Biological Control

Why biological control?

- Insecticide use comes with problems
  - Killing non-target organisms
  - Creating insecticide resistance
  - Potential long-term health effects in humans
- Supplementing or replacing pesticides with **non-chemical control tactics** is a goal in integrated pest management

Biological control- what it isn't

- Judicious use of pesticides
- Host plant resistance
- Natural control
  - Natural control of pests is accomplished by living organisms or caused by abiotic conditions, but with **no human involvement-** it just happens naturally.

Biological control- what it is

The reduction of pest populations by natural enemies aided by human involvement

Who?

predators | parasites | pathogens

To do what?

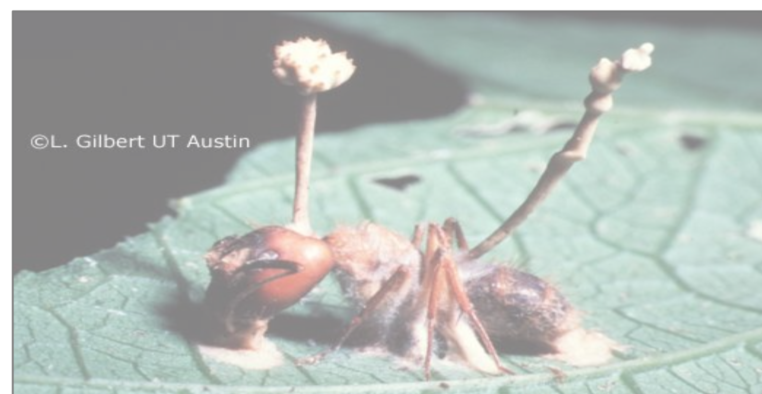
Reduce | delay | prevent

How?

conservation | augmentation | importation

Biological control: Who?

1. **Predators**
2. Parasites (Parasitoids)
3. Pathogens



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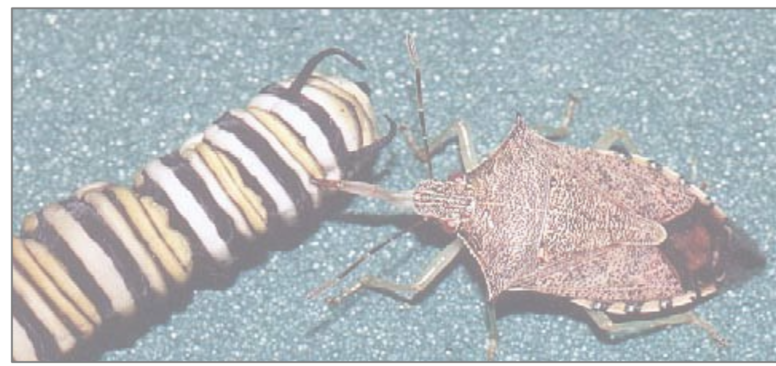

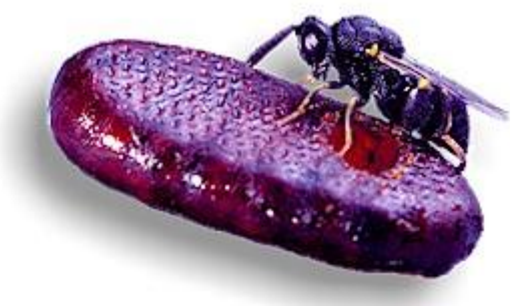

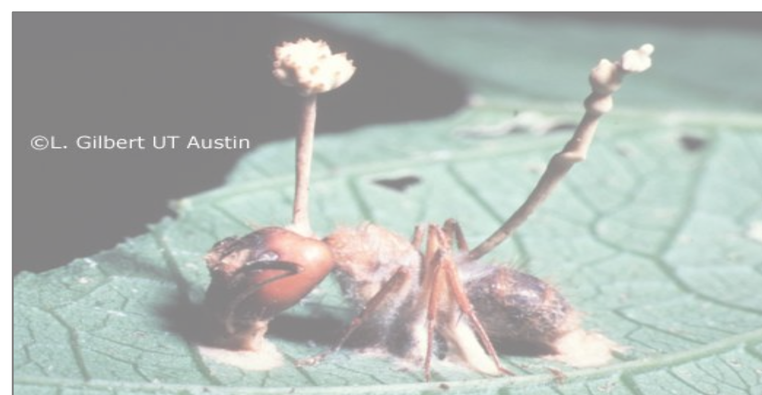

Biological control: Who?

