensers loaded with 10 mg of a 1:1 mixture of formates were distributed in a commercial vineyard, leaving an untreated plot of the same grape variety as control. The disruptive effect was evaluated by monitoring male catches in pheromone traps and by examining grape clusters for the presence of larvae. The results show a significant reduction in the number of damaged grape clusters, total number of larvae, larvae/cluster and male catches in pheromone traps. According to our results, the formate analogs of the aldehyde pheromone components of *C. gnidiella* are potentially useful for the management of this pest in vineyards.

S3.14

Chemoecological insights into the sex discrimination and mating behaviour in *Oplostomus haroldi* (Witte), a scarab pest of honeybees

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Evidence suggesting the presence of sex pheromones in scarabs has been documented for Cetoninae, Dynastinae, Melolonthinae and Rutelinae while their identification has only been possible for some member species in the two latter subfamilies[1]. The Cetonid *Oplostomus haroldi* was recently identified as a pest of honey bee colonies in Tanzania and Kenya[2,3]. Behavioral and chemical analyses of this pest failed to show the involvement of airborne volatiles in sex discrimination and mating, suggesting the use of other cues for these behaviors. Field and laboratory observations revealed that males palpate the pronotum and elytra of females with their maxillary palps prior to mounting and copulation, suggesting the use of these body parts for sex discrimination and the involvement of contact semiochemicals. Bioassays, were conducted to investigate this observation using the treatments: a) two freeze-killed females; one 'washed' thrice in hexane to strip off its cuticular hydorcarbons (CHCs) and the other unwashed and b) two freeze-killed 'washed' females; one 'washed' only and the other with fractions of the female extract applied unto its body surface. Female beetles in each treatment were placed at opposite sides of a Petri-dish lined with filter paper and presented to living males to see if they touched, mounted and attempted to copulate with any of the females. Males strongly demonstrated mating preferences for unwashed females and hexane washed females + female extracts than for hexane-washed females with respect to touching, mounting and attempts to copulate. GC-MS analysis of hexane extracts showed that CHC profiles of both males and females were similar, comprising chain lengths ranging from C_8 to C_{29}. Hydrocarbons of chain length between C_{23} to C_{29} were the most dominant and differed quantitatively between the two sexes, suggesting that these hydrocarbons might play a role in sex discrimination and mating in *O. haroldi*. Identification of the behaviorally-active contact sex pheromone will represent the first in this scarab subfamily.

S3.15

Surveillance of Mosquito Vectors of Rift Valley Fever in the Rift Valley of Kenya with Semiochemical Baits

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In recent years, vector-borne zoonotic diseases have received a lot attention, primarily because of sporadic outbreaks of these diseases in various parts of the world including Kenya. Thus there is the need to develop more sensitive monitoring tools to improve surveillance of vectors of these diseases to aid timely response and intervention. In the present study, we investigated the effect of animal volatiles on catches of an existing trap for mosquito vectors of a specific zoonotic disease, Rift Valley Fever, at different sites in two hot spot zones of the disease in Kenya (Baringo and Ijara districts). The treatment-trap combinations used in this study consisted of (a) standard CDC light trap alone (L), and this trap baited with (b) CO_2 (L+C), (c) CO_2 and animal volatiles (L+C+F), and (d) animal volatiles (L+F) alone. Overall, trap catches from L+C and L+C+F were significantly higher than those trapped by L+F and L only traps. Similarly, L+C+F traps recorded higher mosquito catches than L+C traps but the captures recorded for the two treatments were not significantly different. Mosquito densities and diversity differed among the ecologically distinct sites and catches in the different treatment-traps indicated abundance rather than preference for particular species. Traps baited with C+F trapped mosquitoes only suggesting that this treatment combination has the potential to reduce the time and resources required to sort and process trapped insects for arbovirus detection. GC-EAD analysis of animal odours showed several antennally-active components with antennae of five different mosquito vectors of RVF. Some of the antennally-active compounds have been identified by GC-MS and confirmed with authentic standards. Blends of these compounds are under investigation for behavioural activity.

S3.16

POSTER PRESENTATIONS SYMPOSIUM 7

Tannins in soil systems

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The plant natural products known as tannins are widespread, abundant compounds that enter soil systems via plant decay, leaching and rain throughfall, . While the defining characteristic of tannins is their ability to bind protein, tannins and other phenolics also chelate metals and reduce redox-active metals. It has been suggested that reactions between metals and tannins are critical to soil podzolization, humic substance formation, nutrient availability and mediation of metal toxicity in natural soil systems. We have examined sorption of polyphenolics to soils, and complexation reactions between tannins or small phenolics and metals in aqueous systems. We discuss these reactions in the context of transport and transformation of tannins in the environment and bioavailability/toxicity of metals such as Fe and Al. We suggest that improving our understanding the mechanisms of tannin-metal interactions could help us understand the function of plant tannins in mediating soil formation, fertility, and microbial activity.

S7.1

Exocrine glands of wheel bugs (Heteroptera: Reduviidae: *Arilus* spp.): Clarification and chemistry

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Wheel bugs (Heteroptera: Reduviidae: *Arilus*) are general predators, one of which (*A. cristatus*) is attacking the invasive brown marmorated stink bug in the U. S. Adult *Arilus* females have posteriorly evertible reddish orange osmeterial glands. The modern English literature on *A. cristatus* incorrectly attributes the rancid odor detected when they are collected to their osmeterial glands. Actually, the rancid odor is due to simultaneous emission of Brindley's gland secretions, which in the North (*A. cristatus*) and South (*A. carinatus*) American wheel bugs are blends of 2-methylpropanoic, butanoic, 3-methylbutanoic and 2-methylbutanoic acids. The predominant *A. carinatus* volatile osmeterial components are *(E)*-2-octenal, *(E)*-2-nonenal, *(E)*-2-decenal, *(E,E)*-2,4-nonadienal, *(E)*-2-undecenal, hexanoic acid, 4-oxo-nonanal, *(E,E)*-2,4-decadienal (and an isomer), and 4-oxo-*(E)*-2-nonenal. In *A. cristatus*, the osmeterial secretion has a pine-like odor yet to be fully characterized. Brindley's glands are defensive, and eversion of the osmeterial glands may enhance the aposematic display associated with the painful bite of wheel bugs and noxious Brindley's gland acids. The primary function of *Arilus* osmeterial gland secretions may be the production of sex pheromones, but this hypothesis awaits testing.

S7.2

Improved trap design for longhorned beetles (Coleoptera: Cerambycidae)

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Survey and detection tools are integral components of management programs for longhorned beetles (Coleoptera: Cerambycidae). Our objective was to examine the design features that influence cerambycid trap capture efficiency.
Like previous studies we observed that: (1) trap design had an effect on cerambycid trap catches (standard multiple-funnel traps captured more cerambycids than both panel and stovepipe traps); (2) treating panel traps with a lubricant increased cerambycid trap catches; and (3) multiple-funnel traps with wet cups captured more cerambycids than traps with dry cups. This study also observed that: (A) panel traps treated with an aerosol Teflon formulation were as effective as Fluon treated panel traps; (B) multiple-funnel traps treated with Fluon and the aerosol Teflon formulation captured more cerambycids than untreated multiple-funnel traps; (C) there was no difference between the number of cerambycids captured by Fluon and Teflon treated multiple-funnel traps; (D) lubricant treated multiple-funnel traps captured as many cerambycids as lubricant treated panel traps; (E) treating a dry cup with Fluon did not reduce escapes; and (F) adding a large collar treated with Fluon to the bottom funnel of a multiple-funnel trap increased cerambycid trap captures (untreated collars had no effect on trap catches). These results suggest that it may be possible to increase the trap capture efficiency of multiple-funnel traps in operational settings.

S7.3

The relationship between maturation and contact pheromones for *Monochamus scutellatus* (Coleoptera: Cerambycidae)

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Pheromones are important in mate location and species recognition in insects. It is well known that contact pheromones play a key role in locating a mate for cerambycids. In this study, investigations were conducted to find a relationship between maturation and contact sex pheromones. GC-MS analyses of whole-body extracts of maturation-fed females, unfed females and maturation fed males provided evidence that nutritional conditions influence the cuticular profile and potentially signal female maturation to males. These results indicate that contact pheromone communication varies throughout maturation in female *M. scutellatus*.

S7.4

A male-produced aggregation pheromone of *Monochamus alternatus* (Coleoptera:Cerambycidae), a major vector of pine wood nematode

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The Japanese pine sawyer (JPS), *Monochamus alternatus* Hope (Coleoptera: Cerambycidae), is an efficient vector of pine wood nematode, the causal pathogen of pine wilt disease, which has resulted in devastating losses of pines in much of Asia. We assessed the response of adult JPS to a male-produced compound in field experiments in Fujian Province, P.R. China. Both sexes of JPS were attracted to lures consisting of the pheromone combined with alpha-pinene and ethanol. A follow-up experiment showed that the pheromone was synergized by both ethanol and alpha-pinene. GC-MS analyses of volatiles collected from field-collected beetles of both sexes revealed that the pheromone was produced only by males. The combination of the pheromone with ethanol and/or alpha-pinene will provide a valuable and badly needed tool for quarantine detection, monitoring, and management of JPS.

