CCABB
CONNECTICUT COALITION AGAINST BED BUGS

Bed Bug Forum XI

Bed Bug Research. Understanding an Enigma.

Dr. Gale E. Ridge
Entomologist
The Connecticut Agricultural Experiment Station,
New Haven, Connecticut,
November 7, 2019

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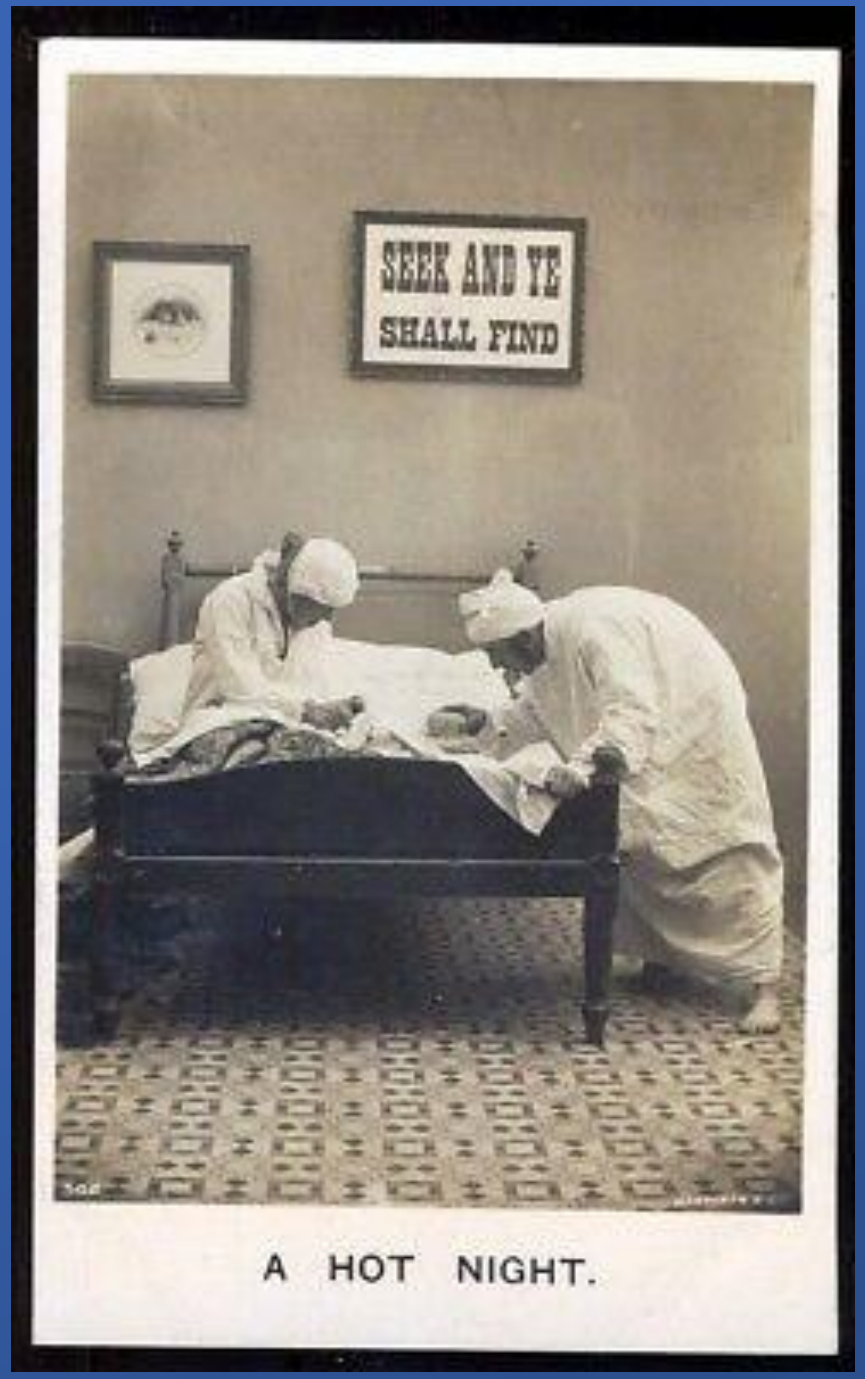

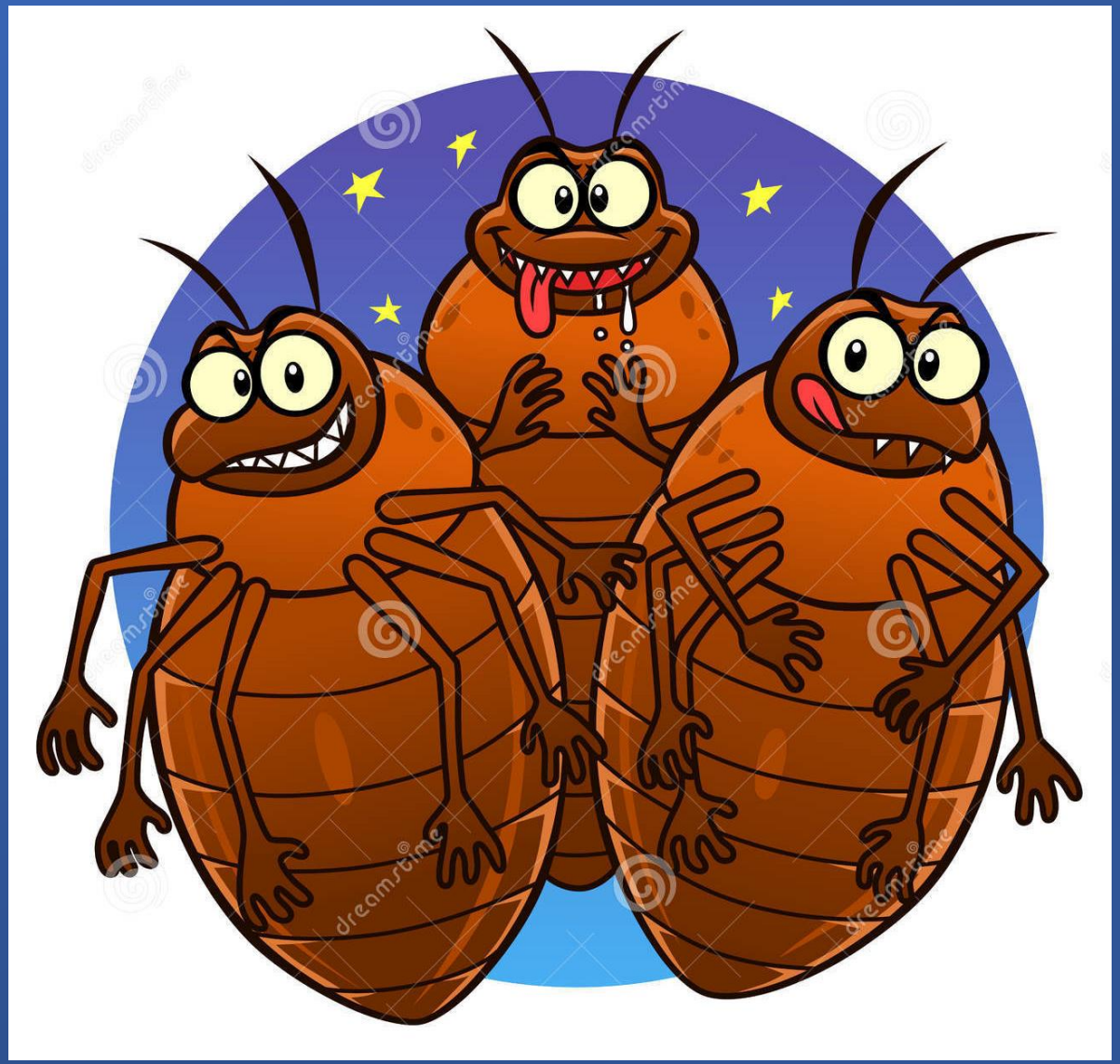

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Dichlorodiphenyltric-hloroethane (DDT)

