"Researching Bed Bugs: What's Known and What's Next"

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Invasive Insect Biocontrol & Behavior Laboratory
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- pheromones (behavior)
- endosymbionts

Review

Received: 5 March 2010 Revised: 5 July 2010 Accepted: 16 July 2010 Published online in Wiley Online Library: 21 September 2010

(wileyonlinelibrary.com) DOI 10.1002/ps.2024

Semiochemicals of the common bed bug, *Cimex lectularius* L. (Hemiptera: Cimicidae), and their potential for use in monitoring and control

Emma NI Weeks,[a,b]* Mike A Birkett,[a] Mary M Cameron,[b] John A Pickett[a] and James G Logan[a]

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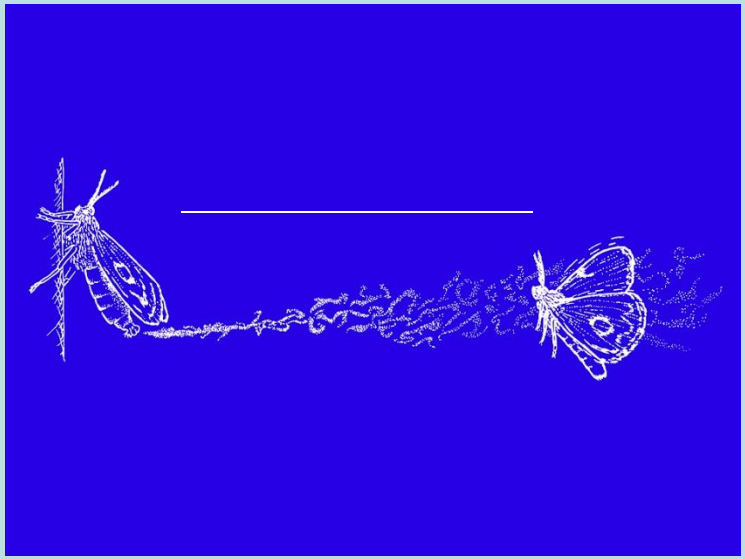
"Semiochemicals (behaviour- and physiology-modifying chemicals) could be exploited for the management of bed bugs …. an increased knowledge and understanding of the biology, behaviour and chemical ecology…."

Pheromone – semiochemical that trigger a response in the same species.

Kairomone – released by one species that benefits another species.



- Sex pheromones

Aerial pheromone application for mating disruption of gypsy moth

Contact sex pheromone Asian longhorned beetle

- Alarm pheromones
- Aggregation pheromones
- Trail pheromones

UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 754 OCTOBER 14, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE BEDBUG.[1]

By C. L. MARLATT,

Entomologist and Assistant Chief of Bureau.

CONTENTS.

THE "BUGGY" ODOR.

The most characteristic feature of the bedbug is the very distinct and disagreeable odor which it exhales, an odor well known to all who have been familiar with it as the "buggy" odor. This odor is by no means limited to the bedbug, but is characteristic of most plant bugs also. The common chinch bug affecting small grains and the squash bugs all possess this odor, and it is quite as pungent with those plant-feeding forms as with the human parasite. The possession of this odor, disagreeable as it is, is very fortunate after all, as it is of considerable assistance in

detecting the presence of these vermin.

"Buggy odor" of bed bugs

Schildknecht (1964) **(E)-2-hexenal** (+++) **(E)-2-octenal** (+)

Collins (1968) (adults) (+++) (+)
(butanone, acetaldehyde)

Levinson & Bar Ilan (1971) *bioactive
"assembling" and "**alerting**" scents
"alarm pheromones"

Levinson *et al.* (1974)
(adults) (+++) (+)
(nymphs) (+) (+++)
(butanone, acetaldehyde, + *two unknowns)

Siljander *et al.* (2008)
airborne aggregation pheromone (+) (++)
(mixed stages, sexes) (additional 12-14 compounds.)