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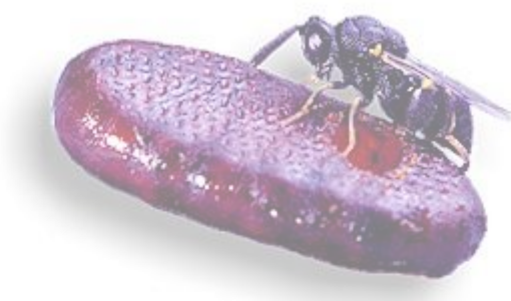
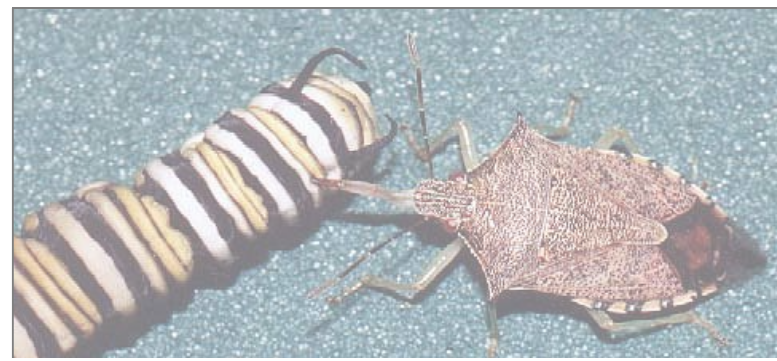




Biological control: To do what?

- **Reduction**
  - natural enemies are introduced after the pest is established.
- **Delay** (pest buildup)
  - early intervention after initial detection of a pest.
- **Prevention**
  - releases of natural enemies are made early in the season, against a predictable pest; rarely done.

How #: 1 Conservation

- nearest to natural control (but conscious and planned)
- may involve enhancing benefits (using attractants or foods to keep predators and parasites in an area)
- often involves altered production practices or pesticide application plans.

Constructed "home" to attract dermapterans

How #2: Augmentation

- adding natural enemies
- works if the practice adds to overall mortality instead of replacing existing mortality factors.
- Involves buying or rearing natural enemies

How #3: Importation

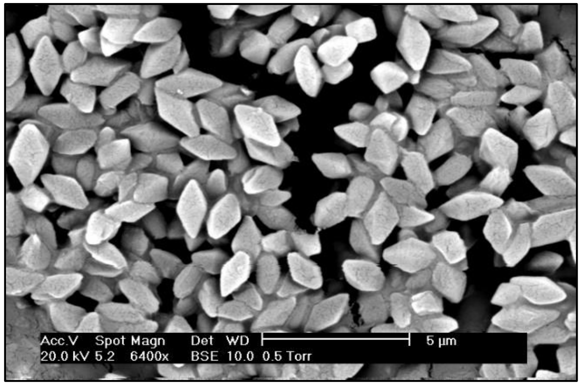
- "classical biological control”
- Many pests are exotic; they were introduced without their natural enemies; importing natural enemies "reunites" the pest with its natural control agents.
- Importation must involve extensive natural history studies and a quarantine stage to avoid unwanted outcomes

The vedalia beetle, imported to control cottony cushion scale. A success story!

Zombie roaches and other parasite tales

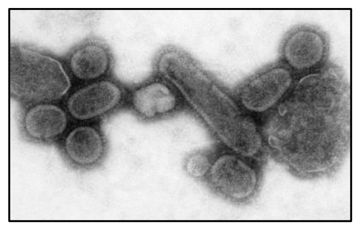
- https://www.ted.com/talks/ed_yong_suicidal_wasps_zombie_roaches_and_other_tales_of_parasites?language=en

Pathogens (Microbial insecticides)



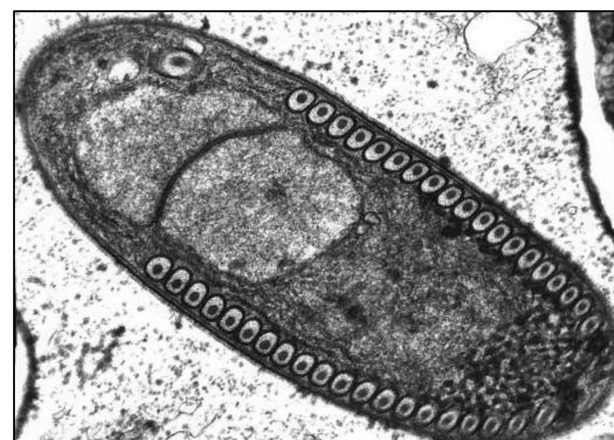
Bacteria

Nematodes



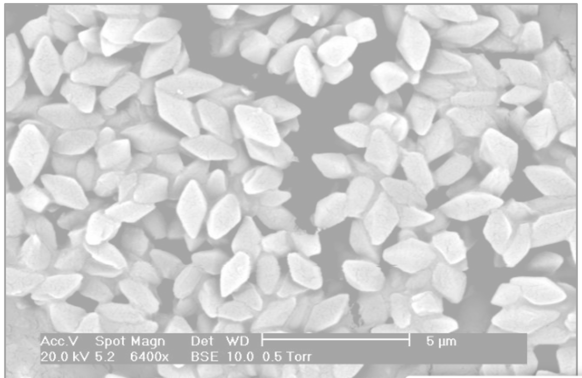
Viruses

Fungi



Microsporidia

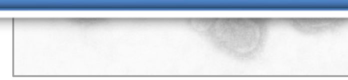
Pathogens (Microbial insecticides)