CDC. Fourth National Report of Human Exposure to Environmental Chemicals (2019)

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Body Form

Nymph

Adult female

Adult male

Pin head

Newly hatched nymphs and egg cases

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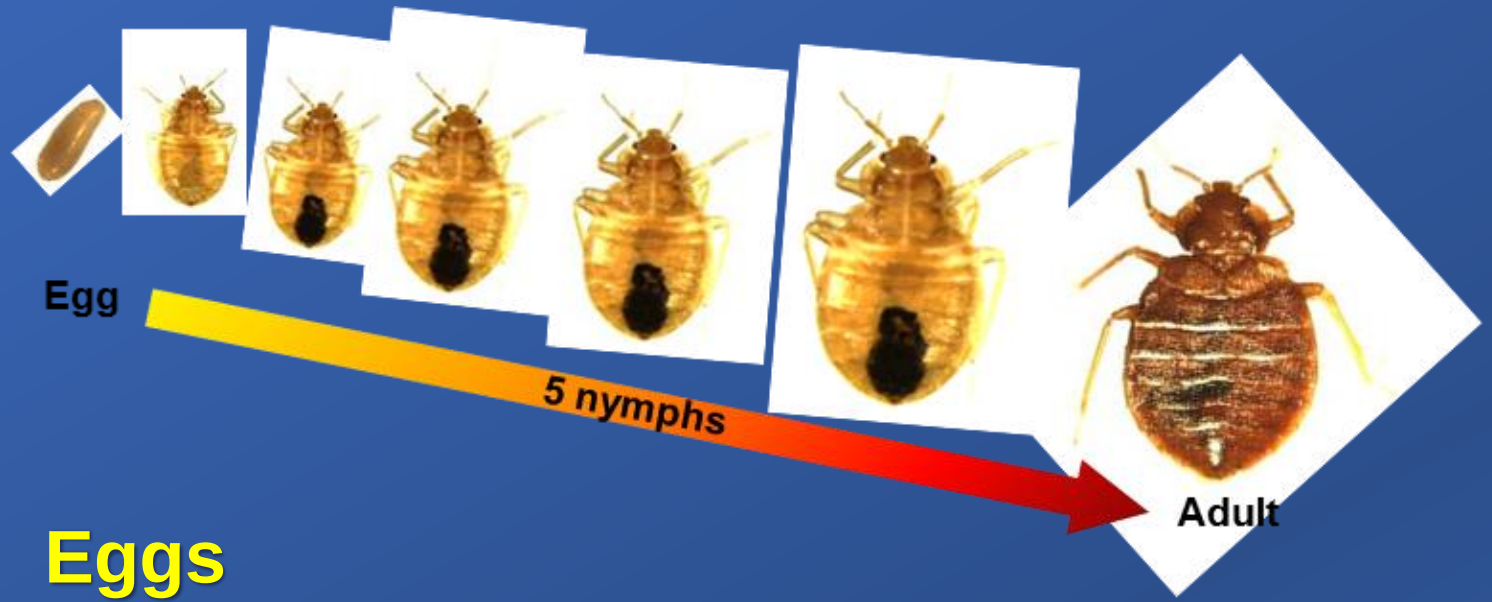
Seven Life Stages



Eggs

5 nymph stages; “instars”

Adults

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Clustering behavior in a refuge

Night stand with fecal spots

Bed bugs commute
Insects of habits!

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List of attributes *Cimex lectularius* L. uses for survival.

1. Quiescent with extended inactivity	18. Capacity to learn	34. Apparent torpor
2. Thigmotactic	19. Track host behaviors i.e. resting patterns	35. Traumatic insemination controls gene flow
3. Touch sensitive	20. Multi-stimulus host seeking	36. Genetic plasticity
4. Retreats regardless of danger	21. Efficient directed movement	37. Population uniqueness impeding gene flow
5. Flat profile	22. Air current sensitive	38. Hybrid vigor
6. Camouflage coloration	23. Excellent climbers except when upside down	49. Females often control mating
7. Desiccation resistant	24. Inbreeding resistant	40. Male influence on female fecundity
8. Not hydroscopic	25. Hitchhiking behavior	41. Males mating with fifth instar proto-females
9. Agoraphobic	26. Prey for other building insects	42. Bullying behavior
10. Aggregation behavior	27. Freeze and/or flight response	43. Males mate guard females
11. Stacking behavior	28. Peaking behavior to furtively reconnoiterer	44. Females egg guard
12. Complex pheromone communication	29. Use of exuvae for protection	45. Eggs laid on live insects and carried
13. Mostly photophobic	30. Dependent on human construction	46. Aggregating in high locations
15. Host switching to survive	31. Human anxiety and fragility	47. Heat response difference that is hunger dependent
16. Compulsive beak cleaning	32. Adult & nymph metabolic differences	48. Use of feces for refuge locating
17. Capacity to investigate	33. Pesticide resistance	49. Avoidance of water, easily drowned

- **Bed Bugs are desert adapted insects**
  They tolerate dry conditions

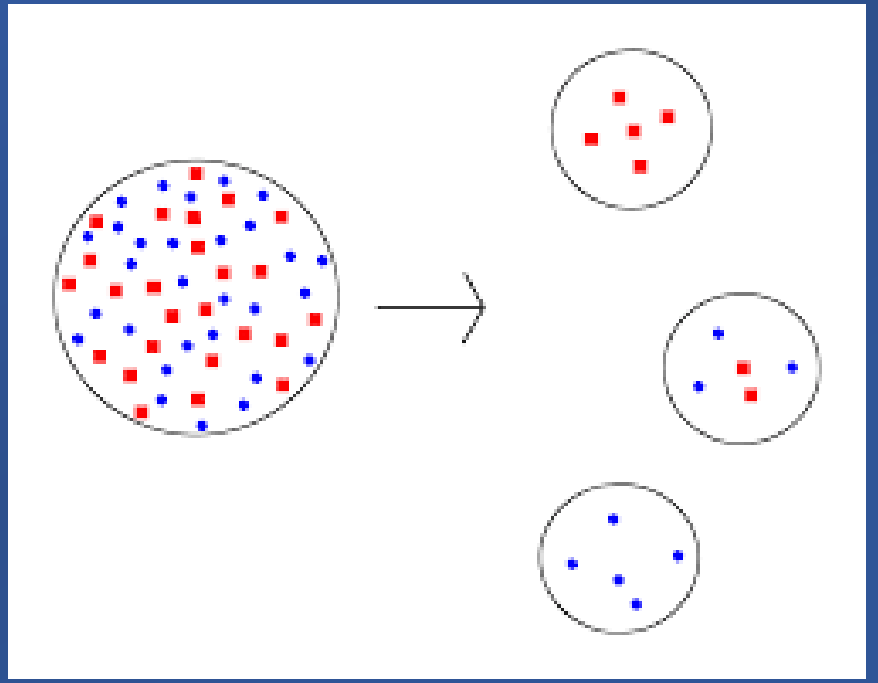
*Joshua Benoit et al. Resistance to dehydration between bouts of blood feeding in the bed bug *Cimex lectularius*, is enhanced by water conservation, aggregation, and quiescence. Tropical Med. 76(5) 2007, pp 987-993

- **Avoidance behavior for very little reason**

- **The Founder Effect**

Each population seems to develop unique responses to stimuli and chemistry but still retain full genetic diversity.

Chromosome counts:
26+X_1X_2Y in males
26+$X_1X_1X_2X_2$ in females



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Bed Bug Evolution

Bed bugs have been on this planet longer than first believed!

