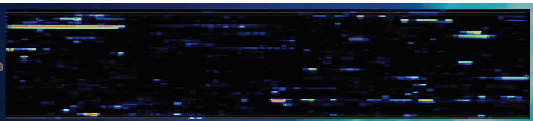
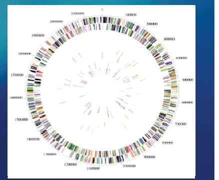
MicrobeGR



MicrobeGR

Basic and Applied Aspects of Insect Symbiosis



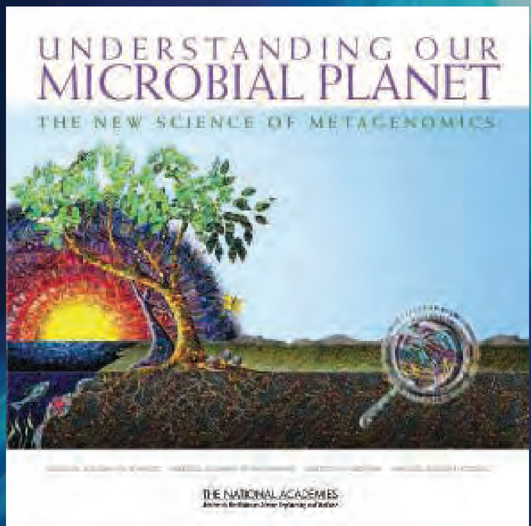
Kostas Bourtzis
Department of Environmental and Natural Resources Management
University of Ioannina, Greece

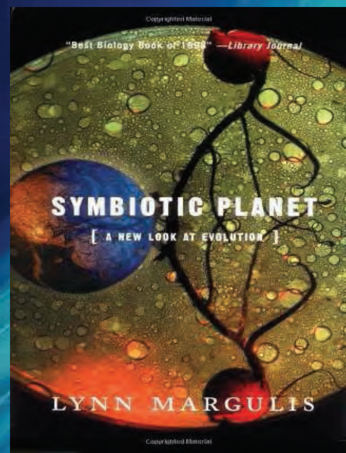
MicrobeGR

Outline of the Presentation

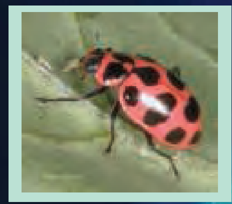
MicrobeGR

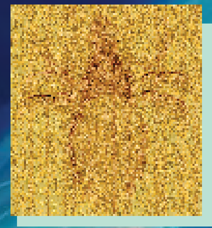
- Introduction to MicroBioKosmos and SymBioKosmos
- Insect Symbionts
  - different classes
  - biological role
  - applications
  - future of Insect Symbiosis in Europe?





What do symbiotic bacteria do in arthropods?





- Supplement nutrition deficiencies
- Help cope with environmental factors (biotic & abiotic)
- Reproductive manipulations

Nutritional Symbiosis

Nutritional Symbiosis I

Buchnera: nutritional symbiont (or organelle) in aphids

letters to nature

Genome sequence of the endocellular bacterial symbiont of aphids *Buchnera* sp. APS

Portiera: in whitefly

Evolutionary genomics: **Is *Buchnera* a bacterium or an organelle?**
Jan O. Andersson

Nutritional Symbiosis II

Wigglesworthia: nutritional symbiont in tsetse flies

Nature Genetics **32**, 402 - 407 (2002)
Published online: 3 September 2002 | doi:10.1038/ng986

Genome sequence of the endocellular obligate symbiont of tsetse flies, *Wigglesworthia glossinidia*

Leyla Akman, Atsushi Yamashita, Hidemi Watanabe, Kenshiro Oshima, Tadayoshi Shiba, Masahira Hattori & Serap Aksoy

Many insects that rely on a single food source throughout their developmental cycle harbor beneficial microbes that provide nutrients absent from their restricted diet. Tsetse flies, of African trypanosomes, feed exclusively on blood and such intracellular microbe for nutritional provisioning ar fecundity. As a result of co-evolution with hosts over mil years, these mutualists have lost the ability to survive o sheltered environment of their host insect cells. We pre complete annotated genome of *Wigglesworthia glossinid brevipalpis*, which is composed of one chromosome of base pairs (bp) and one small plasmid, called pWig1, of Genes involved in the biosynthesis of vitamin metabolite apparently essential for host nutrition and fecundity, ha retained. Unexpectedly, this obligate's genome bears ha both parasitic and free-living microbes, and the gene en important regulatory protein DnaA is absent.

Blochmannia: nutritional symbiont in ants

The genome sequence of *Blochmannia floridanus*: Comparative analysis of reduced genomes

Nutritional Symbiosis III

Wolbachia: … and nutritional symbiont in bedbugs and …

Wolbachia as a bacteriocyte-associated nutritional mutualist

… iron homeostasis and ……

Wolbachia Interferes with Ferritin Expression and Iron Metabolism in Insects

Nutritional Symbiosis IV

Gut symbionts: more than just digestive bugs!