Addition of Alarm Pheromone Components Improves the Effectiveness of Desiccant Dusts Against *Cimex lectularius*

JOSHUA B. BENOIT,[1,2] SETH A. PHILLIPS,[1] TRAVIS J. CROXALL,[3] BRADY S. CHRISTENSEN,[3] JAY A. YODER,[3] AND DAVID L. DENLINGER[1]

J. Med. Entomol. 46(3): 572–579 (2009)

ABSTRACT We demonstrate that the addition of bed bug, *Cimex lectularius*, alarm pheromone to desiccant formulations greatly enhances their effectiveness during short-term exposure. Two desiccant formulations, diatomaceous earth (DE) and Dri-die (silica gel), were applied at the label rate with and without bed bug alarm pheromone components, (*E*)-2-hexenal, (*E*)-2-octenal, and a (*E*)-

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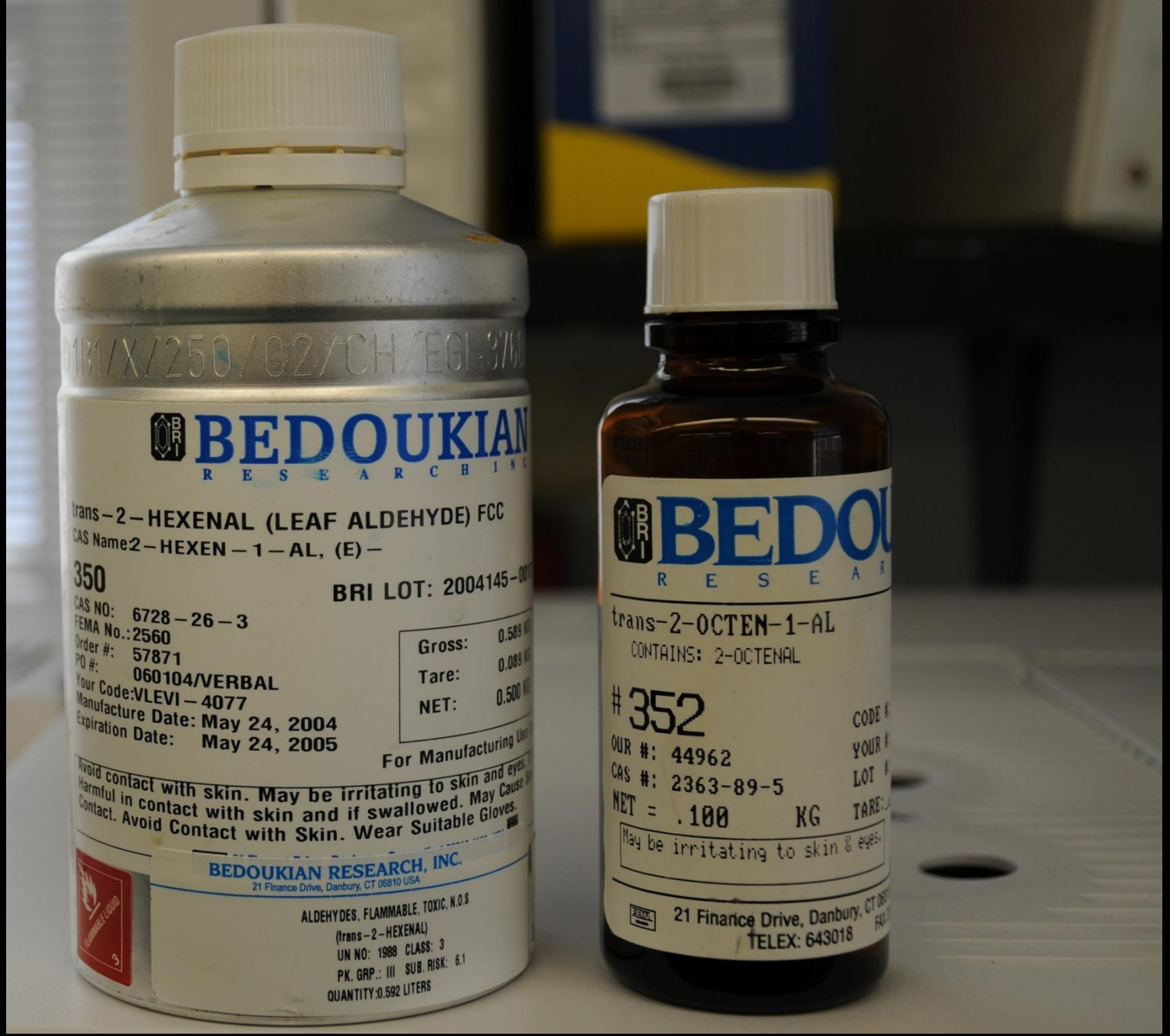
WO/2008/088546) CONTROLLING BEDBUGS WITH SYNTHETIC PHEROMONES AND/OR INFRARED RADIATION