International 15 year research led by Steffen Roth, Bergen, Norway and Ondřej Balvín, Prague, Czech Republic

*Bedbugs Evolved before Their Bat Hosts and Did Not Co-speciate with Ancient Humans
Steffen Roth et al., 2019 Current Biology 29. pp. 1847-1853

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Ancestral bed bugs found at 115 – 122mya (Cretaceous period) as specialists that later frequented bats and birds. Bed bugs predate bats by at least 30 - 50Ma rejecting widely held view that they evolved on bats

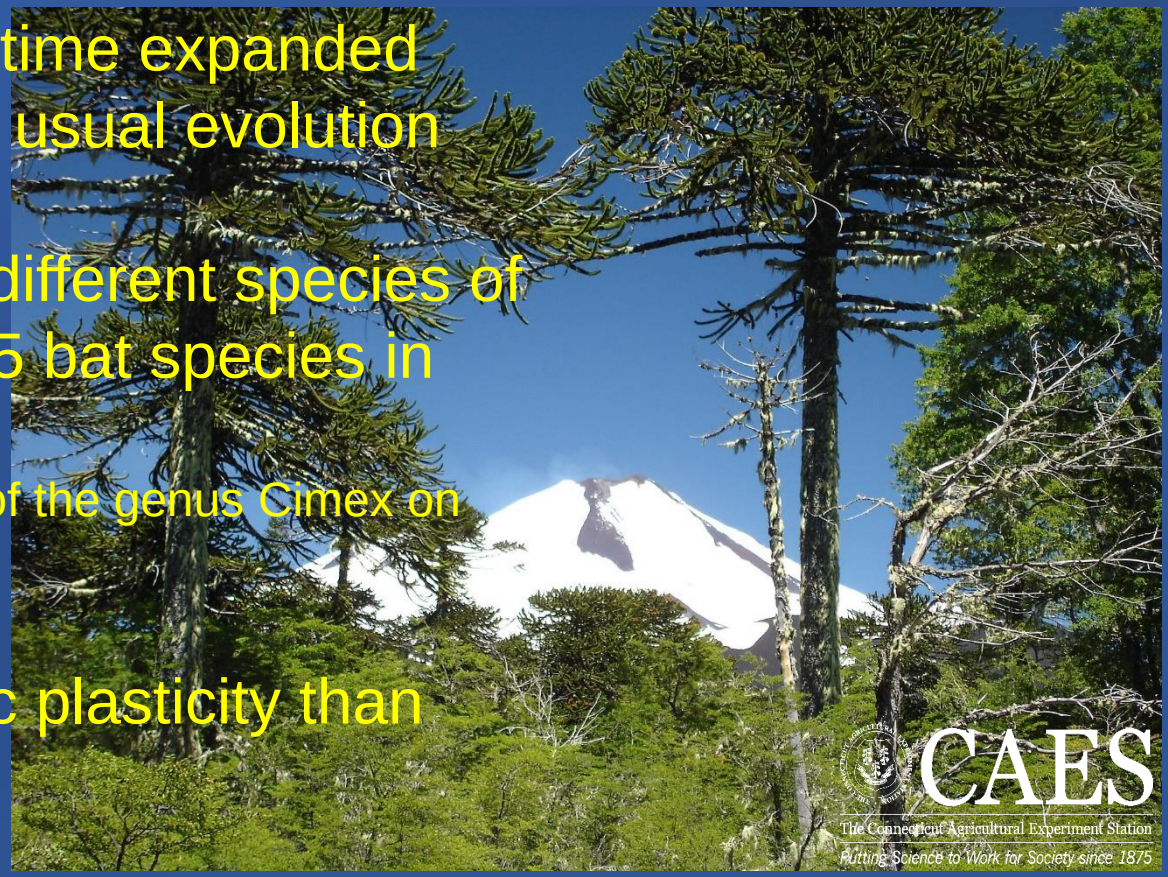
Generalist feeder evolved from specialist ancestors (frequent host switchers, and over time expanded their host portfolio), a reverse from usual evolution

Specialist ancestors bounced between different species of the same host. Recently found on 5 bat species in Europe

*Balvin et al. Distribution and host relations of species of the genus Cimex on bats in Europe. Researchgate 2019

Generalist posses higher level of genetic plasticity than specialists groups

Cretaceous period
Animals: dinosaurs, birds, mammals
Angiosperms (flowering plants)
Gymnosperms (monkey puzzle trees, conifers)
Climate: cool and wet

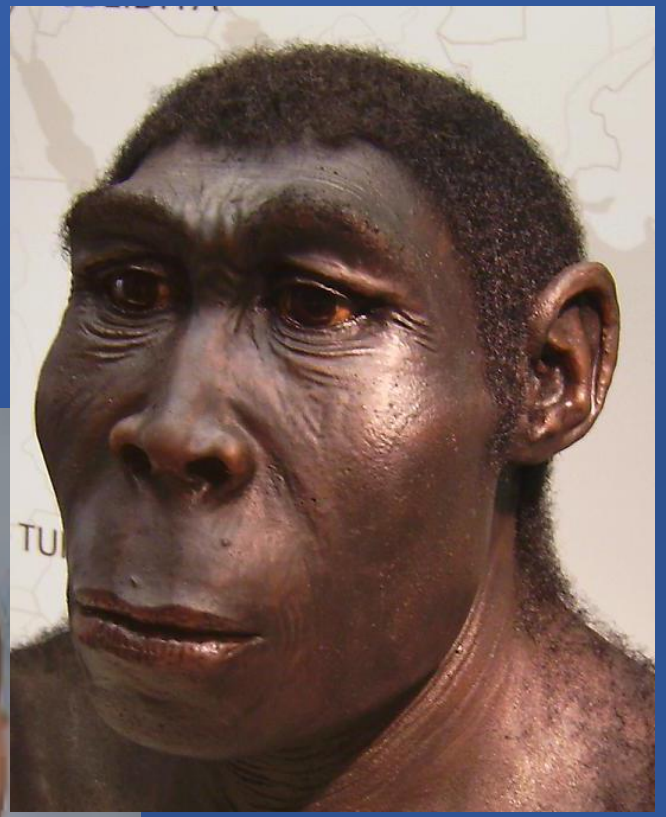


- The two species: Tropical bed bug, *C. hemipterus* and Common bed bug, *C. lectularius* humans “specialists” today diverged into two species before humans evolved ~47 mya. A rejection of the Ashford hypothesis that divergence coincided with the split between *H. sapien sapien* and *H. erectus* at ~1.6 mya

- Bed bug independent of human and bat evolutions

- Number of Cimicidae species has increased from mid-90’s to over 100

- Ability of evolve very quickly



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Professor Mike Siva-Jothy, University of Sheffield

https://www.sheffield.ac.uk/news/nr/bedbugs-parasites-evolved-millions-years-dinosaurs-trex-1.843890

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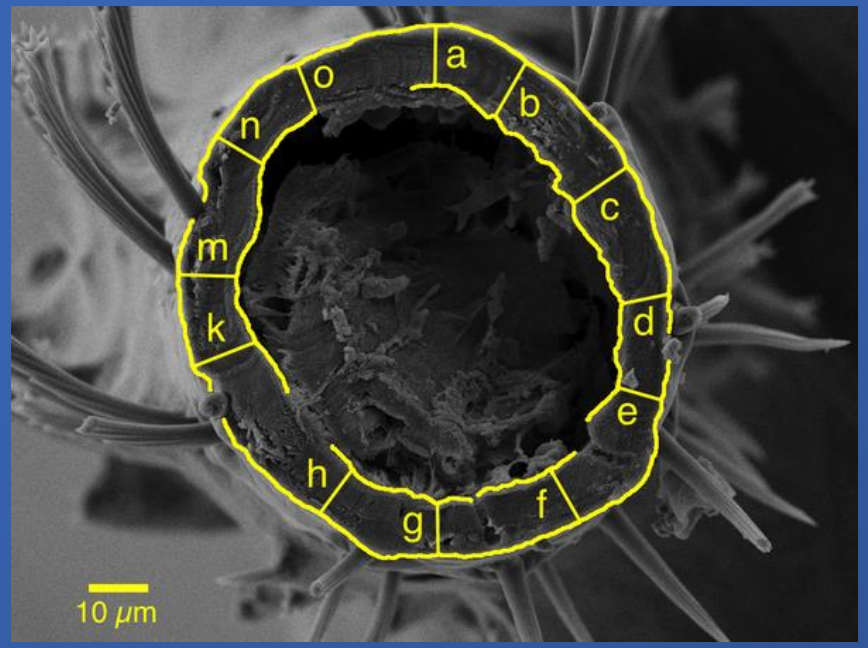
Pesticide resistance by behavior

Healthy Harlan line 3 weeks after exposure to bifenthrin impregnated filter paper

Irvington, New Jersey line dying 24 hours after exposure to bifenthrin impregnated filter paper

Leg cross section



Cuticle thickening in a Pyrethroid-Resistant Strain of Common Bed Bug (Australian study)

Mean cuticle thickness was found to be significantly different ($p < 0.001$) between the three Parramatta-strain response groups

- ‘Resistant’ bed bugs had a mean cuticle thickness of 10.13 μm (S.E. ± 0.15 μm),
- ‘Tolerant’ bugs 9.51 μm (S.E. ± 0.26 μm) and
- ‘Intolerant’ bugs 8.73 μm (S.E. ± 0.18 μm).