S7.5

Sex pheromone components of the box tree pyralid, *Glyphodes perspectalis* and field test in Korea

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Box tree pyralid, *Glyphodes perspectalis*, is the most serious pest of box tree in Korea, and was recently introduced into Europe. The pheromone components of this moth have been identified as (*Z*)-11-hexadecenal (Z11-16:Ald), (*E*)-11-hexadecenal (E11-16:Ald), and (*Z*)-11-hexadecenol (Z-11-16:OH) in Japan. In this study, we identified pheromone components of this species by using GC and GC-MS. Three same components, such as (*Z*)-11-hexadecenal (Z11-16:Ald), (*E*)-11-hexdecenal (E11-16:Ald), and (*Z*)-11-hexadecenol (Z-11-16:OH) were also indentified in Korean population, but there was a little difference in ratios. The ratios of these three compounds of Japanese population and Korean population were 5:1.25:1, and 5:0.96:0.2, respectively. The ratios of Z and E-11-hexadecenal were similar, but the ratio of (Z)-11-hexadecenol was lower compared to Japanese population. In field bioassay, (*Z*)-11-hexadecenal or (*E*)-11-hexadecenal alone was not attractive to males, but the mixture of Z11-16:Ald and E11-16:Ald was attractive to males. The most effective ratios of Z11-16:Ald and E11-16:Ald was 5:1. Other ratios such as 1:1 and 1:5 (Z:E) was not attractive to males. The attractiveness of Z:11-16:OH will be tested in near future.

S7.6

Water stress-induced changes in spruce volatiles

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Drought has long been known to have profound effects on the resistance of forest trees to insect pests. Insect orientation to host trees is often mediated by biogenic volatile organic compounds (BVOC's), therefore it is reasonable to study the effect of drought on BVOC production to understand how these factors affect the insect host plant selection.
Though primary attraction of *Ips typographus* to spruce host has not yet been unequivocally documented, it is well known that bark beetles of this species are strongly attracted to fallen trap trees and can localize them in a long range. In order to determine candidates for Norway spruce host kairomones, we analysed BVOCs from drought stressed trees and from fallen trap trees. Our data show that BVOCs composition of individual spruce trees is highly variable. Intact living trees produce low amounts of BVOC's in comparison with trap trees, where the released spectrum of BVOC's is much higher and more diverse depending on time after cutting down. We have found many antennally active BVOC's from trap trees. Majority of these compounds are present also in both water stressed and non-stressed trees, however the quantitative parameters differ between the three categories.

S7.7

Does jack pine defoliation elicit tree-tree communication?

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Airborne mediated interplant communication is not well documented in conifers, nor is it clear whether conspecific neighbours can interpret these signals to their advantage. In the greenhouse, defoliation of seedlings by jack pine budworm larvae stimulated airborne communication. Volatile collections and GC-MS analyses of monoterpenes were used to determine the effects of defoliation and mechanical wounding treatments. In order to address questions of intra-plant communication, samples were also taken from defoliated and undefoliated branches of the same tree. Results show that there may be a threshold of defoliation intensity at which plants respond on a systemic level. The treated seedlings and their untreated (primed) neighbour were then inoculated with a fungal symbiont of mountain pine beetle to test if the primed neighbours have a different response to this challenge than un-primed yet inoculated controls. Fungal lesion lengths were compared between treatments after 8 weeks. Chemical extractions from needles and phloem tissue were also analyzed to determine differences in chemical response among seedlings. Preliminary results show differences between controls and the primed neighbours of treated seedlings, though mechanisms of this response are yet to be determined.

S7.8

Effect of different environmental conditions on plant defenses mediating interactions between the mountain pine beetle and its host pine trees

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The Mountain Pine Beetle (*Dendroctonus ponderosae*) has killed millions of lodgepole pine (*Pinus contorta*; historical host) trees in British Columbia, Canada and has moved eastwardly into the hybrid zone of lodgepole x jack pine (*Pinus banksiana*) and more recently into jack pine in Alberta. Our objectives were (1) to develop a chemical profile of volatile organic compounds (VOCs) released from the host trees (*P. contorta*, *P. banksiana*); (2) to evaluate if VOC profiles vary with different environmental (ambient vs. water deficit) and biological (fungal inoculation with *G. clavigera* vs. control) treatments.
Fungal-inoculated trees released more overall monoterpenes than control trees. Lodgepole pine emitted higher amounts of monoterpenes than jack pine. The effect of water regime on overall volatile emission seems to be species or site specific. Lodgepole and jack pine trees that experienced ambient water conditions emitted more and less total VOCs, respectively, than trees subjected to water deficit for each species. Chemical analysis of the phloem is in process to evaluate the impact of environmental and biological treatments on the chemically-mediated interactions between MPB and its host trees.

S7.9

Review of the chemical ecology of *D. brevicomis*: Implications to development of a semiochemical-based tool for tree protection

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The western pine beetle, *Dendroctonus brevicomis* LeConte (Coleoptera: Curculionidae, Scolytinae), is a major cause of ponderosa pine, *Pinus ponderosa* Dougl. ex Laws., mortality in much of western North America. Verbenone was first identified in male *D. brevicomis* by Renwick (1967) and was later demonstrated to reduce attraction of tethered, flying *D. brevicomis* females (Hughes and Pitman 1970). Bedard et al. (1980) showed that verbenone reduced the number of *D. brevicomis* trapped at a baited source. Trap catches were further reduced by combining verbenone with ipsdienol (Paine and Hanlon 1991), the latter of which is produced by male *D. brevicomis* (Byers 1982) among other bark beetle species. In western coniferous forests, research has concentrated on the use of antiaggregation pheromones to reduce host finding success for purposes of developing tree protection tools, but more recently scientists have begun to fully explore the chemical environment of forests; and to use systems level thinking in development of semiochemical-based tools and tactics for tree protection (Shepherd et al. 2007).

S7.10

Conifer resistance reduces aggregation pheromones of spruce bark beetle

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Conifers have multiple constitutive and inducible resistance mechanisms against bark beetles and their associated fungi [(1)]. A few studies speculated host defenses possibly interfered aggregation of bark beetles [(2)], but whether or not tree resistance affect beetle pheromone production is still unknown. In the present experiment, we treated Norway spruce (*Picea abies*) stems with methyl jasmonate (MeJA) to induce tree defense, and then measured the amounts of 2-methyl-3-buten-2-ol and (S)-*cis*-verbenol, the two main components of the beetle's aggregation pheromone, released from beetle entrance holes in MeJA-treated and untreated Norway spruce logs. As expected, phloem terpene levels were higher and beetle tunnel length was shorter in MeJA-treated logs relative to untreated logs. In addition, beetles in MeJA-treated logs released significantly less 2-methyl-3-buten-2-ol and *cis*-verbenol, and the ratio between the two pheromone components was significantly altered. These results suggest that host resistance elicited by MeJA application reduce pheromone emission by *I. typographus* and alter the critical ratio between the two main pheromone components needed to elicit aggregation.

1. New Phytol. 167:353–376. 2. Oecologia 148:426–436.

S7.11

exo-Brevicomin biosynthesis in the mountain pine beetle

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exo-Brevicomin is a male-specific aggregation pheromone component of the mountain beetle. It is likely derived via a cytochrome P450 catalyzed epoxidation of the known precursor, (6*Z*)-non-6-en-2-one, followed by cyclization. (6*Z*)-non-6-en-2-one is believed to be produced from a fatty acyl precursor. GC-MS analysis confirmed that male fat bodies converted tri-deuterated decanoic acid to nonan-2-one via α oxidation, strongly implicating that 10:1 fatty acid is the direct precursor to (6*Z*)-non-6-en-2-one, and that there is no desaturase for short chain fatty acid in the male fat body. Microarray and quantitative real-time PCR analysis showed that *CYP6CR1*, a cytochrome P450, is highly expressed in the fat body of unfed males, consistent with GC-MS analyses showing that unfed male fat bodies specifically produce *exo*-brevicomin. These data strongly implicate CYP6CR1 in *exo*-brevicomin biosynthesis. To confirm this, we expressed functional CYP6CR1 in Sf9 (insect) cells using a baculovirus expression system. Functional assays with non-labelled and penta-deuterium labelled (6*Z*)-non-6-en-2-one showed that CYP6CR1 epoxidized (6*Z*)-non-6-en-2-one into the direct epoxide precursor of *exo*-brevicomin. Investigation of the final step of *exo*-brevicomin production is underway.

S7.12

Sight over substance: Insight into cues governing host-location of *Hylobius warreni* Wood

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The Warren root collar weevil (*Hylobius warreni* Wood) is a native, long-lived, flightless insect that feeds on a variety of conifers. While adult feeding does not typically damage mature trees, larval feeding at the root collar can girdle and kill young trees. In recent years, mortality due to larval feeding has become an emerging concern in western Canada, especially in areas where lodgepole pine has been replanted in the wake of salvage harvesting within the mountain pine beetle epidemic. Little is known, however, about the cues used by Warren root collar weevils in finding and orienting to their hosts. Laboratory experiments in Y-tube olfactometers with fresh host material demonstrated that adult insects were thoroughly bored and uncooperative with our hypotheses on chemo-attraction. Subsequent field experiments with visual silhouettes in the absence of chemical cues indicated that host orientation may be primarily visual. Long-range chemical attraction may be unimportant for this insect, which does not need to rapidly sample host cues because it is presented with a low number of choices as it walks rather than flies.