Applicants:
S. C. JOHNSON & SON, INC.
SILJANDER, Eric, D.
TAKACS, Stephen
GRIES, Regine
GRIES, Gerhard



Mention of a proprietary product does not constitute an endorsement or a recommendation for its use by the U.S. Department of Agriculture

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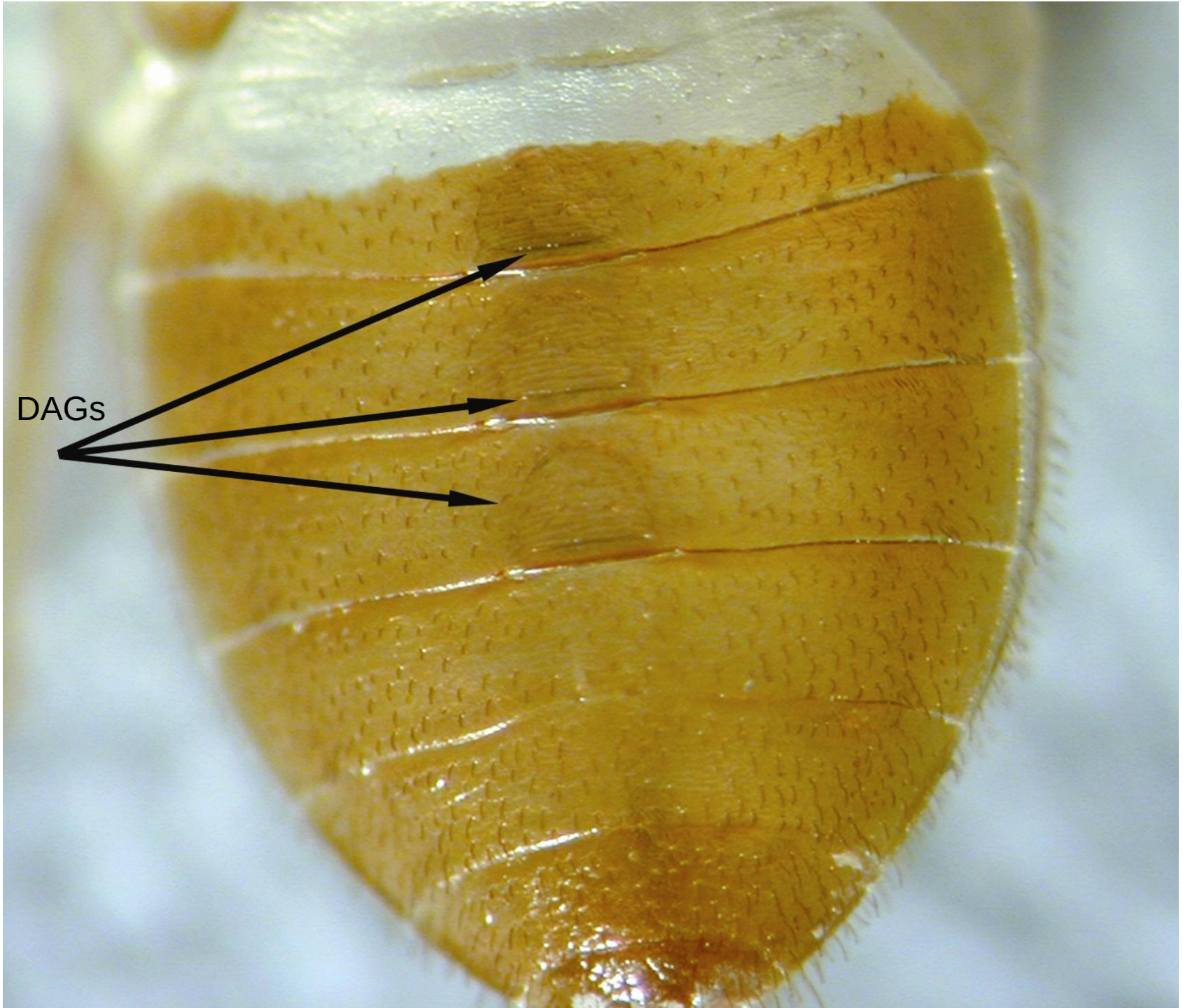
DAGs