ORIGINAL ARTICLE

Manipulation of the microbiota of mass-reared Mediterranean fruit flies *Ceratitis capitata* (Diptera: Tephritidae) improves sterile male sexual performance

Symbionts help insect hosts to cope with environmental factors

Help cope with environmental factors I

OPEN ACCESS Freely available online PLOS BIOLOGY

Aphid Thermal Tolerance Is Governed by a Point Mutation in Bacterial Symbionts

Helen E. Dunbar, Alex C. C. Wilson[¤], Nicole R. Ferguson, Nancy A. Moran[*]

Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, Arizona, United States of America

Symbiosis is a ubiquitous phenomenon generating biological complexity, affecting adaptation, and expanding ecological capabilities. However, symbionts, which can be subject to genetic limitations such as clonality and genomic degradation, also impose constraints on hosts. A model of obligate symbiosis is that between aphids and the bacterium *Buchnera aphidicola*, which supplies essential nutrients. We report a mutation in *Buchnera* of the aphid *Acyrthosiphon pisum* that recurs in laboratory lines and occurs in field populations. This single nucleotide deletion affects a homopolymeric run within the heat-shock transcriptional promoter for *ibpA*, encoding a small heat-shock protein. This *Buchnera* mutation virtually eliminates the transcriptional response of *ibpA* to heat stress and lowers its

Help cope with environmental factors II

PNAS PNAS

Facultative bacterial symbionts in aphids confer resistance to parasitic wasps

Kerry M. Oliver[*], Jacob A. Russell[†], Nancy A. Moran[†], and Martha S. Hunter[*‡]

Departments of [*]Entomology and [†]Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ 85721

Edited by Lynn Margulis, University of Massachusetts, Amherst, MA, and approved December 16, 2002 (received for review August 28, 2002)

Symbiotic relationships between animals and microorganisms are common in nature, yet the factors controlling the abundance and distributions of symbionts are mostly unknown. Aphids have an obligate association with the bacterium *Buchnera aphidicola* (the primary symbiont) that has been shown to contribute directly to aphid fitness. In addition, aphids sometimes harbor other vertically transmitted bacteria (secondary symbionts), for which few benefits of infection have been previously documented. We carried out experiments to determine the consequences of these facultative symbioses in *Acyrthosiphon pisum* (the pea aphid) for vulnerability of the aphid host to a hymenopteran parasitoid, *Aphidius ervi*, a major natural enemy in field populations. Our results show that, in a controlled genetic background, infection confers resistance to parasitoid attack by causing high mortality of developing parasitoid larvae. Compared with uninfected controls, experimentally

A. pisum clones vary greatly in their resistance to *A. ervi* development following oviposition. To determine the possible contribution of SS to this variation, we established genetically uniform aphid lineages that differed only in their SS infection status. To eliminate any effects of genetic variation of the aphids in resistance to parasitism, we inoculated an uninfected *A. pisum* clone with SS from body fluids of clones harboring each of the γ-3 proteobacteria SS types, thus creating three genetically uniform lineages of aphids that differed from the original only by the presence of a particular SS. These lineages were used in experiments to determine the consequences of these facultative symbioses for aphid vulnerability to an important hymenopteran parasitoid. The major protective effects that we documented may contribute to the maintenance and spread of facultative symbionts in host populations.

PNAS

Hamiltonella defensa, genome evolution of protective bacterial endosymbiont from pathogenic ancestors

Patrick H. Degnan[a,1], Yeisoo Yu[b], Nicholas Sisneros[b], Rod A. Wing[b], and Nancy A. Moran[a]

[a]Department of Ecology and Evolutionary Biology, [b]Arizona Genomics Institute, University of Arizona, Tucson, AZ 85721

Edited by Edward F. DeLong, Massachusetts Institute of Technology, Cambridge, MA, and approved April 14, 2009 (received for review January 7, 2009)

Eukaryotes engage in a multitude of beneficial and deleterious interactions with bacteria. *Hamiltonella defensa*, an endosymbiont of aphids and other sap-feeding insects, protects its aphid host from attack by parasitoid wasps. Thus *H. defensa* is only condi-

also be transmitted horizontally either intraspecifically [e.g., sexually (22)] or interspecifically (12, 17). Moreover, protection by *H. defensa* has been shown to be transferable between distantly related aphid species (19).

Help cope with environmental factors III

PNAS

Variation in resistance to parasitism in aphids is due to symbionts not host genotype

Kerry M. Oliver[*†], Nancy A. Moran[‡§], and Martha S. Hunter[*]

Departments of [*]Entomology and [‡]Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ 85721

Contributed by Nancy A. Moran, July 20, 2005

Natural enemies are important ecological and evolutionary forces, and heritable variation in resistance to enemies is a prerequisite for adaptive responses of populations. Such variation in resistance has been previously documented for pea aphids (*Acyrthosiphon pisum*) attacked by the parasitoid wasp *Aphidius ervi*. Although the variation was presumed to reflect genotypic differences among the aphids, another potential source of resistance to *A. ervi* is infection

transmitted (mother to offspring) facultative ("secondary") symbionts (SS) in addition to the obligate primary symbiont *Buchnera aphidicola*. Although the nutritional function of *Buchnera* is relatively well understood (17, 18), the roles of these SS in *A. pisum* are only now coming to light. *Regiella insecticola* (formerly the U-type or PAUS) has been implicated in host-plant specialization in Japanese *A. pisum* (ref. 16; but see ref. 19).