S7.13

POSTER PRESENTATIONS
SYMPOSIUM 4

Alfa-solanine effect on potato cyst nematode *Globodera rostochiensis* and *Globodera pallida* second-stage juveniles

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Potato cyst nematodes *Globodera rostochiensis* (Wollenweber, 1923) Berhens, 1975 and *Globodera pallida* (Stone, 1973) Berhens, 1975 are major pests causing losses of potato harvest worldwide. Alfa-solanine is among the most specific secondary metabolites of potato plants (Friedman, McDonald, 1997, Friedman, 2006). The compound is also known as hatching factor of *G. rostochiensis* (Devine *et al*., 1996).
Behavioral tests were carried out to reveal effect of alfa-solanine on the invasive stage (second stage juveniles move to host roots) of the two species of potato cyst nematodes. Bioassay was carried out in Petri dishes and alfa-solanine concentrations (in ethanol) in the range from $1x10^{-4}$ to $1x10^{-7}$ M were tested, potato root diffusate, ethanol and water were used as controls (1µl of each). In 15 min assay statistically significant attractivity in *G. pallida* was recorded, but not in *G. rostochiensis*. In 30 min test attractivity of alfa-solanine close to that of PRD was revealed in *G. rostochiensis.* This indicates that alfa-solanine is attractive for both species of potato cyst nematodes, however behavioral reaction in *G. pallida* was expressed earlier compare to *G. rostochiensis.*
By today two attractants are known for potato cyst nematodes: linalool (Buda, Cepulyte, 2010) and alfa-solanine (present publication). Reaction to the compounds differs: *G. rostochiensis* is more sensitive to linalool, and *G. pallida* is likely to be more sensitive to alfa-solanine.

S4.1

Partition, sorption and biodegradation of dialkoxybenzenes that modulate insect behavior.

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Plant protection is an important part of modern agriculture, in which high-yielding crop varieties are at risk of disease and pest attack. Non-biodegradable insecticides, which are commonly used to control agricultural pests, have become a major pollutant in the environment since the early 20th century. Thus, there is a need to find compounds which are biodegradable as well as pest-controlling at low doses. Dialkoxybenzenes can be used as new insect control agents for agriculture. Some of these compounds mimic naturally occurring odorants that modulate insect behavior. Before applying these compounds, however, their persistence and biodegradability at the application site and in the environment should be understood. The fate of organic compounds in the environment is a complex phenomenon which is influenced by many processes such as sorption to soil components, volatilization, uptake by plants, as well as biotic and abiotic chemical degradation. In this study, the octanol-water partition coefficient, volatility and sorption on soil components (sand, clay and organic matter) of selected dialkoxybenzenes were investigated. Biodegradation and toxicity experiments with soil bacteria are also underway, and results from these tests will be described.

S4.2

Microbes associated with Pine weevil (*Hylobius abiets*)

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The large pine weevil (*Hylobius abietis L.*) is a severe pest of conifer seedlings in reforestation areas. They lay eggs in the soil close to, or inside, root barks of freshly died trees and place their feces and wood pieces (frass) along with the eggs to protect them from predation. We have isolated microbes (fungi, yeast and bacteria) from the feces and frass of pine weevils collected under sterilized conditions using frass in agar as culturing media. Isolated strains were identified by 16S rRNA as *Penicillium spp.*, *Ophiostoma spp. Leptographium spp*. and *Candida spp*. Volatiles were collected from isolated microbes grown on natural frass liquid culturing media using HS-SPME and GCMS. Major compounds were identified by comparing with NIST library and comparing retention time to pure compounds. Major compounds released from *Penicillium spp* were styrene, isopentyl methylether, 3-methylanisole, 3-octanol, 3-octanone, 1-octene-3-ol. *Ophiostoma spp* produced e.g. methyl salicylate, benzyl alcohol and methyl-4-isopropylbenzoate of which several had antifeedant properties for the pine weevil.

S4.3

Interaction of indolyl and phenyl phytoanticipins with cruciferous pathogenic fungi

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Economically important cruciferous plants (e.g. canola, mustard, cauliflower, cabbage, turnip) produce complex blends of constitutive and induced secondary metabolites with diverse ecological roles, which include self-protection against fungal pathogens, pests and other sorts of stress. For example, glucosinolates are constitutive secondary metabolites with important functions, including defense against various pests such as insects, whereas metabolites resulting from enzymatic degradation of glucosinolates have been shown to be strongly antifungal. On the other hand phytopathogenic fungi are able to overcome plant chemical defenses through metabolism and detoxification, utilizing detoxifying enzymes which makes the plant susceptible to pathogens. To better understand the roles of glucosinolates (e.g. glucobrassicin, 4-methoxyglucobrassicin, 1-methoxyglucobrassicin, phenylglucosinolate and benzylglucosinolate) in the interaction of crucifers with fungal pathogens, their metabolism and that of their enzymatic products by phytopathogenic fungi (*Sclerotinia sclerotiorum, Rhizoctonia solani* and *Alternaria brassicicola*) is under investigation. It appears that glucosinolates are not metabolized and do not display antifungal activity; however, their most antifungal derivatives are transformed via different pathways. Details of this work will be presented and the potential role of indole glucosinolates in the interaction of cultivated crucifers with their fungal pathogens will be discussed.

S4.4

Earthworms smell microorganisms in soil

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Extensive research has documented the role of olfactory cues in mediating aboveground ecological interactions among plants, microbes, and invertebrates. Recent work suggests that such cues play similarly important and complex roles in below-ground interactions, but we are only beginning to understand the chemical ecology of these systems. Earthworms are known to possess chemoreceptors and previous studies have demonstrated their ability to orient and move toward microbial food sources, but the specific chemical cues guiding earthworm foraging have not previously been documented. We found that *Eisenia fetida* were attracted to the filtrate derived from *Geotrichum candidum* colonies, as well as to two individual compounds tested in isolation: ethyl pentanoate and ethyl hexanoate. We also confirmed that worms were attracted to volatile forms of these compounds, that attraction occurs over considerable distances (~1m), and that these cues can be used to attract worms to the soil surface. In addition to elucidating the sensory cues that guide earthworm feeding behavior, these findings have potentially important implications for vermicomposting and other agricultural applications.

S4.5

POSTER PRESENTATIONS SYMPOSIUM 8

Common bean seed resistance to bean weevils and parasitoids: a new arcelin variant

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Seeds of common beans, *Phaseolus vulgaris*, contain a family of closely related proteins, APA proteins (i.e. Arcelin, Phytohemagglutinin, a-Amylase inhibitor), which are considered to play a role in plant defence. Arcelin has been associated with resistance against bean weevils. We investigated the variability of these defence proteins in wild *P. vulgaris* seeds, and assessed their effect on performance of different bean weevil species, and an ectoparasitoid. Beans were field collected, defence protein content was analysed and insect performance was measured. From some bean populations fewer, less heavy beetles emerged and developmental time was significantly longer. Defence proteins in seeds of suboptimal beans could prolong beetle larvae development. This was confirmed in one population by two dimensional IEF/SDS-PAGE and LC-MS/MS analyses that showed a new arcelin variant is present in the seeds.

S8.1

The evolution of honest and dishonest HIPV signals in tritrophic system

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The evolution of Herbivore Induced Plant Volatiles (HIPV) shares common traits of the evolution of language. In the evolution of language, the mutation is the change of symbols and the natural selection is the mutated symbols are understandable and become widely used. And in the evolution of HIPV, the mutation is the change of volatile chemicals and the natural selection is the mutated HIPV is understandable and become widely used in the eco-system. By mutations, a plant changes the response to its feeding damage; we assume that a plant produces HIPV when it has large feeding damage and there are enough herbivores for predators (we will call such a plant as "honest plant"), but by the mutation these plants are able to changes their response and they produces HIPV even if there are not enough herbivores (we will call such a plant as "cry wolfer"). We model this system in 2-diminutional space by using cellular automaton and confirmed that various special pattern of HIPV emerged.

S8.2

Exploring the transcriptomes of leaf beetles to identify putative genes involved in larval defense

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During leaf beetle evolution, larvae of some species have developed the ability to use glucosides of their host plants to produce their own defensive compounds. Until now, little is known about the molecular basis of the sequestration process of these compounds or the relevant transporters.
Because of lacking genomic data of this non-model organism, a cDNA library of *Phaedon cochleariae* transcripts was sequenced using 454 sequencing technology. The resulting fragments and additional Sanger sequences (ESTs) have been *de novo* assembled to reconstruct the transcripts and to build up a transcriptome. Additionally, the transcripts of various tissues of *Phaedon cochleariae* as well as *Chrysomela populi* were sequenced using Illumina sequencing technology. After mapping the sequence reads onto *P. cochleariae*'s transcriptome as well as the *de novo* assembly of *Chrysomela populi*'s transcriptome, the transcript levels will be compared using R statistics (Bioconductor) to identify putative (tissue specific) transporters, as well as putative enzymatic proteins involved in the sequestration process of the defensive compounds.

S8.4

Specifics and genetics of sexual attraction in *Spodoptera frugiperda*

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The noctuid moth *Spodoptera frugiperda* consists of two genetically and behaviorally different but morphologically indistinguishable strains: the corn- and the rice-strain. Both strains reveal several reproductive isolation mechanisms and thus seem to be in the process of sympatric speciation. We found strain-specific female sex pheromone differences as well as differential attraction of males toward synthetic sex pheromone lures in the field. Corn and rice females differ in the relative amount of the critical component Z7-12:Ac, which correspond to strain-specific male responses. This indicates that strain-specific variation in sexual attraction is another prezygotic mating barrier between both strains that could further drive divergence between the strains. One complication in understanding strain divergence in *S. frugiperda* is geographic variation within both strains. By conducting male trapping experiments in several geographic regions in the Americas (Florida, Puerto Rico, Peru, Argentina) we aim to disentangle geographic variation from strain-specific variation in this sexual communication system. In addition, we are establishing a QTL map to find the genetic basis of strain-specific female pheromone differences using RAD sequencing.