Alarm pheromone chemistry -

Percentages of major constituents from the dorsal abdominal glands (DAGs) of *C. lectularius* nymphs.

Compound	Fifth instar *males*	Fifth instar *females*	Fourth instar mixed
(*E*)-2-hexenal	19.9	21.0	22.0
(*E*)-2-octenal	61.6	58.6	57.7
4-oxo-(*E*)-2-hexenal	10.9	11.9	11.8
4-oxo-(*E*)-2 octenal	4.6	4.9	6.4

- Identifications were based on a comparison of retention times and mass spectra with authentic standards.
- Males/females, 180 DAGs each; fourth instar, 60 DAGS
- lesser amounts nonanal, 2,4-octadienal

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(mixed stages, sexes) (additional 12-14 compounds.)

Feldlaufer et al. (2010) (nymphs) (+) (+++)
(20%) (60%)
4-oxo-(*E*)-2-hexenal (11%)
4-oxo-(*E*)-2-octenal (5%)

Contents lists available at ScienceDirect

Animal Behaviour

journal homepage: www.elsevier.com/locate/anbehav

Homosexual interactions in bed bugs: alarm pheromones as male recognition signals

Camilla Ryne*

Department of Ecology, Lund University

Chem. Senses

doi:10.1093/chemse/bjp096

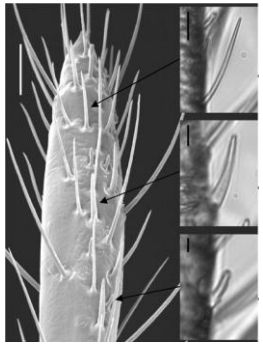
Characterization of the Antennal Olfactory System of the Bed Bug (*Cimex lectularius*)

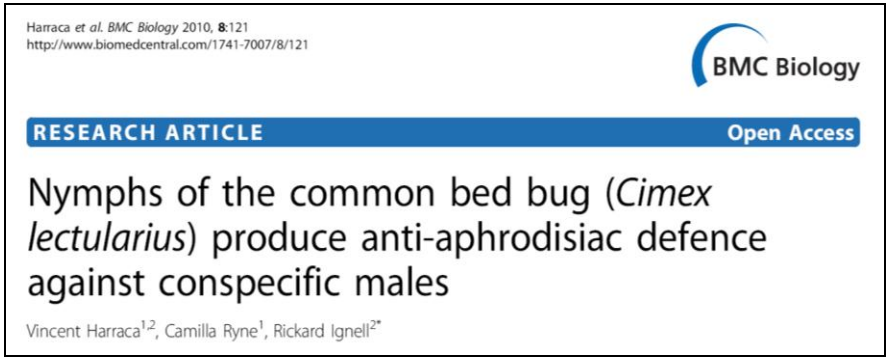
Vincent Harraca[1,2], Rickard Ignell[2], Christer Löfstedt[1] and Camilla Ryne[1]

[1]Division of Chemical Ecology, Department of Ecology, Ecology Building, Lund University, SE-223 62 Lund, Sweden and [2]Division of Chemical Ecology, Department of Plant Protection Biology, Swedish University of Agricultural Sciences, Box 102, SE-230 53 Alnarp, Sweden

Correspondence to be sent to: Camilla Ryne, Division of Chemical Ecology, Department of Ecology, Ecology Building, Lund University, SE-223 62 Lund, Sweden. e-mail: camilla.ryne@ekol.lu.se

Accepted November 30, 2009




Harraca *et al. BMC Biology* 2010, **8**:121
http://www.biomedcentral.com/1741-7007/8/121

BMC Biology

RESEARCH ARTICLE Open Access

Nymphs of the common bed bug (*Cimex lectularius*) produce anti-aphrodisiac defence against conspecific males

Vincent Harraca[1,2], Camilla Ryne[1], Rickard Ignell[2*]

"We report that the aldehydes and 4-oxo-(E)-2-hexenal are detected by olfactory receptor neurons housed in smooth and grooved peg sensilla, respectively, on the adult antennae, at biologically relevant concentrations."