Symbionts and Host Selection Behavior

PNAS PNAS

A newly discovered bacterium associated with parthenogenesis and a change in host selection behavior in parasitoid wasps

E. Zchori-Fein[*], Y. Gottlieb[†], S. E. Kelly[‡], J. K. Brown[*], J. M. Wilson[¶], T. L. Karr[†], and M. S. Hunter[‡‖]

[*]Department of Plant Sciences, 303 Forbes Building, University of Arizona, Tucson, AZ 85721; [†]Department of Organismal Biology and Anatomy, 1027 East 57th Street, University of Chicago, Chicago, IL 60637; [‡]Department of Entomology, 410 Forbes Building, University of Arizona, Tucson, AZ 85721; and [¶]Department of Cell Biology and Anatomy, P.O. Box 245044, University of Arizona, Tucson, AZ 85721

Communicated by Margaret G. Kidwell, University of Arizona, Tucson, AZ, September 4, 2001 (received for review February 6, 2001)

The symbiotic bacterium *Wolbachia pipientis* has been considered unique in its ability to cause multiple reproductive anomalies in its arthropod hosts. Here we report that an undescribed bacterium is vertically transmitted and associated with thelytokous parthenogenetic reproduction in *Encarsia*, a genus of parasitoid wasps. Although *Wolbachia* was found in only one of seven parthenoge-

might expect selection on both bacterial and wasp genomes to act to prevent infected females from accepting hosts that may be suitable for male but not female development. In most cases, these behavioral refinements may be too subtle to measure, but they are likely to be very important in those parasitoids in which males and females generally develop in different host environments (16).

J. Evol. Biol.

doi:10.1111/j.1420-9101.2006.01228.x

Manipulation of oviposition choice of the parasitoid wasp, *Encarsia pergandiella*, by the endosymbiotic bacterium *Cardinium*

S. G. KENYON* & M. S. HUNTER†

Symbionts and Fitness Effects

Heredity , (7 July 2010) | doi:10.1038/hdy.2010.89

Endosymbiont costs and benefits in a parasitoid infected with both Wolbachia and Cardinium

J A White, S E Kelly, S N Cockburn, S J Perlman and M S Hunter

Theory suggests that maternally inherited endosymbionts can promote their spread and persistence in host populations by enhancing the production of daughters by infected hosts, either by improving overall host fitness, or through reproductive manipulation. In the doubly infected parasitoid wasp Encarsia inaron, Wolbachia manipulates host reproduction through cytoplasmic incompatibility (CI), but Cardinium does not. We investigated the fitness costs and/or benefits of infection by each bacterium in differentially cured E. inaron as a potential explanation for persistence of Cardinium in this population. We introgressed lines infected with Wolbachia, Cardinium or both with the cured line to create a similar genetic background, and evaluated several parasitoid fitness parameters. We found that symbiont infection resulted in both fitness costs and benefits for E. inaron. The cost was lower initial egg load for all infected wasps. The benefit was increased survivorship, which in turn increased male production for wasps infected with only Cardinium. Female production was unaffected by symbiont infection; we therefore have not yet identified a causal fitness effect that can explain the persistence of Cardinium in the population. Interestingly, the Cardinium survivorship benefit was not evident when Wolbachia was also present in the host, and the reproduction of doubly infected individuals did not differ significantly from uninfected wasps. Therefore, the results of our study show that even when multiple infections seem to have no effect on a host, there may be a complex interaction of costs and benefits among symbionts.

- Fecundity
- Fertility
- Longevity
- Mating behavior
- etc

Symbionts and Insecticide Resistance

Rapid Report

The presence of *Rickettsia* is associated with increased susceptibility of *Bemisia tabaci* (Homoptera: Aleyrodidae) to insecticides

Svetlana Kontsedalov[1], Einat Zchori-Fein[2], Elad Chiel[2,3], Yuval Gottlieb[1], Moshe Inbar[3], Murad Ghanim[1,*]

Article first published online: 23 APR 2008

DOI: 10.1002/ps.1595

Issue

Pest Management Science
Volume 64, Issue 8, pages 789–792, August 2008

Help cope with environmental factors VII

Mainly vertically (maternal transmission) but also horizontally!

PLoS One

Almost There: Transmission Routes of Bacterial Symbionts between Trophic Levels

Elad Chiel[1,2,3*], Einat Zchori-Fein[2], Moshe Inbar[1], Yuval Gottlieb[4], Tetsuya Adachi-Hagimori[3,5], Suzanne E. Kelly[3], Mark K. Asplen[6], Martha S. Hunter[3]

1 Department of Evolutionary and Environmental Biology, University of Haifa, Haifa, Israel, 2 Department of Entomology, Newe-Ya'ar Research Center, ARO, Ramat-Yishai, Israel, 3 Department of Entomology, University of Arizona, Tucson, Arizona, United States of America, 4 Department of Entomology, the Volcani Center, ARO, Beit-Dagan, Israel, 5 Graduate School of Biosphere Sciences, Hiroshima University, Higashi-Hiroshima, Hiroshima, Japan, 6 Department of Entomology, University of Minnesota, St. Paul, Minnesota, United States of America

Symbiont-induced Reproductive Manipulations

Reproductive manipulations

Wolbachia	Feminization
Cardinium	Parthenogenesis
Arsenophonus	Male killing
Rickettsia	Cytoplasmic Incompatibility
Spiroplasma	

Available online at www.sciencedirect.com

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Current Opinion in Microbiology

ELSEVIER

Wolbachia: more than just a bug in insects genitals

Aggeliki Saridaki and Kostas Bourtzis

Research on the intracellular bacterial symbiont Wolbachia has grown on many levels, providing interesting insights on various aspects of the microbe's biology. Although data from fully sequenced genomes of different Wolbachia strains and from experimental studies of host–microbe interactions continue to arise, most of the molecular mechanisms employed by Wolbachia to manipulate the host cytoplasmic machinery and to ensure vertical transmission are yet to be discovered. Apart from the well-established role of Wolbachia in triggering reproductive alterations, a new fascinating aspect is emerging, related to the ecological benefits that the symbiont provides to

been detected in many host tissues (Figure 1). Wolbachia has evolved several strategies to ensure vertical transmission through the manipulation of host reproductive system. These strategies include feminization, parthenogenesis, male killing and cytoplasmic incompatibility. All the above phenotypes, commonly referred to as 'reproductive parasitism', increase the frequency of infected females in the host population.