Dust resistance by behavior and a thicker cuticle

*David Lilly et. al (2016). Cuticle thickening in a Pyrethroid-Resistant Strain of the Common Bed Bug, *Cimex lectularius* L. (Hemiptera:Cimicidae). PLOS

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Thigmotaxis and physique

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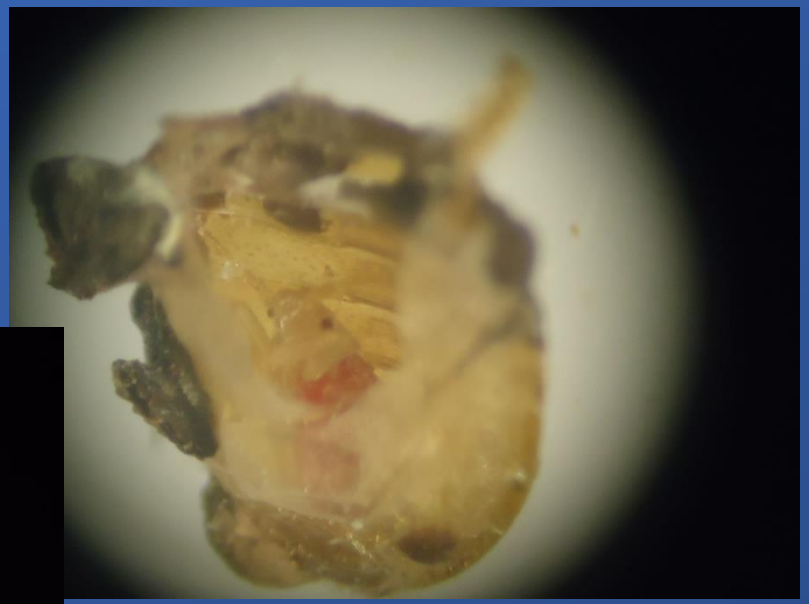
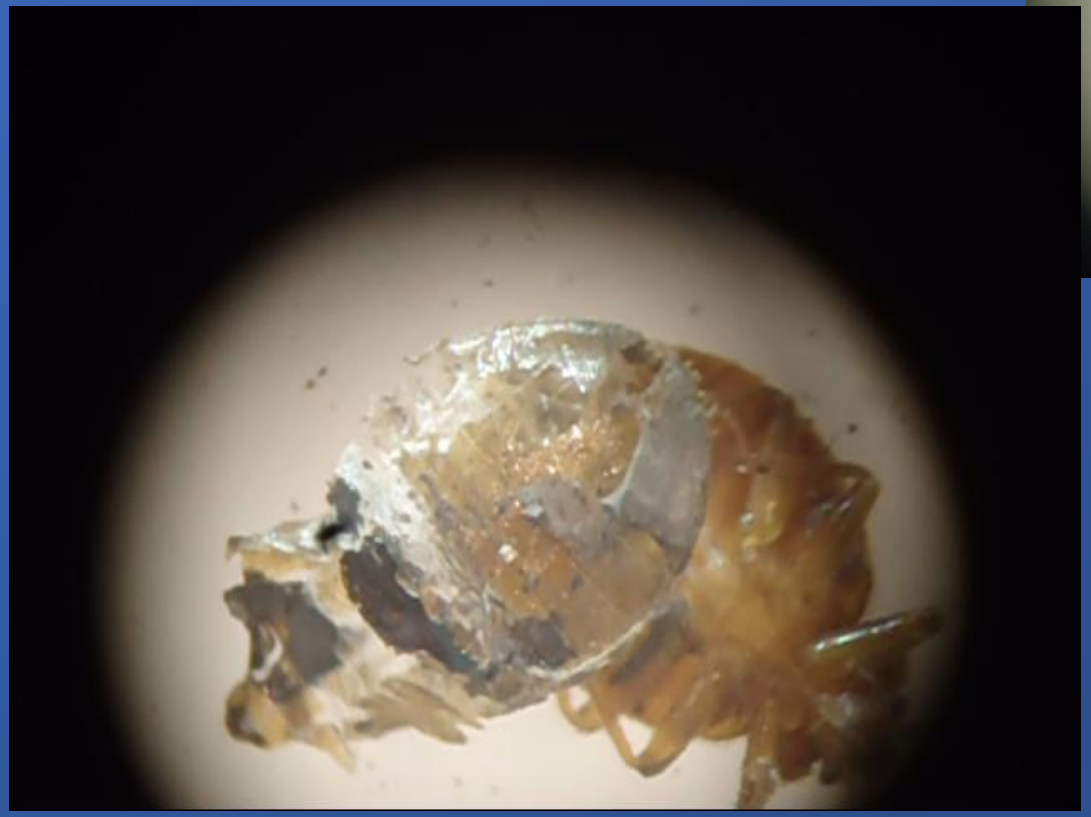
The Refuge





Recently fed 1st instar nymph inside the exuviae of an older nymph

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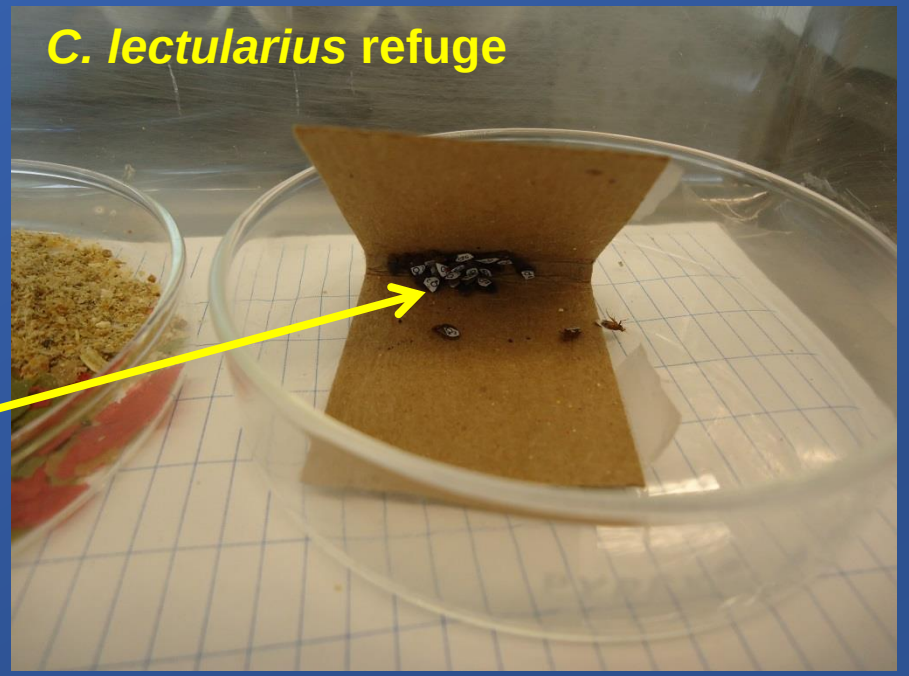
Predation