Pheromones uses ("buggy" odors) -

Safe (easier to register); Competing with natural harborages? (lure/trap)

Are they useful in detection strategies? (canines?; chemical means?)

How can detection at very low levels be made affordable?

Kairomones (uses) (human emanations) -

Are they more useful in monitoring/trapping situations?

What about recently fed bugs?

Semiochemicals (pheromones, kairomones, attractants, repellents) –

behavior, behavior, behavior

Lures/Trap/Monitoring device

What does the number (sex; stage) of bugs caught represent? (other than the presence or absence)

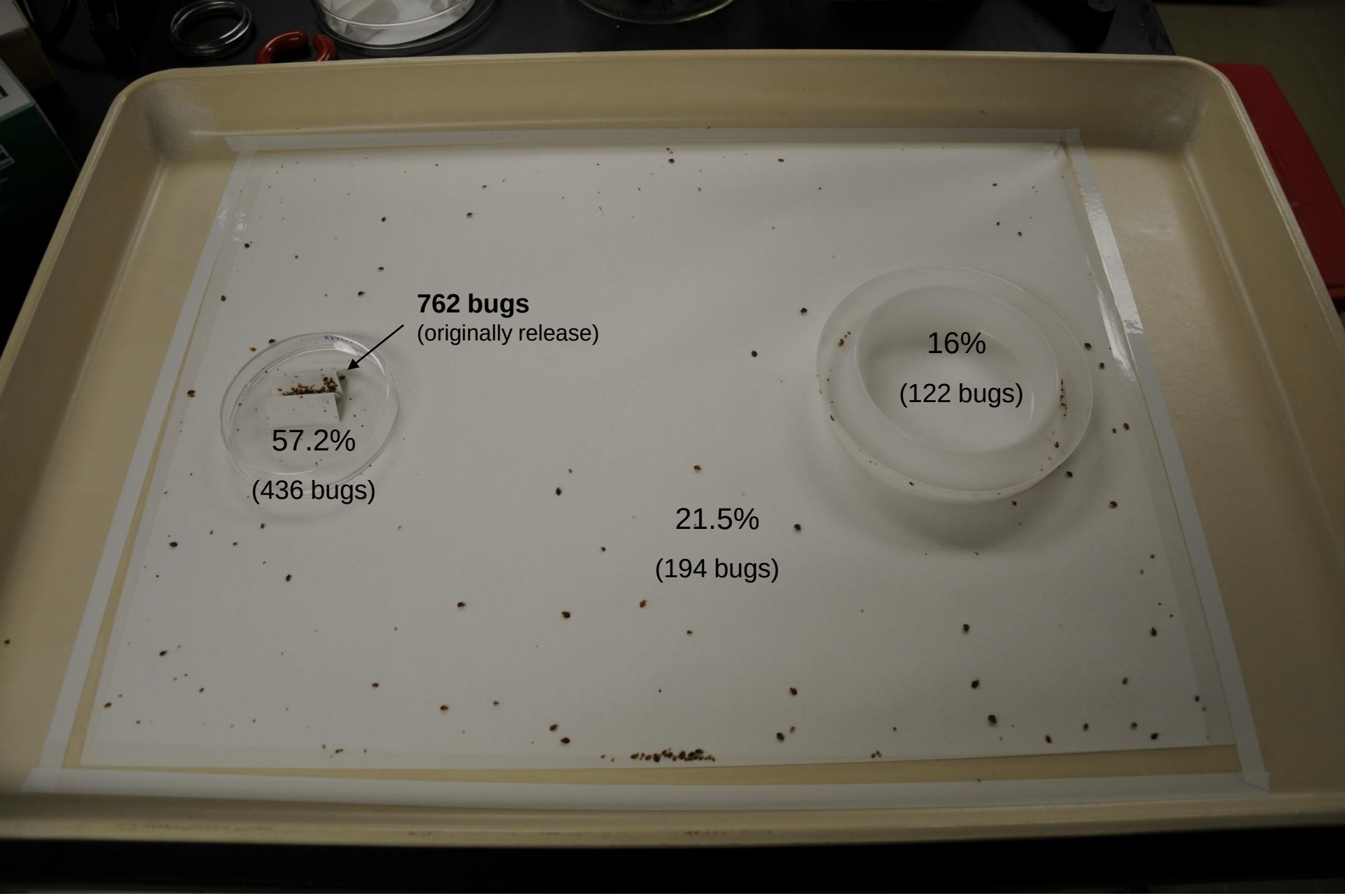


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Photo by Jan Derk

• endosymbionts of insects

bacteria that infect many arthropods; genus *Wolbachia* (approx. 60% of all insect species); maternally-transmitted

- Provide essential nutrients
- Affect host reproduction/sex ratios
- **Provide "protection" from other pathogens**

J. Med. Res. (1924)

STUDIES ON RICKETTSIA-LIKE MICRO-ORGANISMS IN INSECTS *