PCR-based screening methods revealed the widespread distribution of the symbiont in diverse hosts, covering

Wolbachia manipulates oogenesis thru apoptosis

PNAS PNAS

Removing symbiotic _Wolbachia_ bacteria specifically inhibits oogenesis in a parasitic wasp

Franck Dedeine*†, Fabrice Vavre*, Frédéric Fleury*, Benjamin Loppin‡, Michael E. Hochberg§, and Michel Boulétreau*

Edited by Lynn Margulis, University of Massachusetts, Amherst, MA, and approved March 16, 2001 (received for review June 30, 2000)

PNAS

Parasitic inhibition of cell death facilitates symbiosis

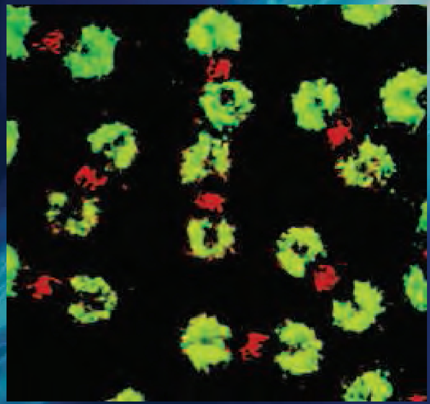
Bart A. Pannebakker*†‡, Benjamin Loppin§, Coen P. H. Elemans¶, Lionel Humblot*, and Fabrice Vavre*

Symbiotic microorganisms have had a large impact on eukaryotic evolution, with effects ranging from parasitic to mutualistic. Mitochondria and chloroplasts are prime examples of symbiotic microorganisms that have become obligate for their hosts, allow-

chambers, while at this stage apoptosis does not occur in the ovarioles of symbiotic control females (Fig. 2) (Mann–Whitney U test: W = 461; n = 45; P < 0.001). Apoptosis is an essential component of insect oogenesis and occurs at several stages

Introduction to Wolbachia biology

Wolbachia interacts with host microtubules



[Bourtzis' Lab]

Host Distribution of Wolbachia Strains

Arthropods

- Insects
- Mites
- Isopods
- Scorpions
- Spiders
- Springtails

Nematodes

- Filarial worms (mainly)

Not infected:

- many species of agricultural importance (e.g. *Bactrocera oleae*)
- many species of medical importance (e.g. *Anopheles gambiae*)
- many species of environmental importance (e.g. *Dendroctonus* spp.)

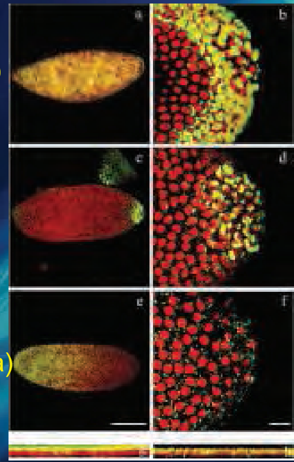
Wolbachia during *Drosophila* embryogenesis

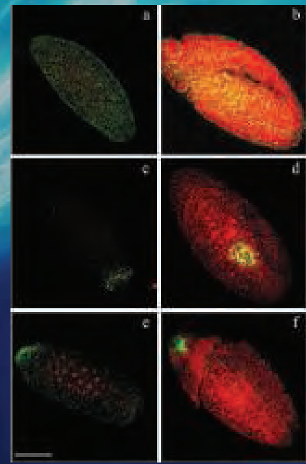
Embryo — Pole cells

D. simulans (*w*Ri)

D. teissieri (*w*Tei)

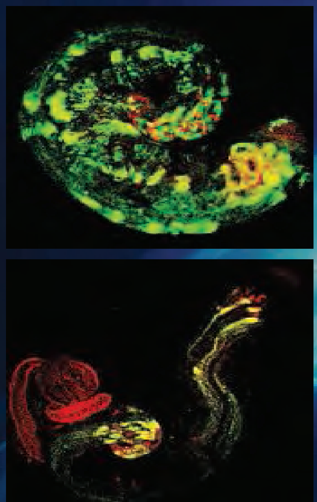
D. simulans (*w*Ma)

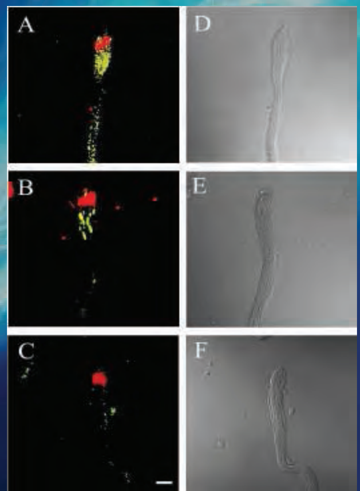




[Veneti et al. (2004) Appl. Env. Microbiol. 70: 5366-5372]