Eaten *C. lectularius*



Peeking

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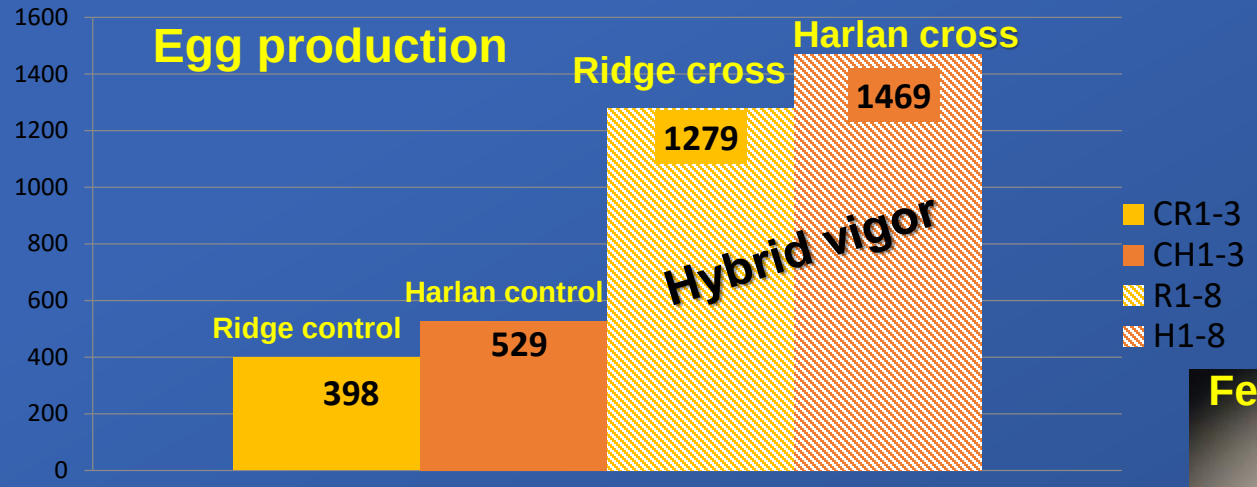
Fecundity



Female egg guarding

Randomly placed infertile eggs from X-mating of a male from New Mexico with Vermont females

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Pro-reslin gene

nature COMMUNICATIONS

ARTICLE

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Unique features of a global human ectoparasite identified through sequencing of the bed bug genome

Joshua B. Benoit[1], Zach N. Adelman[2], Klaus Reinhardt[3], Amanda Dolan[4], Monica Poelchau[5], Emily C. Jennings[1], Elise M. Szuter[1], Richard W. Hagan[1], Hemant Gujar[6], Jayendra Nath Shukla[6], Fang Zhu[6,7], M. Mohan[8], David R. Nelson[9], Andrew J. Rosendale[1], Christian Derst[10], Valentina Resnik[11], Sebastian Wernig[11], Pamela Menegazzi[12], Christian Wegener[12], Nicolai Peschel[12], Jacob M. Hendershot[1], Wolfgang Blenau[10], Reinhard Predel[10], Paul R. Johnston[13], Panagiotis Ioannidis[15], Robert M. Waterhouse[15,16], Ralf Nauen[17], Corinna Schorn[17], Mark-Christoph Ott[17], Frank Maiwald[17], J. Spencer Johnston[14], Ameya D. Gondhalekar[18], Michael E. Scharf[18], Brittany F. Peterson[18], Kapil R. Raje[18], Benjamin A. Hottel[19], David Armisén[20], Antonin Jean Johan Crumière[20], Peter Nagui Refki[20], Maria Emilia Santos[20], Essia Sghaier[20], Sèverine Viala[20], Abderrahman Khila[20], Seung-Joon Ahn[21], Christopher Childers[5], Chien-Yueh Lee[5,22], Han Lin[5,22], Daniel S.T. Hughes[23], Elizabeth J. Duncan[24], Shwetha C. Murali[23], Jiaxin Qu[23], Shannon Dugan[23], Sandra L. Lee[23], Hsu Chao[23], Huyen Dinh[23], Yi Han[23], Harshavardhan Doddapaneni[23], Kim C. Worley[23], Donna M. Muzny[23], David Wheeler[25], Kristen A. Panfilio[26], Iris M. Vargas Jentzsch[26], Edward L. Vargo[14], Warren Booth[27], Markus Friedrich[28], Matthew T. Weirauch[29], Michelle A.E. Anderson[2], Jeffery W. Jones[28], Omprakash Mittapalli[30], Chaoyang Zhao[30], Jing-Jiang Zhou[31], Jay D. Evans[32], Geoffrey M. Attardo[33], Hugh M. Robertson[34], Evgeny M. Zdobnov[15], Jose M.C. Ribeiro[35], Richard A. Gibbs[23], John H. Werren[4], Subba R. Palli[6], Coby Schal[36] & Stephen Richards[23]

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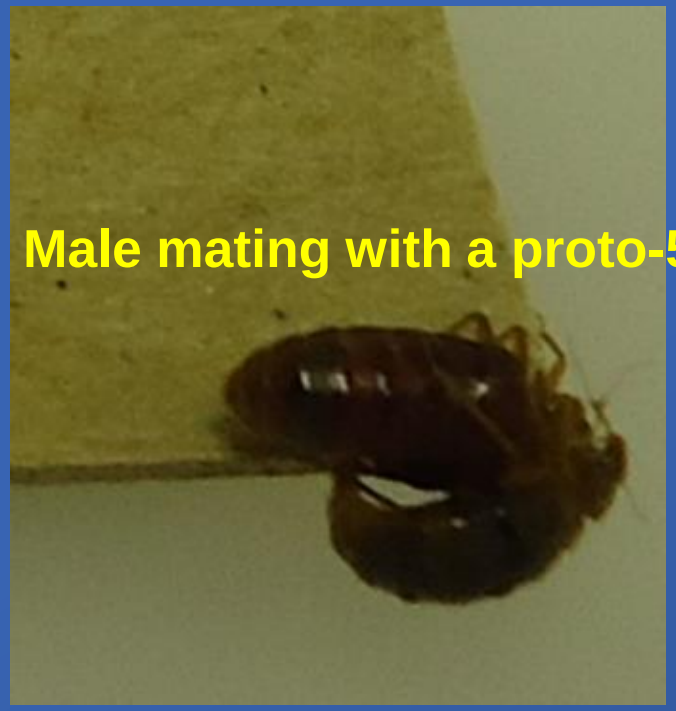
Sexual competition and mate guarding