MARSHALL HERTIG, Minneapolis
and
S. BURT WOLBACH, Boston
(*From the Department of Pathology, Harvard University Medical School, Boston*)

SYNOPSIS

(1921)

Review

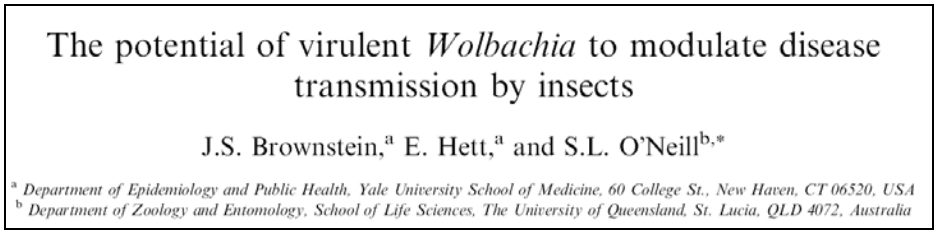
Cell PRESS

Symbiont-mediated protection in insect hosts

Jeremy C. Brownlie[1] and Karyn N. Johnson[2]

[1] School of Biomolecular and Physical Sciences, Griffith University, Brisbane, 4111, Australia
[2] School of Biological Sciences, The University of Queensland, Brisbane, 4072, Australia

- Flies protected from viruses by *Wolbachia*
- pea aphid protected from fungal pathogens

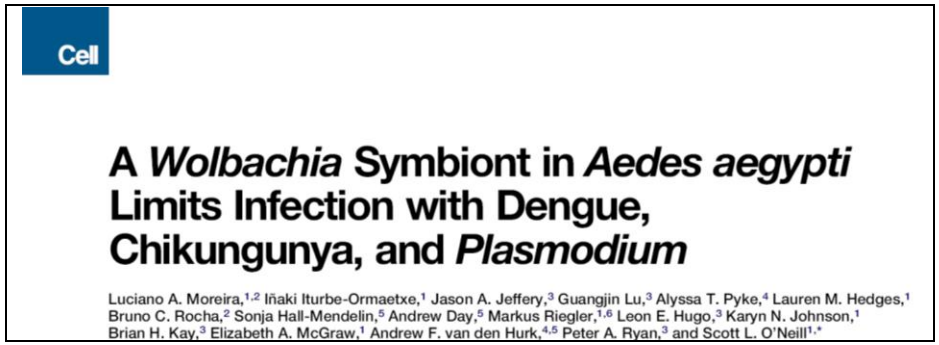


The potential of virulent *Wolbachia* to modulate disease transmission by insects

J.S. Brownstein,[a] E. Hett,[a] and S.L. O'Neill[b,*]

[a] *Department of Epidemiology and Public Health, Yale University School of Medicine, 60 College St., New Haven, CT 06520, USA*
[b] *Department of Zoology and Entomology, School of Life Sciences, The University of Queensland, St. Lucia, QLD 4072, Australia*