Wolbachia during *Drosophila* spermatogenesis





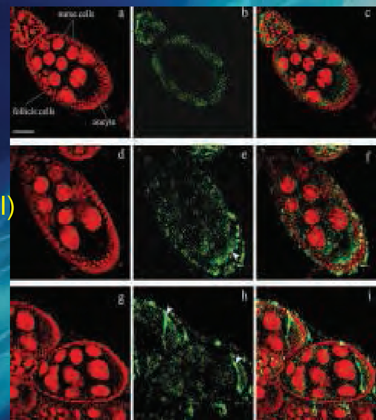
[Veneti et al. (2003), Genetics 164: 545-552; Clark et al. (2002), Mech. Devel. 111: 3-15; Clark et al. (2003), Mech. Devel. 120: 85-98]

Wolbachia during *Drosophila* oogenesis

D. simulans (*w*Ri)

D. melanogaster (*w*Mel)

D. simulans (*w*No)



oskar-like mRNA pattern

bicoid-like mRNA pattern

[Veneti et al. (2004) Appl. Env. Microbiol. 70: 5366-5372]

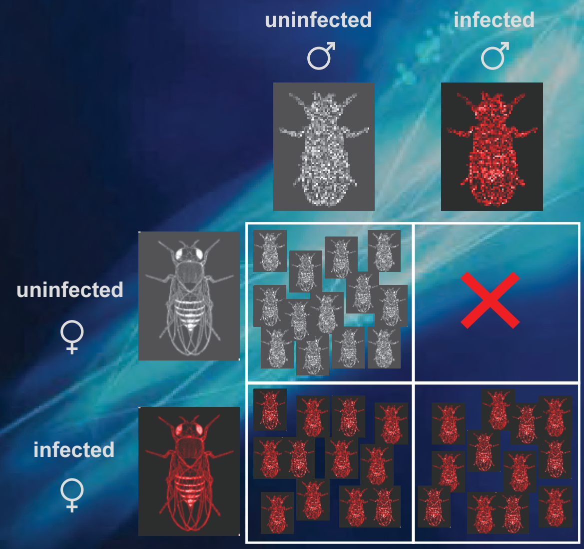
Wolbachia-Induced Reproductive Abnormalities

Wolbachia induce a number of reproductive alterations, such as:

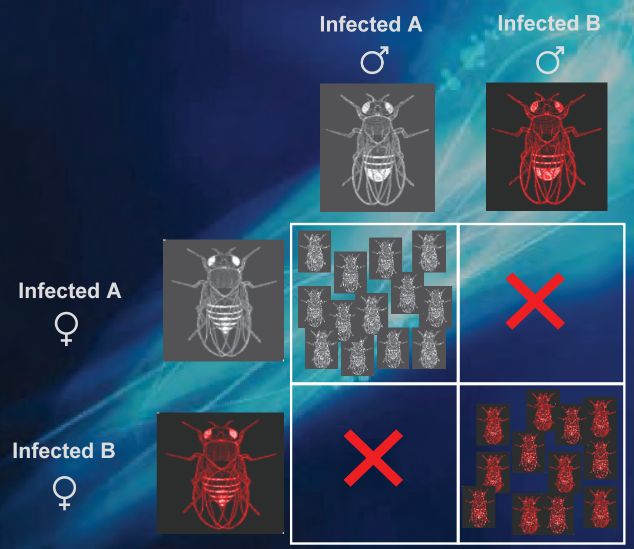
- Feminization
- Parthenogenesis
- Male-killing
- Cytoplasmic Incompatibility

- Spreading
- Curing - Antibiotics

Uni-Directional CI



Bi-Directional CI



Wolbachia Genomics

PNAS

The mosaic genome structure of the *Wolbachia* wRi strain infecting *Drosophila simulans*

Lisa Klasson[a,1], Joakim Westberg[a,1], Panagiotis Sapountzis[b], Kristina Näslund[a], Ylva Lutnaes[a], Alistair C. Darby[a,2], Zoe Veneti[c], Lanming Chen[d,3], Henk R. Braig[e], Roger Garrett[d], Kostas Bourtzis[b,c], and Siv G. E. Andersson[a,4]

Wolbachia-based applications

Wolbachia and Applied Biology

For example:

1. Asexuality

2. As an expression vector

3. As a tool for the modification of population age structure

4. As a spreading mechanism

5. As a tool for population suppression of insect pests

and

6. Wolbachia and Immunity

Wolbachia and Applied Biology

For example:

1. Asexuality

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and

6. Wolbachia and Immunity

PNAS

Wolbachia-induced cytoplasmic incompatibility as a means for insect pest population control

Sofia Zabalou[*,†], Markus Riegler[‡,§], Marianna Theodorakopoulou[¶], Christian Stauffer[‡], Charalambos Savakis[*,∥], and Kostas Bourtzis[**,††]

[*]Department of Medical Sciences, Medical School, and [¶]Department of Biology, University of Crete, Heraklion 711 10, Crete, Greece; [†]Technological Educational Institute of Crete, Heraklion 711 10, Crete, Greece; [‡]Institute of Forest Entomology, Forest Pathology and Forest Protection, Department of Forest and Soil Sciences, BOKU, University of Natural Resources and Applied Life Sciences, 1190 Vienna, Austria; [§]Department of Zoology and Entomology, University of Queensland, St. Lucia QLD 4072, Australia; [∥]Institute of Molecular Biology and Biotechnology, Foundation for Research and Technology, Hellas, Vassilika Vouton, P.O. Box 1527, Heraklion 711 10, Crete, Greece; and [**]Department of Environmental and Natural Resources Management, University of Ioannina, 2 Seferi Street, Agrinio 30100, Greece