8.5S

Protein profiles of larval and adult mountain pine beetles infesting lodgepole pines

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Upon encountering a new host tree, adult mountain pine beetles, *Dendroctonus ponderosae*, must detoxify host secondary metabolites and produce pheromones to coordinate a mass attack. Following successful reproduction, larval beetles survive in phloem tissues saturated with the constitutive and induced chemical defences left behind from the colonization phase. We surveyed expressed proteins in adults feeding in phloem tissue compared to starved adults; and in larvae ranging in age from early larvae to just prior to pupation. In total, we detected ~750 proteins each in males and females (~49 of which showed significant differences between treatments) in the feeding experiment. We also detected ~1000 proteins each in early and late instar larvae (~690 of which showed significant differences between time points). Comparisons to a mountain pine beetle genomic database allowed us to make predictions of protein identity. Proteins of interest in the feeding experiment included those with potential function in detoxification, odorant binding, and endocrine and reproductive physiology. Proteins of interest in developing larvae included some with potential function in detoxification, odorant binding and other chemosensory functions, isoprenoid biosynthesis, and endocrine physiology.

S8.6

POSTER PRESENTATIONS
SYMPOSIUM 5

Interactions between ants and termite soldiers: does fighting influence the chemical signatures?

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Interactions between social insects are very complex. This study focused on understanding the interactions of subterranean termites with their immediate environment, for example with ants. A recent study showed that colonies of *Hypoponera eduardi,* living commensally in their nests, altered their chemical signatures (cuticular hydrocarbons (CHCs)) depending on the termite species with which they were in contact, but no clear differences in aggressiveness in dyadic encounters between ants and termite workers were seen. This raises other questions. Does *H. eduardi* predation strategy change in an encounter with *Reticulitermes sp*. soldiers? Does the ant's chemical signature change after a fight? An experiment using solid phase microextraction (SPME) was carried out to analyze the CHCs of ants before and after fights combined with behavioral observations. The results are being analyzed but it has already been observed that the ant behavior varied from attack to retreat, depending on the colony. The chromatograms revealed a significant transfer of the termite signature to the ants during fighting, decreasing rapidly the following day. The study of the plasticity of the chemical signature and the predation strategy of ants and termites will provide greater understanding of such complex interactions.

S5.1

Strepsiptera, their sex pheromone and its possible biosynthesis in female body

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The *Strepsiptera* are rare endoparasites of various insects including bees. We studied the mating system of *Stylops* nr. *melittae*, parasite of the solitary bee *Andrena vaga*. The *Stylops* female is not leaving host, and protrude from it only cephalothorax. It is filled with Nassonow's gland producing the sex pheromone[*], in order to attract males. Adult males leave the host bee on the first warm spring day, and, according to their life span of few hours only, they have just few chances to mate.Differences between Strepsiptera sexes are enormous. While males look like weird but recognizable insects, adult females are larviform, and only cephalothorax and abdomen concealed in the bee are recognizable. Abdomen is filled with the eggs and the fat body cells (adipocytes). Adipocytes contain energy storage for developing larvae, and also precursors for pheromone biosynthesis. Sex pheromone is not representative natural compound. Although aldehydes are common pheromones, tri-methyl-branched aldehyde of *Stylops* belongs to singular structures. Here we report on the quantity of pheromone in the virgin females, as well as on the presence of unusual branched fatty acids in the female fat body triacylglycerols, sharing similar skeleton with the sex pheromone.
[*]*Reference*: Lecture of T. Tolasch on the ISCE 2010 Meeting in Tours (p. 176 in book of abstracts)

S5.2

Nest wax signals mirror the social status of bumblebee colonies

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In the primitively eusocial bumblebee *Bombus terrestris* workers are capable of laying unfertilized eggs. Nonetheless, they refrain from own reproduction in favor of their mother's progeny during the social phase (sp) and compete for reproduction only at the end of the breeding season (competition phase cp). Timing the onset of worker reproduction is crucial as it is not in the workers' interest to decrease gyne production. In this study we examined the signaling means of nest wax and its influence on the onset of worker reproduction.
Analyzing the chemistry of nest wax at different stages of colony development we found aldehydes, alkanes, alkenes, and wax type esters – the same substances, that are displayed on the cuticle surface of female bumblebees. The composition of these substances varied between sp and cp. From behavioral assays we found, that workers start to compete for reproduction despite the presence of a queen when facing a cp wax environment. Effecting bumblebee worker reproduction, nest wax scent might be a very potent communication device also in other areas of social insect life as it is an information source accessible to all colony members at all times.
– We thank the Carl Zeiss Stiftung and the DFG for financial support.

S5.3

Historical biogeography: consequences on sexual pheromones evolution among bumblebee species

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Divergence in sexual pheromones (SP), is considered as main force promoting the speciation. The sexual signal is under a strong stabilizing selection which avoids reproductive interference with sister species. Studies suggest that SP evolve by major saltational shifts in chemical composition which increase the divergence of SP between two young species to avoid mismating. However, the sexual selective pressure can decrease if taxon is allopatric from its sister species because individuals with some small pheromonal changes cannot mismate. The evolution becomes a gradual evolution (small changes are not eliminated by selective pressure). Therefore, the species biogeography influences the evolution of sexual pheromones. However, the present biogeography is consequences of historical biogeography. Moreover, to understand the premating signals evolution, steps before the speciation in the intraspecific level must be known.
The present study deals with this evolution by a comparison of the historical biogeography (phylogeography and molecular clock) and SP geographic variations (chemical analyses) of three *Bombus* (*B. pascuorum*, *B. lapidarius* and *B. soroeensis*) and their sister species.

POSTER PRESENTATIONS
SYMPOSIUM 6

Agonists and Antagonists of Olfactory Responses: Tools for the Study of Insect Olfaction

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Insects perceive a myriad of odours from their environment, including pheromones and kairomones. We have synthesized analogs of the gypsy moth (*Lymantria dispar*) pheromone and of plant odorants, and we have tested these on their own as well as mixed with odours known to be detected by various species of moth. Here we will present results obtained with the gypsy moth. Electroantennogram (EAG) studies have revealed that the analogs can have three types of activity. First, the analogs can be odorants themselves. Second, when mixed with the pheromone, some compounds either enhance or diminish the extent of depolarization of the antenna, relative to the pure pheromone. Third, when mixed with the pheromone, some compounds either accelerate or slow the recovery of the antenna, relative to the pure pheromone. We have attempted to interpret a potential mechanism of the agonists and antagonists, based on structure-activity relationships (SAR) and *in-vitro* experiments.

S6.1

Lipid Analysis of the Gypsy Moth: a look into chemical communication

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Insects make use of small molecule compounds for intra-species communication. In the case of the gypsy moth, the adult male makes use of the innervated sensory hairs covering his antennae to induce an electrochemical signal resulting in olfaction. These hairs contain high concentrations of lipids. The interaction of these lipids with the most prominent protein in the sensory hairs, pheromone binding protein (PBP), as well as with the major component of the female's pheromone blend ((+)-(7R,8S)-2-methyl-(7,8)epoxyoctadecane) is of interest here. The majority of the lipids in the sensory hairs will be found in the biomembrane sheathing the olfactory neuron. The composition of the biomembrane is inherently related to its function. Then, if the sensory hairs employed for olfaction by the gypsy moth are so rich in lipids, their composition is likely integral in chemical signaling. Analysis of the major lipid classes and total fatty acids, by a variety of chromatographic techniques, mass analysis and NMR, has revealed sensory-specific species. Analysis has also revealed the lipid composition of various other tissues, having sensory hairs and known to contain PBP, to be very closely related to that of antenna. This suggests that pheromone olfaction may not be specific to the antenna.

S6.2

Characterization of molecular regulation mechanisms of the PBAN/Pyrokinin receptors in the pest moth *Helicoverpa armigera*

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Moths, which are active at night, rely on sex-pheromonal communication to attract conspecifics for mating. In most moth species, males perceive a species-specific sex-pheromone blend broadcasted by the female during calling behavior. The sex-pheromone biosynthesis pathway in female moths produce and release species-specific sex-pheromone components to attract conspecific males is known to be activated by binding of pheromone biosynthesis activating neuropeptide (PBAN) to its receptor (PBAN-R). The current study revealed that PBAN-R or a PBAN-like/pyrokinin receptor is not merely limited to the pheromone gland but is expressed, although at lower levels, both in neural tissues and surprisingly in the reproductive organ of males. Thus, an age-dependent pattern of PBAN-R gene transcript levels was shown in males. Consequently, this study demonstrated for the first time the functional significance of the PBAN-R in male moths through gain and loss of function by PBAN-R gene silencing and that PBAN regulates the biosynthesis of some of the putative male pheromonal components. In addition, this study also showed that the transcriptional temporal up-regulation of this receptor in the pheromone gland increase at a critical period of 5 hours post-eclosion. In conclusion, this study established a better understanding of the regulation of chemical communication and synchrony between female and male moths allowing species-specific encounters for mating and reproduction.

S6.3

Molecular detection of (E)-β-farnesene by aphids and their predators is mediated by a highly conserved Odorant Binding Protein

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The sesquiterpene (E)-beta-farnesene (EBF) is the principal component of the alarm pheromone of many aphid species. In addition, it serves as kairomone for several aphid natural enemies such as the ladybird *Harmonia axyridis* and the hoverfly *Episyrphus balteatus,* which use it to localize their prey and oviposition sites, respectively. In the context of the development of more efficient and environmentally friendly pest controlling strategies, insect olfactory systems are often exploited or even manipulated and therefore there is considerable interest in a better understanding of the olfactory mechanism of aphids and their natural enemies. We report that the recognition of EBF in aphids and in the aphid predators *H. axyridis* and *E. balteatus* is mediated by a highly conserved OBP (named OBP3) capable to specifically recognize the principal component of the aphid alarm pheromone. To our knowledge this is the first evidence that insect species belonging to distinct Orders display the same discriminatory recognition strategy for a common semiochemical.