- *Drosophila* (reduces adult lifespan)



Cell

A *Wolbachia* Symbiont in *Aedes aegypti* Limits Infection with Dengue, Chikungunya, and *Plasmodium*

Luciano A. Moreira,[1,2] Iñaki Iturbe-Ormaetxe,[1] Jason A. Jeffery,[3] Guangjin Lu,[3] Alyssa T. Pyke,[4] Lauren M. Hedges,[1] Bruno C. Rocha,[2] Sonja Hall-Mendelin,[5] Andrew Day,[5] Markus Riegler,[1,6] Leon E. Hugo,[3] Karyn N. Johnson,[1] Brian H. Kay,[3] Elizabeth A. McGraw,[1] Andrew F. van den Hurk,[4,5] Peter A. Ryan,[3] and Scott L. O'Neill[1,*]

- reduces lifespan
- inhibits pathogens ability to develop

OPEN ACCESS Freely available online

PLoS one

***Wolbachia*-Mediated Resistance to Dengue Virus Infection and Death at the Cellular Level**

Francesca D. Frentiu[1], Jodie Robinson[2], Paul R. Young[2], Elizabeth A. McGraw[1], Scott L. O'Neill[1]*

1 School of Biological Sciences, The University of Queensland, Brisbane, Australia, **2** Centre for Infectious Disease Research, School of Chemistry and Molecular Biosciences, The University of Queensland, Brisbane, Australia

- *Wolbachia*-infected mosquito cell lines inhibit virus replication
- directly related to density

- Bed Bug Endosymbionts -

Insect Molecular Biology (1997) 6(3), 301–304

SHORT NOTE

Phylogenetic characterization of two transovarially transmitted endosymbionts of the bedbug *Cimex lectularius* (Heteroptera: Cimicidae)

V. Hypša and S. Aksoy

- *Wolbachia*
- BEV-like (*Euscelidius variegatus*)

Phylogenetic Characterization of *Wolbachia* Symbionts Infecting *Cimex lectularius* L. and *Oeciacus vicarius* Horvath (Hemiptera: Cimicidae)

JASON L. RASGON[1] AND THOMAS W. SCOTT[2]

The W. Harry Feinstone Department of Molecular Microbiology and Immunology, Johns Hopkins Malaria Research Institute, Bloomberg School of Public Health, Johns Hopkins University, 615 N. Wolfe Street, Baltimore, MD 21205

- *Wolbachia* similar between bug sp.

POPULATION BIOLOGY/GENETICS

Geographic Distribution of *Wolbachia* Infections in *Cimex lectularius* (Heteroptera: Cimicidae)

JOYCE M. SAKAMOTO[1] AND JASON L. RASGON[2]

- Similar infection rates from five NA regions
- potential for using Wolbachia to control