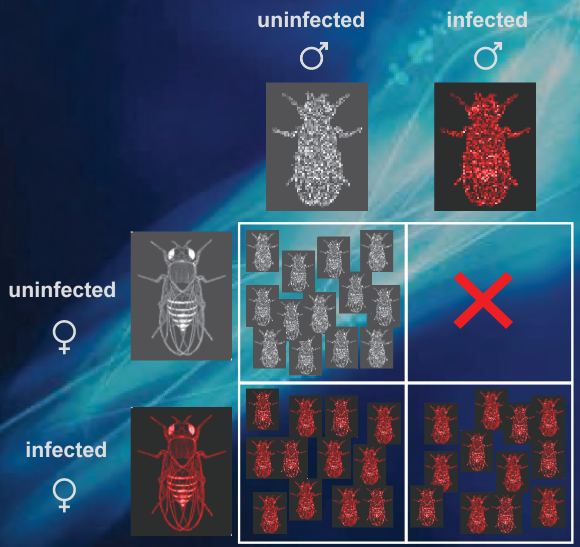
Edited by John H. Law, University of Georgia, Athens, GA, and approved September 9, 2004 (received for review May 31, 2004)

Biological control is the purposeful introduction of parasites, predators, and pathogens to reduce or suppress pest populations. *Wolbachia* are inherited bacteria of arthropods that have recently attracted attention for their potential as new biocontrol agents. *Wolbachia* manipulate host reproduction by using several strategies, one of which is cytoplasmic incompatibility (CI) [Stouthamer, R., Breeuwer, J. A. J. & Hurst, G. D. D. (1999) *Annu. Rev. Microbiol.* 53, 71–102]. We established *Wolbachia*-infected lines of the medfly *Ceratitis capitata* using the infected cherry fruit fly *Rhagoletis cerasi* as donor. *Wolbachia* induced complete CI in the novel host. Laboratory cage populations were completely suppressed by single releases of infected males, suggesting that *Wolbachia*-induced CI could be used as a novel environmentally friendly tool for the control of medfly populations. The results also encourage the introduction of *Wolbachia* into pest and vector species of economic and hygenic relevance to suppress or modify natural populations.

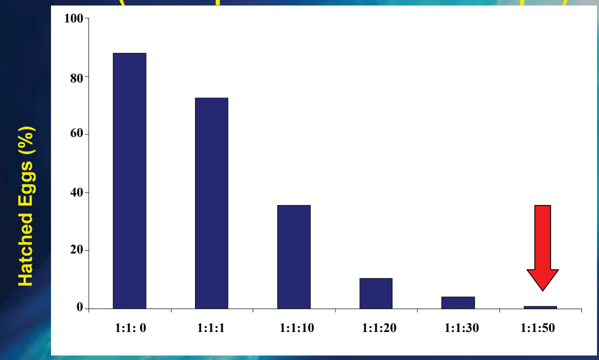
transfer of natural bacterial symbionts from a related species, *R. cerasi* (Diptera, Tephritidae) (18), to an uninfected laboratory strain of medfly *C. capitata* (Diptera, Tephritidae), the Benakeion strain.

Previous studies have demonstrated high levels of incompatibility between natural populations of *R. cerasi* (10, 19), the basis of which was recently shown to be *Wolbachia* (18). Populations of *R. cerasi* are either infected by a single *Wolbachia* variant, *w*Cer1, or coinfected by two variants, *w*Cer1 and *w*Cer2. Incompatibility occurs between males from doubly infected populations and females from singly infected populations, suggesting the *w*Cer2 infection as the cause of CI (18). Additionally, transfer of *w*Cer2 in *Drosophila simulans* also resulted to the induction of CI (17). An additional, yet uncharacterized, *Wolbachia* strain (*w*Cer3) has been recently found in Sicilian populations of *R. cerasi* (M.R. and C. Stauffer, unpublished results).

Uni-Directional CI



Suppression of medfly populations using *Wolbachia*-induced CI (Incompatible Insect Technique)



Transinfected Males Ratio

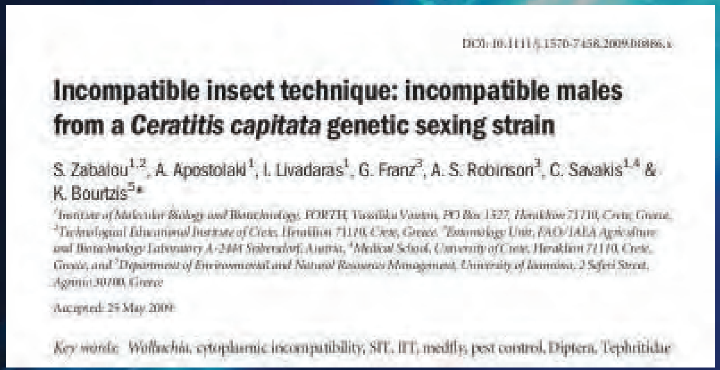
Number of adults	300	300	300	306	290	520
Number of eggs scored	3000	3000	2097	1688	858	700

[Zabalou et al. (2004), PNAS, 101: 15042-15045]

IIT like SIT

Entomol. Exp. Appl.