S6.4

Different effects of plant density on insect immigration rates depending on the insect's search modality

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Habitat size is an important predictor of spatial variation in animal densities. However, habitat size often correlates with the amount of available resources within habitats, complicating the understanding of the factors driving animal distributions. We addressed this problem by investigating densities of terrestrial insects in habitat patches with a constant area but with varying number of plants. Using a theoretical model and a field experiment, we derive predictions on immigration rates of contact searchers, visual searchers and olfactory searchers, which should be determined by either habitat size or plant density. A meta-analysis on published data revealed a correspondence between observations and predictions, and variation among groups could largely be explained by search behavior. The responses varied considerably among groups, and we conclude that a general theory of insect responses to habitat heterogeneity should be based on species traits, such as search behavior.

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S6.5

Spatial Organization of Olfactory Receptor Neurons on the Antennae of Female Moth, *Spodoptera littoralis*: Differences in Sensitivity and Temporal Response

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Scanning electron microscopy on the antennae of female *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae), revealed six morphological types of olfactory sensilla; basiconic, auricilic, coeloconic, long and short trichoid and grooved pegs. Single-sensillum recordings were made from individual olfactory receptor neurons (ORNs) housed in these sensilla. Odour stimuli comprising floral and green leaf volatiles (GLVs), oviposition deterrents and female sex pheromone components, elicited strong and selective responses. In total 452 sensilla were screened from both segments, out of which 196 responded to tested stimuli. Responding ORNs were classified into 32 functional classes: 24 from basiconic, 3 auricilic, 2 coeloconic and 3 from long-trichoid. The ORNs housed in basciconic, coeloconic and auricilic responded to plant compounds while from long-trichoid responded to pheromone components. Two morphological sensilla types were non-responsive but showed spontaneous activity. More than 50 % classes of ORNs were found on both segments at similar positions while differed in sensitivity and temporal characteristics which could provide additional information for odour discrimination. That the majority of the ORNs from basiconic sensilla were highly sensitive to GLVs and floral odours, reflects the role of volatiles emitted from vegetative and floral parts of the plants in host-selection.

S6.6

Testing novel compounds for behavioral control of the red flour beetle, *Tribolium castaneum*

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The red flour beetle (*Tribolium castaneum*) is an economically important pest of stored grain products. Due to concerns over the consequences of insecticide use (e.g. toxic residue, insecticide resistant populations) there is interest in developing alternative methods of pest management, such as semiochemical-based behavioral controls. We aim to develop a novel management technique that may be used commercially, and we also seek to explore this insect's sensory physiology and its connection to foraging behavior. To do this, we have tested a large array of modified natural compounds for behavioral activity. Adult flour beetles were presented with flour disks treated with varying concentrations of test compounds to look at effects on searching and feeding. We plan to conduct electroantennograms using candidate compounds to investigate the relationship between sensory and behavioral responses and to further guide the development of a new pest control method.

S6.7

A new role for antennal grooming: Maintenance of olfactory sensitivity

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In insects, grooming can effectively remove foreign material from the body surface. We investigated a new hypothesis: That self-grooming serves to remove excess cuticular hydrocarbons (CHCs) from sensory appendages and it thus contributes to sensory acuity. The American cockroach, *Periplanata americana*, regularly grooms its antennae. We hypothesized that preventing grooming will disrupt CHC homeostasis on the antennae. Cleaning of the antenna was prevented in two ways: (1) by blocking the movement of the antenna at its base, or (2) by gluing the mouthparts. Antennae that were prevented from being groomed accumulated 3–4 times more CHCs than the groomed antennae. Scanning electron micrographs showed an excess of cuticular coating on the blocked antenna, compared with the groomed antenna of the same individual. Furthermore, the blocked antenna was significantly less sensitive to the sex pheromone periplanone-B and the general odorant geraniol acetate in electroantennogram tests.
These results demonstrate that (1) there is constant CHC efflux to the cuticular surface of the antenna, (2) self-grooming serves to remove excess CHCs from the antennae, and (3) antennal grooming contributes to high sensitivity of the chemosensory systems of the antennae.

S6.8

POSTER PRESENTATIONS
SYMPOSIUM 9

The warty orchids still catch the wasps. Sexual deception and speciation in the warty hammer orchid *Drakaea livida*

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Orchids are well known for their species diversity and specialised pollination systems. *Drakaea* orchids (hammer orchids), endemic to Western Australia, are pollinated by the sexual deceit of male thynnine wasps through mimicry of the insect pheromones. In general each species of hammer orchid is pollinated by one specific species of wasp, with most orchid species easily identified by their unique floral morphology. Recently, it was discovered that pyrazine-based compounds are used as semiochemicals by *Drakaea* orchids to attract their specific pollinators.

One common *Drakaea* is the warty hammer orchid, *D. livida*. In field studies, we found that two distinct populations of *D. livida* were attracting different species of thynnine wasp. Preliminary chemical analysis has revealed that these two populations showed different chemical profiles. EAD-studies confirmed that two different pollinators responded to different pyrazine-based compounds from the floral extracts. We will present the latest findings in the chemistry of pollination of the warty hammer orchid. Our results may lead to the conclusion that there are 2 morphologically indistinguishable species present or that divergent speciation is occurring.

S9.1

Volatile Organic Compounds (VOCs) released by *Eucalyptus benthamii* after the herbivory of *Thaumastocoris peregrinus* (Hemiptera, Thaumastocoridae)

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It has been demonstrated that plants respond to insect herbivory by synthesizing and releasing VOCs. The objective of this study was to compare the VOCs released by young *E. benthamii* plants before and after the herbivory of *Thaumastocoris peregrines*, and to verify the difference in the amount of VOCs released during photophase and scotophase. After feeding for 24h, the insects were removed from the aeration chambers and the collection of volatiles initiated for a period of five days. VOCs extractions were made every 12h or 24h, and analyzed immediately by GC-MS. The volatiles are mainly monoterpenes and sesquiterpenes, and the three major compounds released after herbivory is a monoterpene (α-pinene), and two sesquiterpenes (tentatively identified as aromadendrene and viridiflorol). α -pinene is the main compound and ranged from 14.5 ng ± 22.46 to 180.58 ng ± 17.83 after herbivory. Differences between photophase and scotophase were not statistically different. Future studies will test the perception and the attraction of mated and virgin females to the attacked plants.

S9.2

Role of plant volatiles in host selection for oligophagous insects: the case of two gelechiid moth species specialized on Solanaceous plants

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Tuta absoluta and *Phthorimaea operculella* (Lepidoptera: Gelechiidae) are two closely related species of pest found on Solanaceous plants, mainly on tomato (*Lycopersicum esculentum*) and potato (*Solanum tuberosum*). Both insect species are originally from South America and expanded their host range and geographic range quite recently. In the present study, we aimed to characterize the behavioral mechanisms as well as the cues involved in host selection of females of these two oligophagous species. This was achieved by combining wind tunnel experiments, oviposition bioassays, plant volatile analysis and electrophysiological recordings. Wind tunnel experiments showed that host plant volatile leaves stimulate upwind oriented flight of these two species. In addition, volatiles are also important cues for female egg-laying as shown by the oviposition experiments. Headspace collections of tomato and potato leaves showed several compounds common to both host plants. Screening of headspace collections with antennae obtained from female moths of both species showed a response to several compounds. Our results allow us to compare the set of compounds detected by both moth species and these compounds may become useful tools for management of these pests.

S9.3

Wireworms use barley root volatile chemicals to locate their host plant in soil

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Wireworms are soil dwelling pests of many crops. Aldrin and lindane are used to provide satisfactory treatment of infested fields. Their withdrawal from the market for environmental reasons gave birth to new needs in wireworm's management. In order to enhance integrated management of this pest, we paid attention to the interactions of *Agriotes sordidus* Illiger and barley roots and their mediation by volatile organic compounds.

We use tube-shaped olfactometers filled with humidified vermiculite as a substrate, to determine the attraction or repellency of volatile blends emitted by barley roots or grains. The attraction or repellency is first assessed with vegetal matter itself. Emission profiles of such material are determined by SPME coupled with GC-MS analysis.

These chemicals are tested on the larvae using to alginate beads characterized by prolonged and low-rated emission of substance. Larvae were attracted by the odors of intact barley roots and some of the voaltile chemicals released by the roots were also attractive.

S9.4

Variation in odour profiles of intact and herbivore damaged cabbage, cauliflower, curly kale and broccoli cultivars

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The goal of this research was to identify the chemical cues which determine specificity of odour bouquets released from selected *Brassica oleracea* cultivars, in order to understand impact of volatile phytochemicals on host plant selection by gravid females of *Pieris rapae* and *Mamestra brassicae* in the agricultural systems with different spatial arrangement of cultivars. Qualitative and quantitative variability of 52 volatiles present in headspaces of cabbage, cauliflower, curly kale and broccoli was sufficient to differentiate between cultivars at intact, herbivore-damaged and post-damaged stages by multivariate analyses. Thirty two compounds were released by intact cultivars including 22 terpenoids, 3 esters, 1 sulphide, 1 isothiocyanate and 5 other compounds. The most distinct volatile blends originated from curly kale followed by cabbage, cauliflower and broccoli. Herbivore treated plants in addition released 20 compounds not present in intact cultivars, including 3 dominant groups namely esters, terpenoids and sulphides. After remove of caterpillars, release of green leaf volatiles significantly decreased while the most of other esters remain above detection level. Plant cultivars effected the composition of the volatile blends at the large extent compare to herbivores.