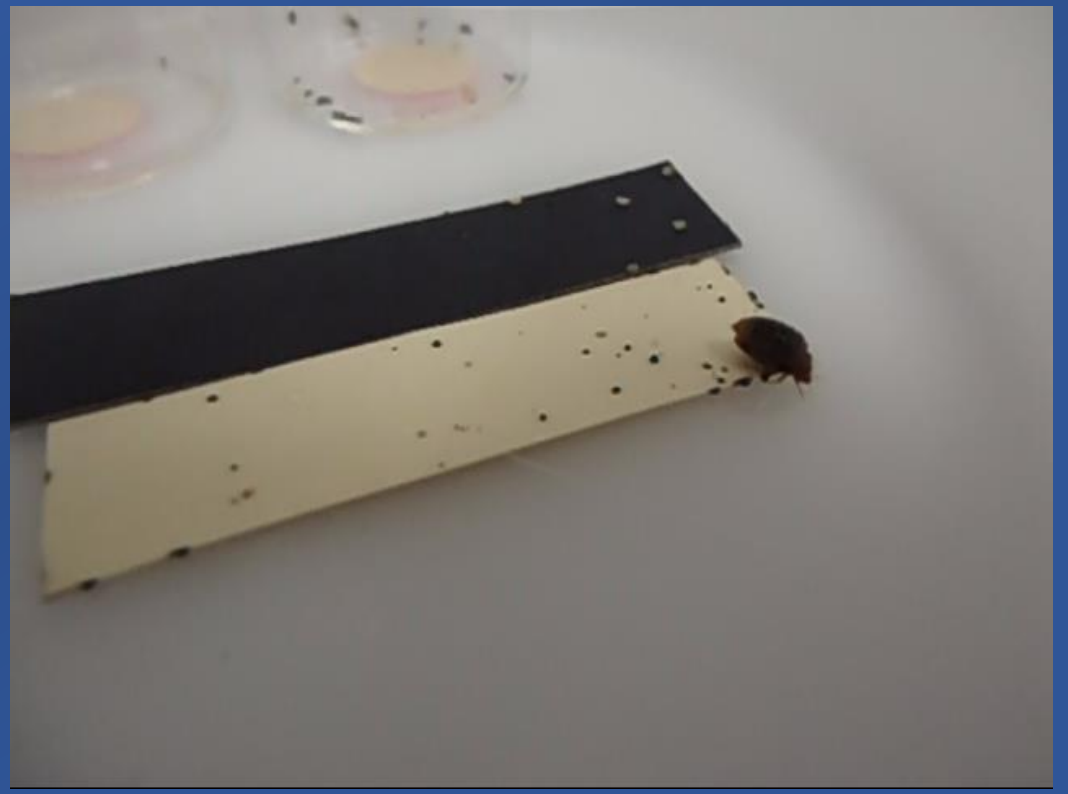


Male mating with a proto-5th instar female nymph

Dorsal guarding

Lateral guarding

Male competition



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Tapping

Sibling 1st instar nymphs with no access to a host. One on left had fed on an older nymph that had been given a blood meal

Live 1st instar nymph after feeding on an adult

Hitch hiking

Stacking

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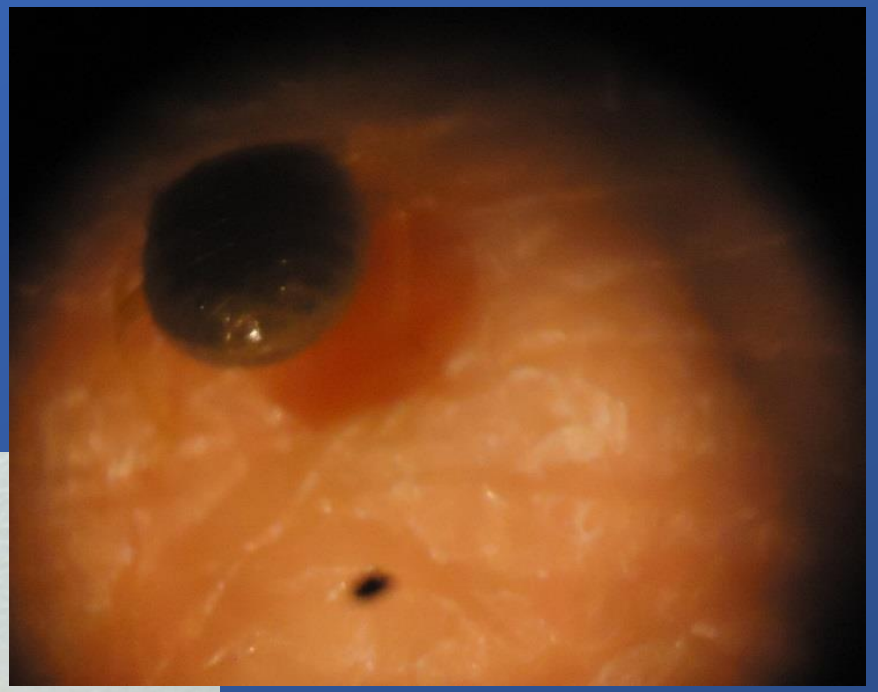
Chemistry



A sick insect walking away after defecating on a host

Chemistry rich refuge

Climbup® bed bug interceptors have a measure of control against small bed bug populations

*International Entomology Meetings, Vancouver, Canada. 2018

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Ivermectin invivo study with a rabbit

Dr. Kimberly McClure

*Gale E. Ridge et al. Xenointoxication of a rabbit for the control of the Common bed bug *Cimex lectularius* L. Using Ivermection. 2019. Scientifica

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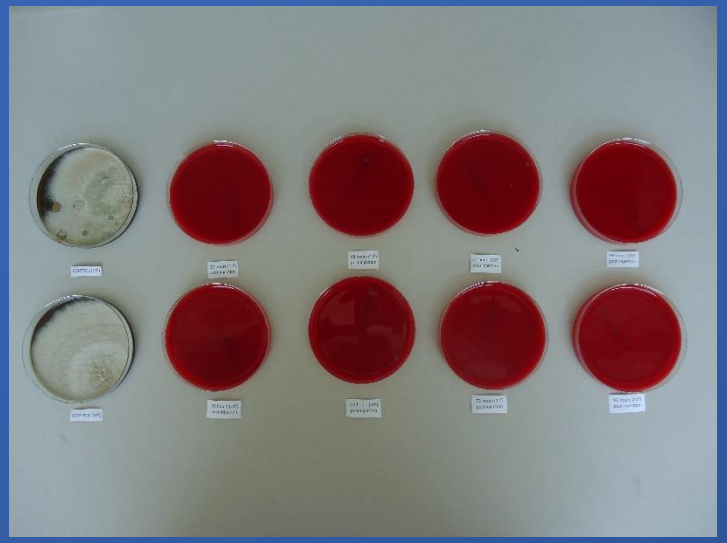
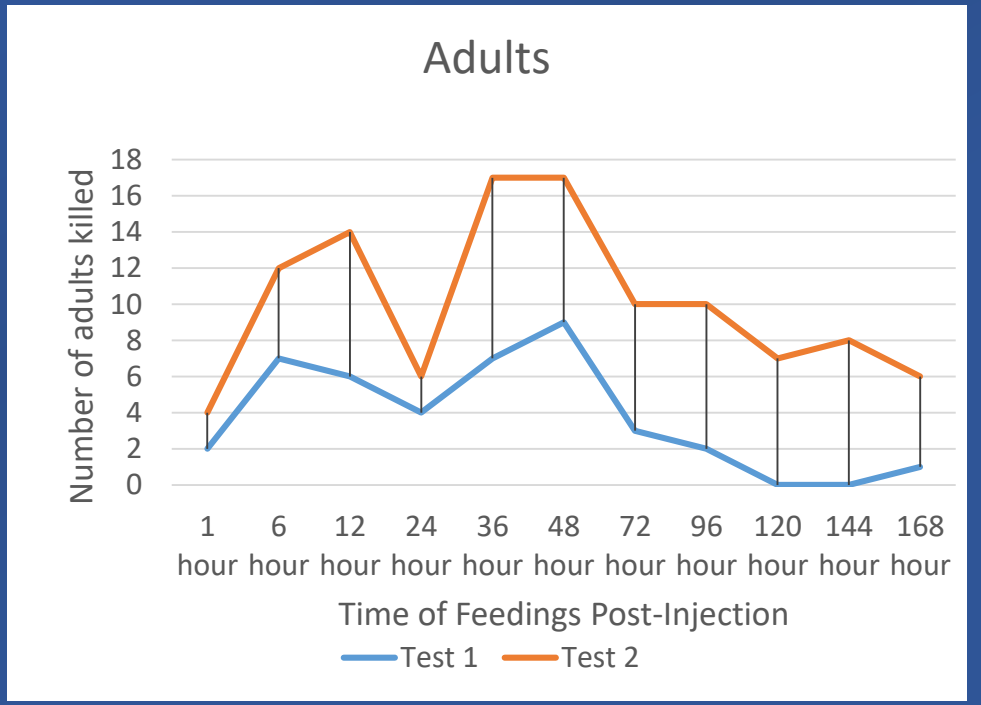


Dose dependent toxicity

- No blood digestion
- Paralysis and torpor
- Loss of control when feeding
- Sterilized adults
- Gut microbiome harm (36-96h)
- Nymph molting harm



Bed Bug Disclosure Policies in Rental Markets

A number of municipalities have proposed or initiated policies to stem the bed bug epidemic…….One contentious policy is disclosure, whereby landlords are obligated to notify potential tenants of current or prior bed bug infestations. Aimed to protect tenants from leasing an infested rental unit, disclosure also creates a kind of quarantine, partially and temporarily removing infested units from the market…….. We find disclosure to be an effective control policy to curb infestation prevalence.