100% CI (100% embryonic mortality)


DOI: 10.1111/j.1570-7458.2009.00886.x

Incompatible insect technique: incompatible males from a *Ceratitis capitata* genetic sexing strain

S. Zabalou[1,2], A. Apostolaki[1], I. Livadaras[1], G. Franz[3], A. S. Robinson[3], C. Savakis[1,4] & K. Bourtzis[5]*

[1]*Institute of Molecular Biology and Biotechnology, FORTH, Vassilika Vouton, PO Box 1527, Heraklion 71110, Crete, Greece,* [2]*Technological Educational Institute of Crete, Heraklion 71110, Crete, Greece,* [3]*Entomology Unit, FAO/IAEA Agriculture and Biotechnology Laboratory A-2444 Seibersdorf, Austria,* [4]*Medical School, University of Crete, Heraklion 71110, Crete, Greece, and* [5]*Department of Environmental and Natural Resources Management, University of Ioannina, 2 Seferi Street, Agrinio 30100, Greece*

Accepted: 25 May 2009

Key words: *Wolbachia*, cytoplasmic incompatibility, SIT, IIT, medfly, pest control, Diptera, Tephritidae

Incompatible Insect Technique (I.I.T.)

- Based on the mechanism of Wolbachia-induced CI
- Analogous to S.I.T.
- Effective sexing system is neccessary
- Environmentally friendly technology
- Low technological input
- Low cost technology
- Higher competitiveness of released males
- Successful applications (Medfly, Olive fly, *C. pipiens, Cadra cautella*)
- We welcome suggestions for collaborations to apply the I.I.T. to your favourite insect pest species!

Wolbachia and Applied Biology

For example:

1. Asexuality
2. As an expression vector
3. As a tool for the modification of population age structure
4. As a spreading mechanism
5. As a tool for population suppression of insect pests

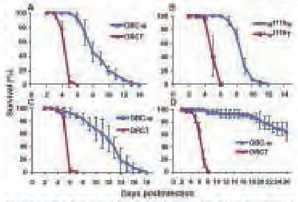
and

6. Wolbachia and Immunity

BREVIA

Wolbachia and Virus Protection in Insects

Lauren M. Hedges, Jeremy C. Brownlie, Scott L. O'Neill, Karyn N. Johnson*



Immune Activation by Life-Shortening *Wolbachia* and Reduced Filarial Competence in Mosquitoes

Zakaria Kambris, Peter E. Cook, Hoang K. Phuc, Steven P. Sinkins*

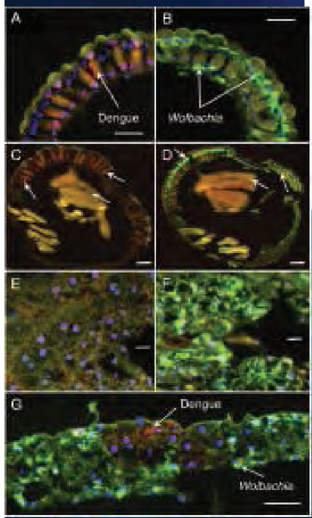
Wolbachia strain *w*MelPop reduces the longevity of its *Drosophila melanogaster* host and, when introduced into the mosquito *Aedes aegypti*, halves its life span. We show that *w*MelPop induces up-regulation of the mosquito's innate immune system and that its presence inhibits the development of filarial nematodes in the mosquito. These data suggest that *w*MelPop could be used in the global effort to eliminate lymphatic filariasis and possibly for the control of other mosquito-borne parasites where immune preactivation inhibits their development. The cost of constitutive immune up-regulation may contribute to the life-shortening phenotype.

Wolbachia pipientis is a maternally inherited intracellular bacterium of invertebrates, capable of spreading itself through populations by reproductive manipulation such as cytoplasmic incompatibility (CI). The strain *w*MelPop or "popcorn," unusually, reduces the longevity of its *Drosophila melanogaster* host (1) and also has been shown to halve life-span when the mosquito *Aedes aegypti* was stably transinfected (2). The *w*MelPop life-shortening phenotype offers the prospect of a disease control system by potentially skewing the population structure toward younger individuals. Vectorial capacity is particularly sensitive to mosquito age because mosquito-borne pathogens require an extrinsic incubation period between ingestion and transmission that is long relative to mean life-span in the field, such that only older mosquitoes within a population are potentially infective. *w*MelPop was also found to be inherited at high rates and to induce strong CI in *Ae. aegypti*, which provides a reproductive advantage to infected females. The *w*MelPop strain should be capable of spreading through populations despite the reduction in mean life-span, because reproduction by older individuals makes a relatively small contribution to the next generation (2–6).

We compared host gene expression using whole-genome microarrays in genetically identical *Ae. aegypti* lines infected and uninfected with *w*MelPop (7) to examine the mechanism underlying the life-shortening phenotype. Of 199 gene transcripts up-regulated by more than a twofold threshold, 78 had putative immune-related functions (Fig. 1 and table S2). These included genes that encode 17 CLIP domain, serine proteases, nine FREPs (fibrinogen-related proteins), six cecropins, four TEPs (thioester-containing proteins), three defensins, three PPOs (prophenoloxidases), two lysozymes, two PGRPs (peptidoglycan recog-

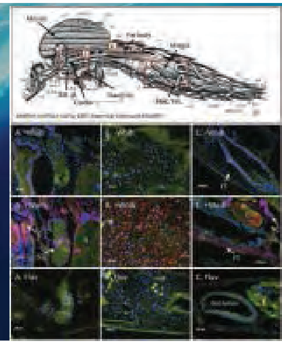
Peter Medawar Building for Pathogen Research and Department of Zoology, University of Oxford, South Parks Road, Oxford OX1 3PS, UK.
*To whom correspondence should be addressed. E-mail: steven.sinkins@zoo.ox.ac.uk

Cell



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

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



Horizontal Gene(Genome) Transfer(s)

Wolbachia (and other symbionts?) Jumps!