S9.5

Monoterpene composition in needles of four pines species which differ in suitability for sawfly oviposition

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Diprion pini L. is among the major folivorous insects causing defoliation of *Pinus spp.* in Europe. It prefers to oviposite on *P. sylvestris* and *P. nigra* and almost never on *P. banksiana* and *P. strobus* (Barre, 2002). Sawfly oviposition preference occurs due to different composition of secondary metabolites, which are known to tackle interactions between plants and insects. These compounds are involved in pine's defense mechanisms against defoliators.
Fifteen monoterpenes had been identified by GC analysis using synthetic standards and differences in GC profiles were established. Principal component analysis (PCA) of the compounds revealed two clusters of similar compositions: one includes that of *P. banksiana* and *P. strobus* (not suitable for *D. pini* oviposition) and another of *P. sylvestris* and *P. nigra* (suitable for *D. pini* oviposition). The main compounds that stipulate clusters divergence are limonene, b-pinene and myrcene. Relative concentrations of these metabolites were significantly higher in *P. banksiana* and *P. strobus*. Further studies on behavior effect of these compounds in the interaction between *D. pini* and *Pinus* spp. are in progress.

S9.6

Nicotiana attenuata and the mirid bug *Tupiocoris notatus* – herbivory as a mutualistic interaction?

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Herbivory is thought to be detrimental to plant fitness and commonly results in a metabolic shift from primary to secondary metabolism in herbivore-attacked plants. The wild tobacco *Nicotiana attenuata,* when attacked by *Tupiocoris notatus* mirid bugs, becomes resistant against more damaging *Manduca* spp. larvae through mirid-induced direct and indirect defenses. Moreover, mirid damage induces an increase in primary metabolism allowing the plant to compensate for the lost tissue and resources allocated into induced defenses. As a result, plants in environments with both herbivores gain a fitness benefit from mirid attack. This observation suggests that the interaction between *N. attenuata* and *T. notatus* may be mutualistic. A mutualistic interaction requires fitness benefits for both, plant and insect. We predict a preference of mirids for plants that optimally support the insects' performance. This preference could result from differences in constitutively expressed traits and/or the phenotypic plasticity of these traits in response to the attacking mirid. We test mirid preference/performance on different *N. attenuata* genotypes and compare the bioassay data with constitutive and induced plant secondary metabolite production as a first step to characterize effects on insect fitness in this potentially mutualistic interaction.

S9.7

Diurnal and nocturnal herbivore induction on maize elicit different innate response of the fall armyworm parasitoid, *Campoletis flavicincta*

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Herbivore-attacked plants produce specific volatile substances that represent important cues for host finding by natural enemies. The fall armyworm *Spodoptera frugiperda* (Lep.: Noctuidae) is a voracious herbivore and feed on maize in all periods of the day. Given that plant needs light to synthesize de novo herbivore-induced volatiles, volatile blend may be changed depending on time of the day the plant is induced, what could interfere in natural enemy foraging. In this sense, the current study aimed to investigate differential attractiveness of maize elicited by fall armyworm regurgitant under light and dark conditions to its specialist larval parasitoid *Campoletis flavicincta* (Hym.: Ichneumonidae). All bioassays used Y-tube olfactometer to assess parasitoid response to odors from undamaged maize, mechanical damage and regurgitant-treated plants at 0-1, 5-6 and 24-25h after induction. The results showed that naïve wasps were attracted to volatiles emitted by nocturnal regurgitant-treated maize at 5-6h, but not to odors from diurnal regurgitant-treated plants. The differential attractiveness is likely due to blend composition as nocturnal regurgitant-treated plants emit aromatic compounds and the homoterpene (3E)-4,8-dimethyl-1,3,7-nonatriene in larger amounts than diurnal treated plants.

S9.8

Vegetation diversity and its impact on tritrophic interactions: a case study of *Plantago lanceolata,* weevils and larval parasitoids

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Vegetation diversity may affect tritrophic interactions by influencing host plant quality. Here, we investigated the hypotheses that (a) vegetation diversity affects secondary metabolites and nutritional quality of the weed *Plantago lanceolata* and, if so, that (b) chemistry of *P. lanceolata* affects the specialist herbivorous weevils *Mecinus pascuorum* and *M. labilis*, their larval parasitoid *Mesopolobus incultus* and the interaction between them (parasitization rate). We determined vegetation diversity and abundance of weevils and parasitoids on *P. lanceolata* growing in 77 grassland plots differing in diversity. Furthermore, we determined leaf nitrogen content and quantities of the major plant iridoids aucubin and catalpol in leaves of *P. lanceolata* collected from these plots. GLM data analysis revealed that increasing vegetation diversity was not linked with leaf nitrogen content, but with enhanced quantities of both iridoids. Abundances of weevils were not affected by iridoid concentrations, but negatively by leaf nitrogen. No plant parameter did significantly affect parasitoid abundance and parasitization rate. In conclusion, even though vegetation diversity affected quantities of *P. lanceolata* iridoids, this within-first-trophic-level effect had no further bottom-up effects on the higher trophic levels studied here.

S9.9

Aposematic Red Leaf Margins Deter Insect Herbivores

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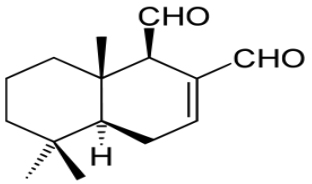
Well-defended animals are known to warn off attackers by their contrasting colours (aposematism). Despite much theorising, this has not been proven in plants. The native New Zealand horopito shrub (*Pseudowintera colorata*) possesses traits that are well suited to test these hypotheses. Its leaves are rich in polygodial, a pungent hot-tasting sesquiterpene dialdehyde known to be a potent antifeedant. Furthermore, leaves are strikingly coloured and characterised by a mosaic of irregular patches of red anthocyanin pigments against a green background, often with highly coloured red leaf margins. In this study, using digital image analysis, HPLC analyses, and animal feeding trials, we examine the role of margin coloration in horopito. Leaves collected from the field show a negative correlation between margin size
and herbivory. Red leaf margins had higher levels of polygodial. Green-margined leaves suffered from more herbivory in laboratory feeding trials under white light, but no preference was found in trials using monochromatic red or green light, or in the dark. This supports the aposematic role of leave margins in horopito.



S9.10

Geographic association between defence traits and leaf damage in *Datura stramonium*

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Plants have evolved different defensive traits that allow them to avoid foliar damage imposed by herbivores. In a geographic context it is expected that the outcome of the plant herbivore interaction varies due to the different biotic and abiotic conditions inherent to each population. The geographic mosaic theory of coevolution (GMTC) proposes that traits that mediate an interaction will geographically vary because of the existence of a selection mosaic. Leaf trichomes and tropanic alkaloids have been considered defensive traits against herbivores in the ruderal weed *Datura stramonium*. Based on previous work this research studies the geographic association of leaf damage with trichome density and tropanic alkaloids concentration in 28 natural populations of *D. stramonium*. If tropanic alkaloids and trichomes are a resistance component against herbivores, there will be a negative association between these traits and leaf damage. Additionally, if physic factors (temperature or precipitation) constrain the defensive traits expression is expectable that geographic variation in foliar damage could be partially explained by the defensive traits-physic factors interaction. We found a geographic pattern which relates foliar damage with trichome density and atropine concentration. Populations with greater leaf damage showed more investment in defensive traits. Leaf damage variation was also explained by the interaction between defensive traitsand water availability within populations.

S9.11

Differential terpenoid catabolism between female and male *Chrysolina herbacea*

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The interaction between the mint bug *Chrysolina herbacea* and its plant hosts is due to the ability of the insect to tolerate high amounts of toxic terpenoids during herbivory and its capability to catabolise and biotransform them in the digestive tract. We analysed the VOC composition of male and female *C. herbacea* frass from insects feeding on *Mentha aquatica*. VOCs were sampled by HS-SPME and analyzed by GCxGC-qMS, and the results compared through quantitative comparative analysis of 2D chromatographic data. Most terpenoids from *M. aquatica* were completely catabolized by *C. herbacea* and were absent in the frass volatile fraction. The monoterpene1,8-cineole was oxidized and frass yielded several hydroxy-1,8-cineoles, among which 2α-OH-, 3α-OH-, 3β-OH- and 9-OH-1,8-cineole**.** Frass from male *C. herbacea* had significantly higher amounts of hydroxy-1,8-cineoles than frass form female. The latter producing frass with a higher quantity of mono- and sesquiterpenes than male frass. The specific role of hydroxyl-1,8-cineole derivatives produced by male insects as female attractant compounds is discussed.

S9.12

Chlorophyll degradation and complexation in the gut of generalist and specialist Lepidopteran caterpillars

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Plant feeding herbivores excrete most of the ingested chlorophyll as partly degraded derivatives lacking the phytol side chain and the central magnesium ion. An ecological role of digested and degraded chlorophylls in the interactions between insects, their food plant and other insects has been described recently. To gain more information on chlorophyll degradation in plant-feeding insects, regurgitate and frass of five Lepidopteran caterpillars, *Spodoptera littoralis*, *Spodoptera eridania*, *Heliothis virescens*, *Helicoverpa armigera*, and *Manduca sexta*, were analysed for chlorophyll catabolites. The major catabolites were determined as pheophorbide *a/b* and pyropheophorbide *a/b* by using LC-MS, LC-NMR, UV, and fluorescence spectrometry. None of the compounds were detected in fresh leaves of the food plants (*Phaseolus lunatus*, *Nicotiana tabacum*). The spectrum of metabolites can be attributed to the combined action of esterolytic gut proteins and the strongly alkaline milieu in the digestive tract. Substantial amounts of chlorophyll *a/b* were found to be strongly complexed in the mid-gut, but not in the feces and not in microwave treated digestive fluids suggesting non-covalent binding of chlorophyll *a/b*. The chlorophyll-binding protein (ChlBP) from *S. littoralis* was identified as the already known Chlorophyllide *a* binding protein from the silk worm *Bombyx mori* by LC-ESI/ MS-sequencing.