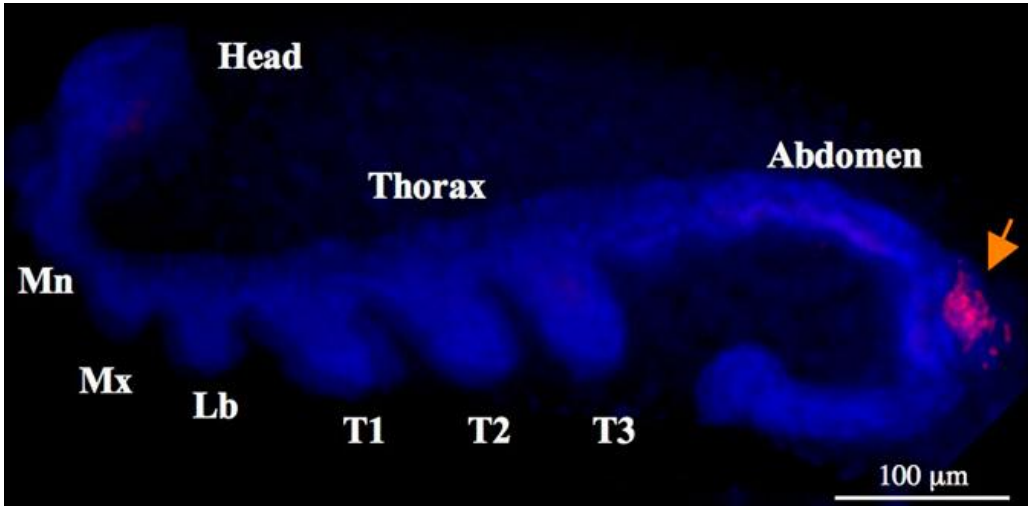
PNAS

Wolbachia as a bacteriocyte-associated nutritional mutualist

Takahiro Hosokawa, Ryuichi Koga, Yoshitomo Kikuchi, Xian-Ying Meng, and Takema Fukatsu[1]

National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba 305-8566, Japan

- localized in bacteriomes
- elimination of *Wolbachia* – retarded growth & sterility
- Nutritional role (rescue with B vitamins)



(Hosokawa et al. 2010. PNAS 107: 769-774)

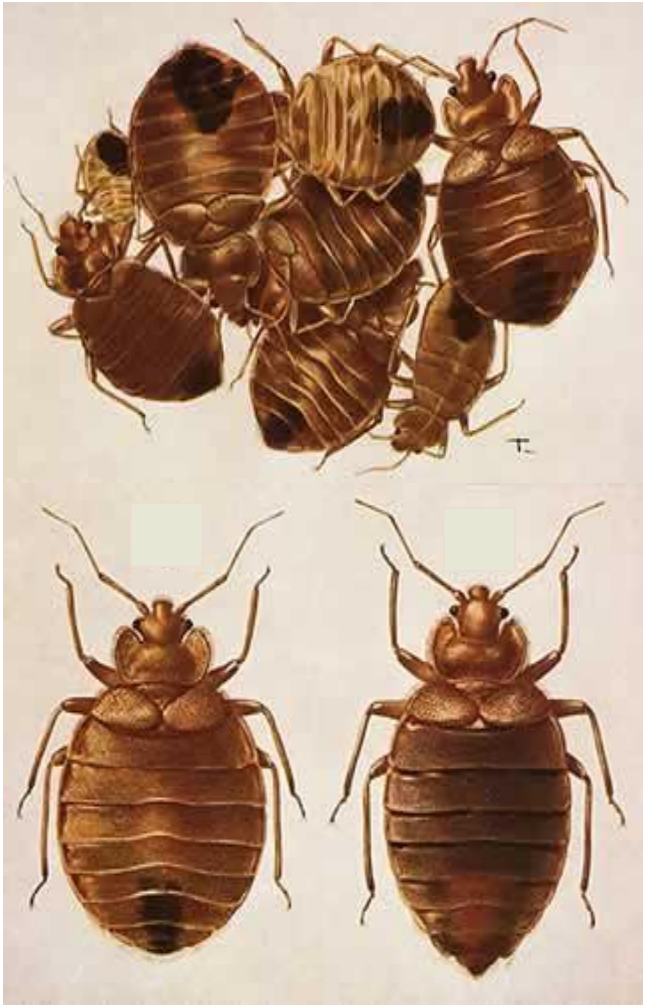
"What's Known and What's Next"

What role, if any, do bed bug symbionts play in the bug's inability to transmit human pathogens?
(Would the elimination of bed bug symbionts facilitate the development of human pathogens?)

Would the elimination of bed bug symbionts make them susceptible to insect-specific viruses/pathogens?

What methods are available for eliminating symbionts in bed bugs?

[Chang, K.P. (1974) Effects of elevated temperature on the mycetome and symbiotes of the bed bug *Cimex lectularius* (Heteroptera). J. Invert. Pathol. 23: 333-340.]



FRONTPIECE

Cimex lectularius Linnaeus. Left, female; right, male; above, cluster of nymphs and adults (Terzi).

From **R. L. Usinger *Monograph of Cimicidae* (1966)**

Thanks to:

Jeff Aldrich, USDA-ARS, Beltsville

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Mike Domingue, Pennsylvania State University

Harold Harlan, AFPMB, Silver Spring

Matt Kramer, USDA-ARS, Beltsville