Science 2007

Widespread Lateral Gene Transfer from Intracellular Bacteria to Multicellular Eukaryotes

Julie C. Dunning Hotopp,[1*†‡] Michael E. Clark,[2*] Deodoro C. S. G. Oliveira,[2] Jeremy M. Foster,[3] Peter Fischer,[4] Mónica C. Muñoz Torres,[5] Jonathan D. Giebel,[2] Nikhil Kumar,[1‡] Nadeeza Ishmael,[1‡] Shiliang Wang,[1] Jessica Ingram,[3] Rahul V. Nene,[1§] Jessica Shepard,[1||] Jeffrey Tomkins,[5] Stephen Richards,[6] David J. Spiro,[1] Elodie Ghedin,[1,7] Barton E. Slatko,[3] Hervé Tettelin,[1‡¶] John H. Werren[2¶]

Conclusions

A Single Conclusion

- Do not ignore Symbionts! since they control Insects'….
  - Biology
  - Ecology
  - Evolution

Symbiosis Work in Bourtzis' Lab

MicrobeGR MicrobeGR

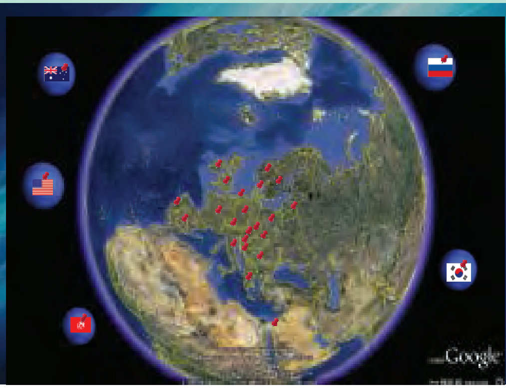
In the frame of:

- EU FP7 MicrobeGR project (http://microbegr.env.uoi.gr)
- EU COST FA0701 "Arthropod Symbiosis: from fundamental studies to pest and disease management" (http://www.cost-fa0701.com/ & http://w3.cost.esf.org/index.php?id=181&action_number=FA0701)

EU COST ACTION FA0701

"Arthropod Symbiosis: from fundamental studies to pest and disease management"

Prof. Kostas Bourtzis, Chair (Greece)
Dr. Einat Zchori-Fein, Vice Chair (Israel)



Participants

Austria, Croatia, Czech Republic, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Israel

Latvia, Norway, Portugal, Poland, Serbia, Slovenia, Spain, Sweden, Switzerland, The Netherlands, United Kingdom

Australia, Korea, Russia, Tunisia, United States

111 experts
4 SMEs
20+2 COST countries
5 Non COST countries

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- **Bourtzis' lab**

Current Members

- George Tsiamis
- Eva Dionyssopoulou
- Aggeliki Saridaki
- Antonios Avgoustinos
- Athina Hamalaki
- Evangelos Doudoumis
- Evangelos Diakoumis

Past Members

- Sofia Zabalou
- Zoe Veneti
- Stefan Oehler
- Aggeliki Apostolaki
- George Papafotiou
- Ioannis Livadaras

- **IMBB / Fleming**
- Babis Savakis

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- Corey Brelsfoard

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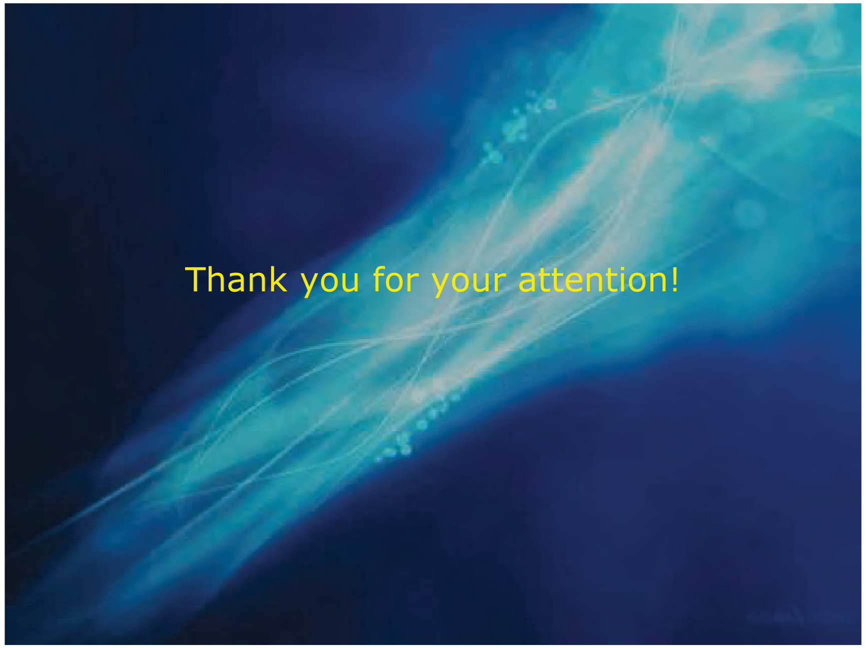
Thank you for your attention!