S9.13

Metabolism of camalexin and derivatives by the cruciferous pathogen *Alternaria brassicicola*

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Phytoalexins such as camalexins are important antimicrobial metabolites produced *de novo* by cruciferous plants (Brassicaceae family) in response to pathogen attack and other forms of stress. Many pathogens of crucifers detoxify phytoalexins using specific enzymes, thus depriving the plant of useful chemical defenses. To better understand the interaction of fungal pathogens with their host crucifers, the metabolism of phytoalexins by economically important phytopathogenic fungi is under investigation. In this work, the transformation of three naturally occurring camalexins by the phytopathogenic fungus *Alternaria brassicicola* was investigated. Kinetic analysis of the biotransformation of each phytoalexin indicated that these phytoalexins were metabolized and that the rates of transformation were similar. The antifungal activity of each compound against *A. brassicicola* was evaluated using a mycelial radial growth assay. 5-Chlorocamalexin showed the strongest activity inhibition of growth, followed by 5-fluorocamalexin, 1-methylcamalexin, 5-methylcamalexin, camalexin and 6-methoxycamalexin. This work demonstrated that *A. brassicicola* was able to detoxify each camalexin through a pathway similar to that followed by *Botrytis cinerea*.

S9.14

Partial purification, characterization, and substrate specificity of indolyl-3-acetaldoxime dehydratase from the phytopathogenic fungus *Leptosphaeria maculans*

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Indole-3-acetaldoxime (IAOx) is an important intermediate in the biosynthesis of several plant secondary metabolites. It is a precursor of several cruciferous phytoalexins (e.g. brassinin and camalexin), as well as of indole glucosinolates (glucobrassicin) and the plant hormone indole-3-acetic acid. Previous work showed that the plant pathogen *Sclerotinia sclerotiorum* transformed IAOx to indolyl-3-acetonitrile using an indolyl-3-acetaldoxime dehydratase, IADSs. In this work, IADSs activity was screened in mycelia from different crucifer pathogenic fungi. *Leptosphaeria maculans* isolate Laird 2 metabolized IAOX and mycelial cell-free extracts showed the highest activity among the tested pathogens. Partially purified indolyl-3-acetaldoxime dehydratase showed Michaelis–Menten kinetics, had an apparent molecular mass of 40 kDa and maximum activity at pH 6.5 and 22-25 ^{0}C. The enzymatic activity was enhanced by the addition of the reducing agent sodium dithionite to the assay mixture and also enhanced under anaerobic conditions in the presence of dithionite. The enzyme was stabilized in the presence of detergents and glycerol; however, it was strongly inhibited by dithiothreitol and antiproteases. On the basis of its substrate specificity, the enzyme appears to be an indolyl-3-acetaldoxime dehydratase similar to IADSs. Partial purification, stabilization and substrate specificity studies of IAD from Laird 2 will be described and results compared with previous work.

S9.15

Personalized pesticides-a new paradigm: volatilization of individual components of botanical inset repellents from human skin

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Botanical pesticides are generally considered as safer alternatives for conventional chemical pesticides. Unlike conventional pesticides, botanical pesticides consist of several components that may play an active role in the toxicity of the mixture. These components not only can chemically interact with each other and synergize or suppress each other's effect, but they also can affect the physical properties of the mixture such as volatilization rate. Our objective in this project was to study volatilization of a commercial botanical insect repellent from human skin. We analyzed a sample of an insect repellent on human skin with an ultra-fast gas chromatograph (zNose™) and noticed that different constituents are released from the mixture at different times in human subjects. We found significant differences in volatilization patterns based on our subjects' gender, ethnicity and skin color and condition. The results of this study not only create a foundation for more detailed studies in future, but also can help the industry to promote the concept of "personalized pesticides" as an alternative for " generic formulation".

S9.16

Identification of oviposition kariomone of *Mycodiplosis coniophaga*

Zhang, Aijun
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Heptyl butyrate was identified as female oviposition kariomone of gall midge, *Mycodiplosis coniophaga* (Winnertz) from the fruit of the Chinese crabapple, *Malus hupehensis* (Pamp.) Rehder (Rosaceae), covered with aecia of cedar apple rust, *Gymnosporangium* sp. (Uredinales: Pucciniaceae). Our field assays demonstrated that heptyl butyrate itself was significantly attractive than the heptyl isobutarate, an analog of the kariomone. However, attraction could be significantly inhibited by addition of *trans-beta*-ocimene, which was another component identified from the same volatile source. In 2009, more than 10,000 *M. coniophaga* females were captured in traps baited with 0.25-1.0 gram of synthetic heptyl butyrate in Beltsville, Maryland.

S9.17

Multimodal stimulation of *Diaprepes abbreviatus*: photochromatic stimulus elicits stronger response than chemical stimulus

Otálora-Luna, Fernando[1]; Lapointe, Stephen[1]; Dickens, Joseph[1]
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[2] USDA, ARS, U.S. Horticultural REsearch Laboratory, Ft. Pierce, FL 34945. stephen.lapointe@ars.usda.gov
[3] USDA, ARS, Invasive Insect Biocontrol and Behavior Lboratory, Beltsville, MD 20705. joseph.dickens@ars.usda.gov

We investigated the response of the neotropical root weevil, *Diaprepes abbreviatus* (Curculionidae: Otiorhynchinae) to visual and odor signals separately and in combination. A four-way arena was constructed and placed on top of a locomotion compensator to expose the insect simultaneously to 2 color choices (LEDs) and an air stream containing plant and conspecific odors including a putative pheromone. When exposed to LEDs in the absence of odors, green light was more attractive than blue. Weevils also oriented to a combination of odors consisting of kairomones from citrus leaves and a putative pheromone. When presented with blue light alone in conjunction with odors (kairomones and pheromone), weevils responded by walking toward the stimulus. When given the choice between blue light with odors and green light, weevils responded to the green light significantly more often than to the blue light + odors.

S9.18

Essential oils as fumigant against rice weevil, *Sitophilus oryzae* (Linnaeus)

Phoonan, Wachiraporn[1]; Chatchawan, Chaisuekul[2]; and Chavasiri, Warinthorn[3]
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[3] Chulalongkorn University, Faculty of Science, Department of Chemistry, Bangkok, Thailand 10330, e-mail. warintho@yahoo.com

The fumigant activity of twenty-five essential oils was evaluated on an important stored-product insect pest *Sitophilus oryzae* Linn. The essential oils from *Cinnamomum porrectum* (Roxb) Kosterm (Thep ta-ro) exhibited the highest fumigant toxicity against adults of *S. oryzae* after 24 h exposure, followed by those from *Mentha arvensis* Linn (Japanese mint) and *Zingiber cassumunar* Roxb (plai) with LC_{50} 79, 138 and 260 μL/L air, respectively. The main constituents of each essential oil were analyzed by spectroscopic techniques and then tested in fumigation bioassay. Safrole, the major component of the essential oil from *C. porrectum*, exhibited the most potent fumigant (LC_{50} = 57.9 μL/L air) at the concentration of 100 μL/L air after 24 h exposure. Additionally, the residue of safrole could not significantly be detected on the fumigated rice. The major component-fumigant activity relationship study indicated that the major constituent was not necessarily the active ingredient. Thus, the essential oils from these Thai plant sources and their major constituents may be developed as a potent fumigant for storage grains.

S9.19

POSTER PRESENTATIONS SYMPOSIUM 2

Smelling disease: the harlequin crab is able to detect if its sea cucumber host is infected by skin ulceration disease or not

Caulier, Guillaume[1]; Flammang, Patrick[1]; Eeckhaut, Igor[1]
[1] University of Mons, Marine Biology Laboratory, 6 Avenue du Champs de Mars, B-7000 Mons, Belgium.

Skin ulceration disease is a bacterial infection that induces serious lesions on the body wall of sea cucumbers. It is highly contagious and can cause the death of 95% of sea cucumbers when they are reared in aquaculture ponds. The harlequin crab *Lissocarcinus orbicularis* is a common ectocommensal of the sea cucumber *Bohadschia vitiensis.* Using host choices experiments in a Davenport olfactometer, we recently demonstrated that these crabs are attracted by kairomones that enable them to specifically recognize their hosts by means of chemical sensing. In this study, we observed that individuals of *B. vitiensis* presenting skin ulcerations are no longer attractive to the crabs. Moreover, when given the choice between two sea cumbers, harlequin crabs are able to distinguish healthy individuals from diseased ones, with a significant preference for sea cucumbers that are not infected by skin ulceration disease. We hypothesize that, in addition to attractive kairomones, other semiochemicals could be emitted by diseased sea cucumbers. This study is the first to highlight that a symbiont would be able to discriminate if its host is ill or not by sniffing its

S2.1

Progress Toward the Total Synthesis of Salinosporamide C

Draper, Jason A.; Britton, Robert
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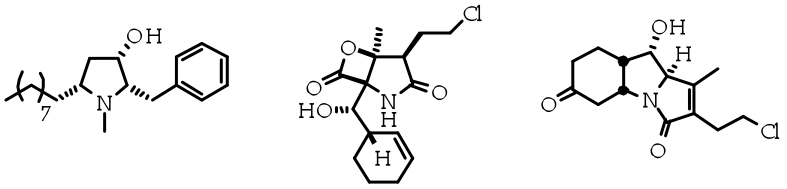
The secondary metabolites of the marine actinomycete *Salinispora tropica* offer intriguing biosyntheses, promising anticancer activity via selective proteasome inhibition (salinosporamide A), and enticing molecular architecture. We report our attempts to access some of the high value targets shown below by total syntheses which emphasize conciseness, flexibility, and stereocontrol. The key tactic employed is elaboration of ketochlorohydrins by introduction of nitrogen and subsequent pyrrolidine formation by intramolecular chloride displacement.