Over the short term (within 5 years), disclosure policies result in modest increases in cost to landlords, while over the long term, reductions of infestation prevalence lead, on average, to savings. These results are insensitive to different assumptions regarding the prevalence of infestation, rate of introduction of bed bugs from other municipalities, and the strength of the quarantine effect created by disclosure……..

*Sherrie Xie e al. 2019. Dynamics of bed bug infestation and control under disclosure policies. PNAS

Forensic Entomology

*Coby Schal et el. 2018. Isolation, identification and Time course of human NA typing from bed bugs, *Cimex lectularius.* Forensic Sci. Intern.

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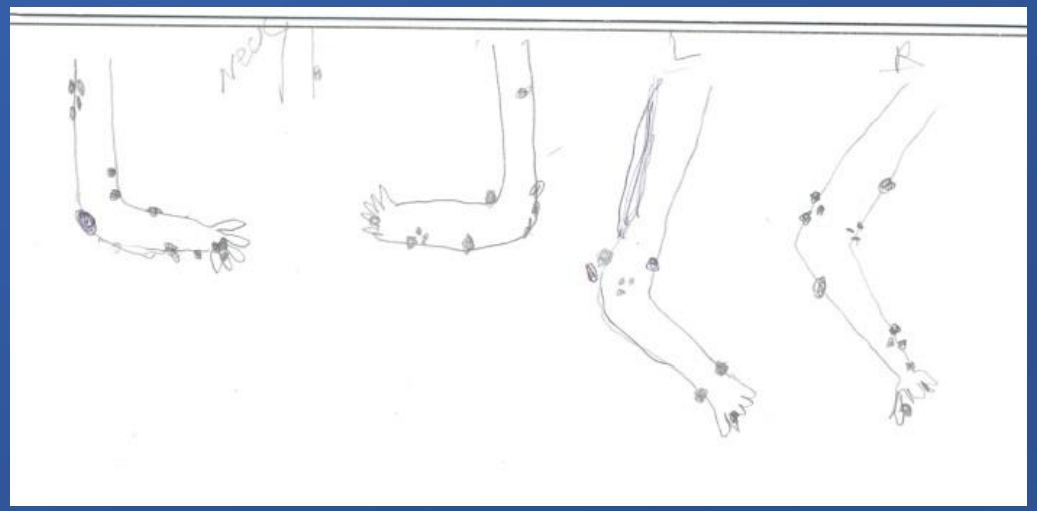
Suggested strategies

- DO NOT PANIC!!!!
- **Vacuum** to remove refuge detritus, insects, and eggs.
  Repeat every 10 days to intercept insect's biology.

  Aim for cracks and crevices.
- Climbups™ bed bug interceptors or equivilant.
- Do not wash and clean refuges while treating.
  Bait insects using their own natural refuges.
- Do not use over the counter (OTC's) pesticides.
- Work with family owned Connecticut Pest Management
  Professionals with experience.
- Proactive behavior such as regular preemptive inspection.
- Communicate and Cooperate