Preussin Salinosporamide A Salinosporamide C

S 2.2

Maps & Directions

Telephone Numbers

Justin Ankermann: 778-7823012	Residences: 778-782-4503
Erika Plettner (office): 778-782-3586	Executive Inn: 1-888-433-3932
E. P. group student office: 778-782-5759	Best Western: 604/931-9011
Campus security: 778-782-3100 or 778-782-4500	Ramada Inn: 604-931-4433
Coquitlam Taxi companies: (604) 524-4733, (604) 524-1111, (604) 636-8500	Burnaby Taxi Companies: (604) 435-6655, (604) 200-3771

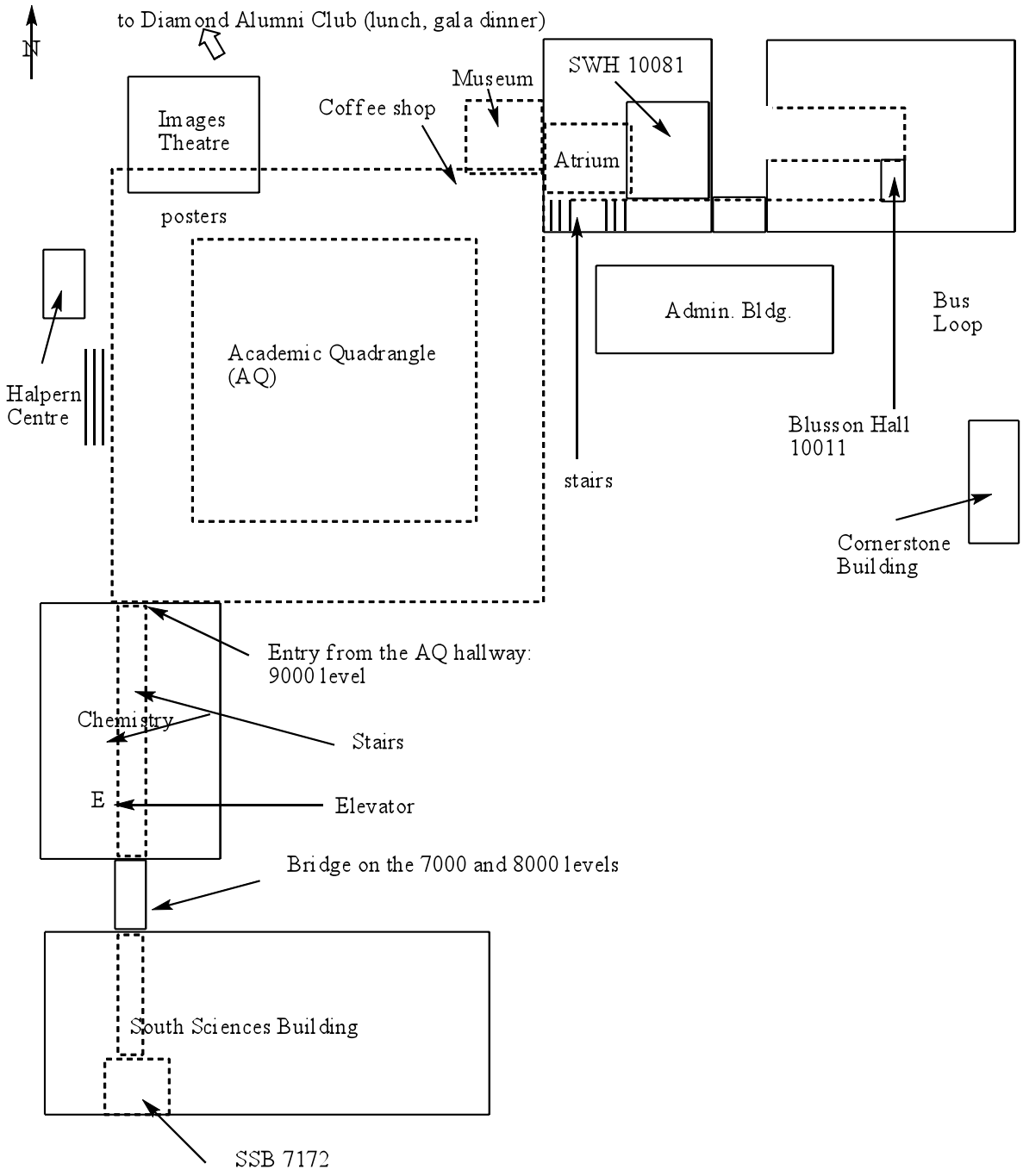
Transit Information

Weekdays from start of service to 6:30 PM
1 zone fare : $2.50 (adult) $1.75 (concession)
2 zone fare : $3.75 (adult) $2.50 (concession)
Saturdays, Sundays and after 6:30 PM
All zones : $2.50 (adult) $1.75 (concession)

Trip planning: http://www.translink.ca/

1) From SFU to Executive Inn or Best Western: take bus 145 to Production Way Station, then switch to the Sky train and go one stop to Lougheed Town Center.
2) From SFU to downtown Vancouver: a) take bus 145 to Production Way Station, then switch to the Sky Train (Millenium Line, direction VCC Clark) and go to Commercial Drive/Broadway. There, take the stairs or elevator up and switch to the Expo/Millenium line, direction Waterfront.
Alternative b) Take bus 135.
3) From SFU to the airport: as in no. 2a) above, go all the way to Waterfront. There, switch to the Canada Line. Note this line splits, so be sure to board a train that is bound for the airport.

Location of the Presentation Rooms, Posters and Social Activities



Where on or near campus can I find…?

Item	Place(s)
Bank	Scotiabank, Cornerstone Building, 604-294-6862, www.scotiabank.com
Beverages (speciality juices, tea)	Booster Juice, Corenrstone Building, 604-568-2979 Pearl Fever Tea House, Corenrstone Building, 604-569-2011
Book store	SFU Bookstore, Maggie Benston Center
Cafeteria	Two locations: West Mall Complex (WMC) and Academic Quadrangle (East side).
Convenience Store	Simon C's (Academic Quadrangle, 8000 level, West) Your Dollar Store with More, Cornerstone Building, 604-936-9154
Dentist	SFU Dental Service, Cornerstone Building, 604-267-3368
Doctor	Maggie Benston Center (emergency No. 2-4500)
Dry cleaner	see Kensington Square or Lougheed Town Center
Emergency	Campus security: call 2-4500
Food court	Inside the Maggie Benston Center (soups, sandwiches and light lunches)
Fresh fruits and vegetables	Nester's Market, 604-298-1807, www.nestersmarket.com Pocket Farmer's Market (only on Wednesday)
Groceries	Nester's Market, 604-298-1807, www.nestersmarket.com
Hairdresser	Azzi Hair Studio, Cornerstone Building
Mall (Coquitlam side)	Lougheed Town Center (across from the Executive Inn, take bus 145 and the sky train) http://www.lougheedtowncentre.com/
Mall (North Burnaby)	Kensington Square (take bus 135) http://shopkensingtonsquare.ca/
Medication	Pharmacy inside Nester's Market
Prayer room / Congregation	Interfaith Center (AQ) / Ellesmere Church 778-782-8474
Printing Service	Cornerstone Printing, Cornerstone Building, 604-568-3929
Restaurant (Chinese)	Bamboo Garden, Cornerstone Building, 604-298-9869 Plum Garden Noodle House, Cornerstone Building, 604-299-9813
Restaurant (Coffee & sandwiches)	Renaissance Café (Cornerstone Bldg. + several locations around campus), 604-205-5854
Restaurant (Indian)	Hymalayan Peak, Cornerstone Building, 604-205-9069
Restaurant (Italian)	Club Ilia, Cornerstone Building, 604-568-4993
Restaurant (Japanese)	Ichibankan Express, Cornerstone Building, 604-291-2982
Restaurant (Korean)	Spicy Stone, Cornerstone Building, 604-299-3663
Restaurant (Middle Eastern fast food)	Donair Town, Cornerstone Building, 604-298-8188
Restaurant (Organic)	Nature's Garden, Cornerstone Building, 604-299-0552
Restaurant (Pizza)	Pizza Point, Cornerstone Building, 604-299-6446
Restaurant (Pub)	Highlands Pub (Maggie Benston Center)
Restaurant (fine dining, West Coast)	Horizon's (you need to take a trail through the forest to Centennial Park; consult a map), 604-299-1155, http://www.horizonsrestaurant.com/
Sports Facility (including swimming pool)	Chancellor's Gymnasium (visitors can get a day pass at the main gym office; please consult the timetables for various facilities)
Trails	Consult a campus map. Caution: there is a **bear** in the woods around campus! Do not walk on the trails alone.
Transit tickets	Maggie Benston Center (Student Society Store), on buses or at stations
Travel Agent	Travel Cuts (Cornerstone Building), 604-659-2850

In an emergency on campus call 2-4500 (please do not call 911)
Off campus emergency: 911

Index of Presenters

Every effort has been made to include all registered authors in this index. We apologize for any errors or omissions.