Delusions of Parastosis/Infestations



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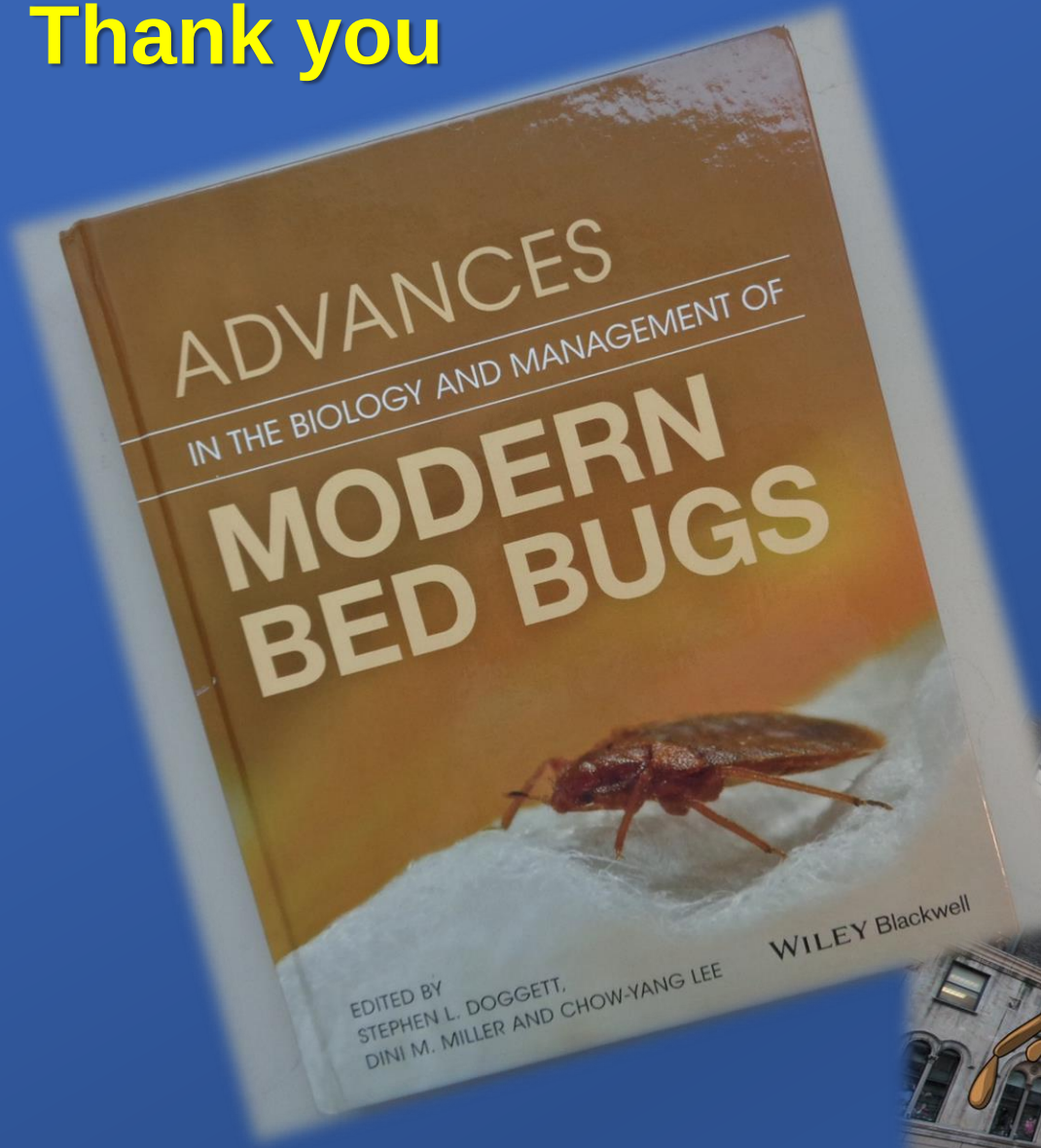
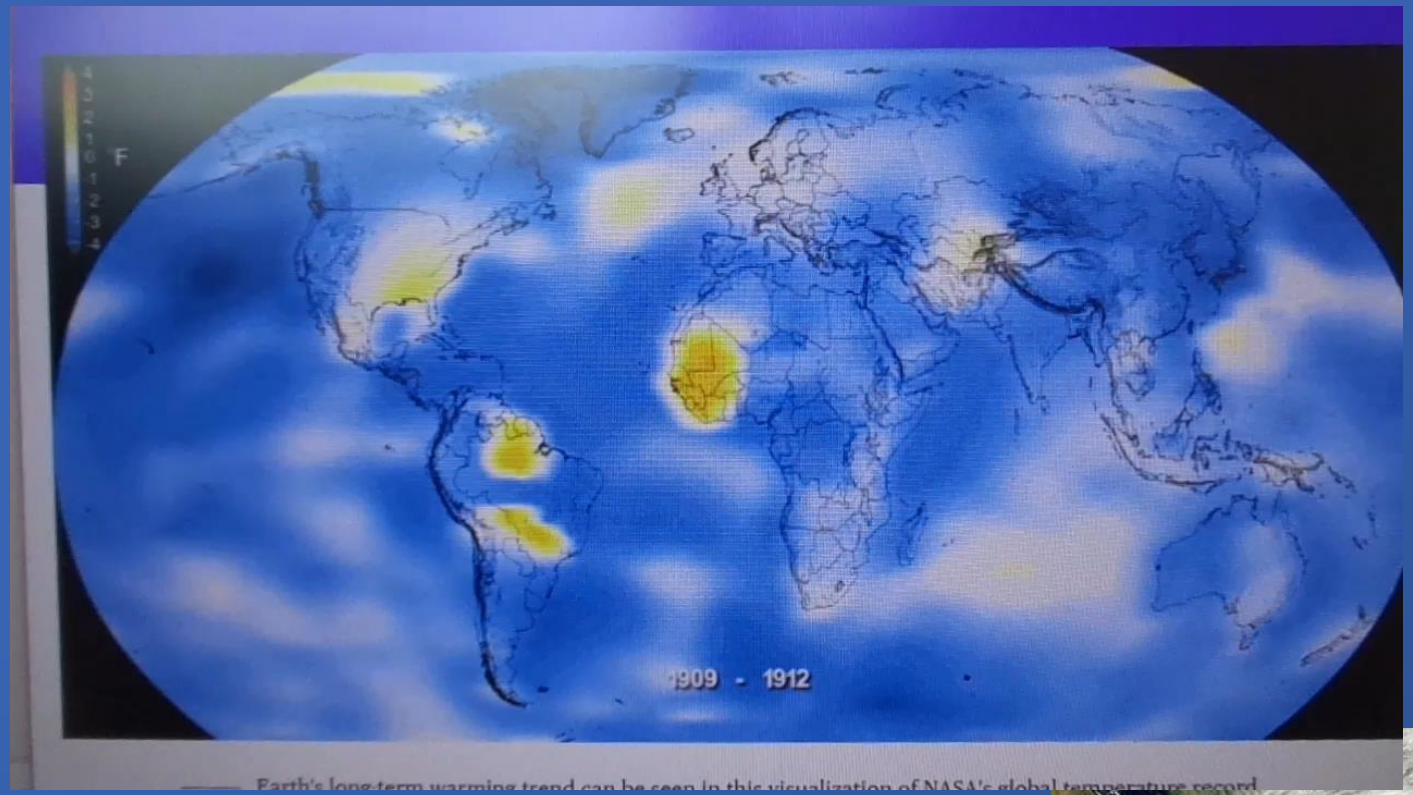
Allergies: prescription drugs food, tree, grass, weed, dust mites, mold,
AIDS
Anemia
Atopic dermatitis (eczema) redness itchy
Anxiety
Carbon monoxide
Carcinoma (type of skin cancer)
Cholestasis (reduced bile flow from liver)
Cirrhosis (late stage liver disease)
Congestive heart failure
Depression - intense itching depression
Diabetes
Developed allergies to prescribed drugs
Dry skin
Encephalitis (brain inflammation)
Endocrine abnormalities (blood biochemical regulation)
Fibromyalgia (pain disorder after illness or trauma)
Fluoride poisoning
Folate deficiency
Heavy metal toxicity
Hemochromatosis (liver disease)
Hepatic disease (alcoholic fatty liver disease)
Hepatitis
Huntington's disease
Hyper awareness of normal nerve end firing
Hallucination
Hypertension (high blood pressure)
Hyperthyroidism
Hypoglycemia (low blood sugar)
Hypothyroidism
Hypovitaminosis including B12 deficiency
Hysteria
Illegal drug use
Insect phobia
Internet surfing and falling victim to confirmation bias
Intestinal bacterial flora imbalance
Itch (neurological abnormalities)
Lack of sleep as a contributing factor
Lymphoma
Many cancers including Leukemia
Meningitis (central nervous system membrane inflammation)
Medically induced delusions of parasitosis (MIDP)
Menopause
Mental retardation
Munchausen (mental disorder of fake illness to get attention)
Neoplasia (abnormal tissue growth)
Neurotic excoriation disorder
Niacin overdose
Nocturnal pruritus
Obsessive compulsive disorder (OCD)
Poor nutrition
Postpartum depression
Pulmonary diseases (heart and lung disease)
Power of suggestion
Renal diseases
Rheumatoid arthritis
Schizophrenia
Several autoimmune diseases including Multiple Sclerosis and Lupus
Shingles and/or history with chickenpox
Shock and/or trauma with possible PTSD
Small fiber polyneuropathy
Stress
Stroke
Syphilis
Thiamine deficiency
Tuberculosis
Uremia (kidney and/or bladder disease)

Thank you



Designs by Katherine Dugas (CAES)



A closing thought.

Abiotic and biotic environment feedback loops have at an unprecedented rate responded to unchecked human behavior. Climate change is a product of this which is beyond human control. Above, is earth temperature averages in 4 year increments compiled by NASA (1880 to the present). Adaptive resilience on all matters, needs consideration. The video repeats three times.

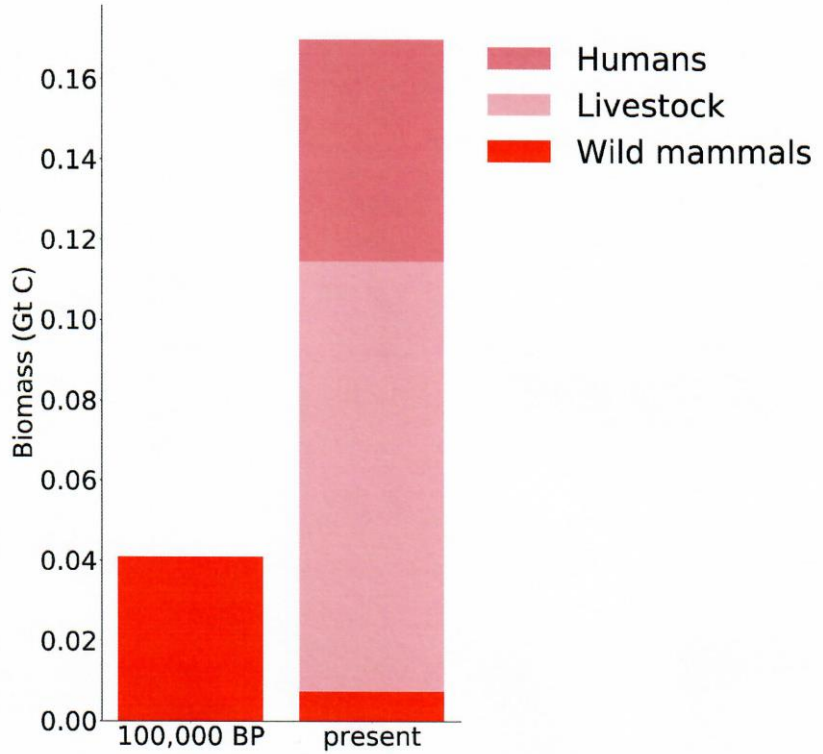


Figure 3. The impact of human civilization on the biomass of mammals. The biomass of wild mammals, livestock (dominated by cattle) and humans before human civilization and at present. Values are based on estimates presented in detail in the relevant sections for humans and livestock, wild mammals and pre-human biomass.
* Bar-On, Phillips, and Milo (2018). The biomass distribution on Earth, Proc. Nat Acad, of Sci. 115(25): 650606511...

Hurricane Patricia 2015 with 215 mph sustained winds