Bacteri

matodes

Augmentation



Viruses

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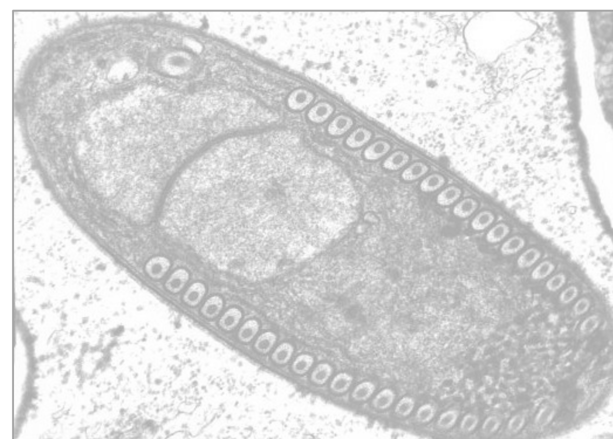


Microsporidia

Pathogens

Many are important in causing population crashes in nature (natural biotic control, not biocontrol), especially...

- **viruses** in *Heliothis* / *Helicoverpa* (tobacco budworm and corn earworm), alfalfa looper, tent caterpillars and forest sawflies;
- **fungi** in alfalfa weevil, potato leafhopper, and green cloverworm;
- **microsporidia** in grasshoppers, corn borer, many others (not complete population crashes, just markedly "poor performance")

Though some have been mass-produced and packaged, for the most part, these have not been readily formulated as effective "microbial insecticides".

Pathogens: Viruses

- Most potential insecticides are nuclear polyhedrosis viruses (NPVs)
- Must be ingested to infect hosts
- Infected caterpillars turn to ooze and release virus particles that can be consumed by other larvae

Caterpillar killed by virus

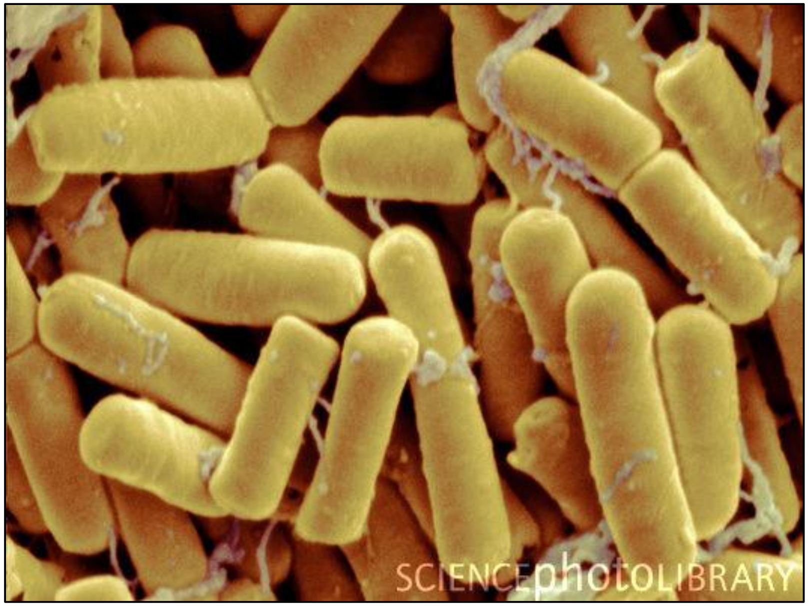
Pathogens: Viruses

Limitations

- Virus must be produced in live host insects
- Require different facilities than those used by insecticide manufacturers
- Species-specific and therefore have limited markets
- Slow-acting and often less effective than chemical insecticides
- Hindered by exposure to sunlight; UV radiation destroys virus particles

Pathogens: Bacteria

- *Bacillus thuringiensis*: rarely responsible for obvious natural control, but effective as a microbial insecticide ...
  - *B.t. kurstaki* and *B.t. aizawai* -- kill caterpillars (Dipel, Agree, XenTari)
  - *B.t. israelensis* -- kills larvae of several mosquitoes, black flies, fungus gnats (Altosid, Vectobac, Gnatrol)
  - *B.t. tenebrionis* -- kills larvae of Colorado potato beetle, elm leaf beetle, a few others (M-One, M-Trak, Foil)



Pathogens: Bacteria

- *B. sphaericus* -- Larvae of some mosquitoes (no commercial formulations at present)
- *B. popilliae* & *B. lentimorbus* -- kill larvae of Japanese beetle, not as effective against other white grubs (Doom, Japidemic)

Pathogens: Insect-pathogenic fungi

Insect-pathogenic fungi often cause disease outbreaks in insect populations, but few have been commercialized as biopesticides, largely because of…

1. difficulty in producing virulent strains that maintain viability "on the shelf“.
2. The importance weather conditions and microhabitat factors on the effectiveness of products applied in the field.

Fungi that kill insects

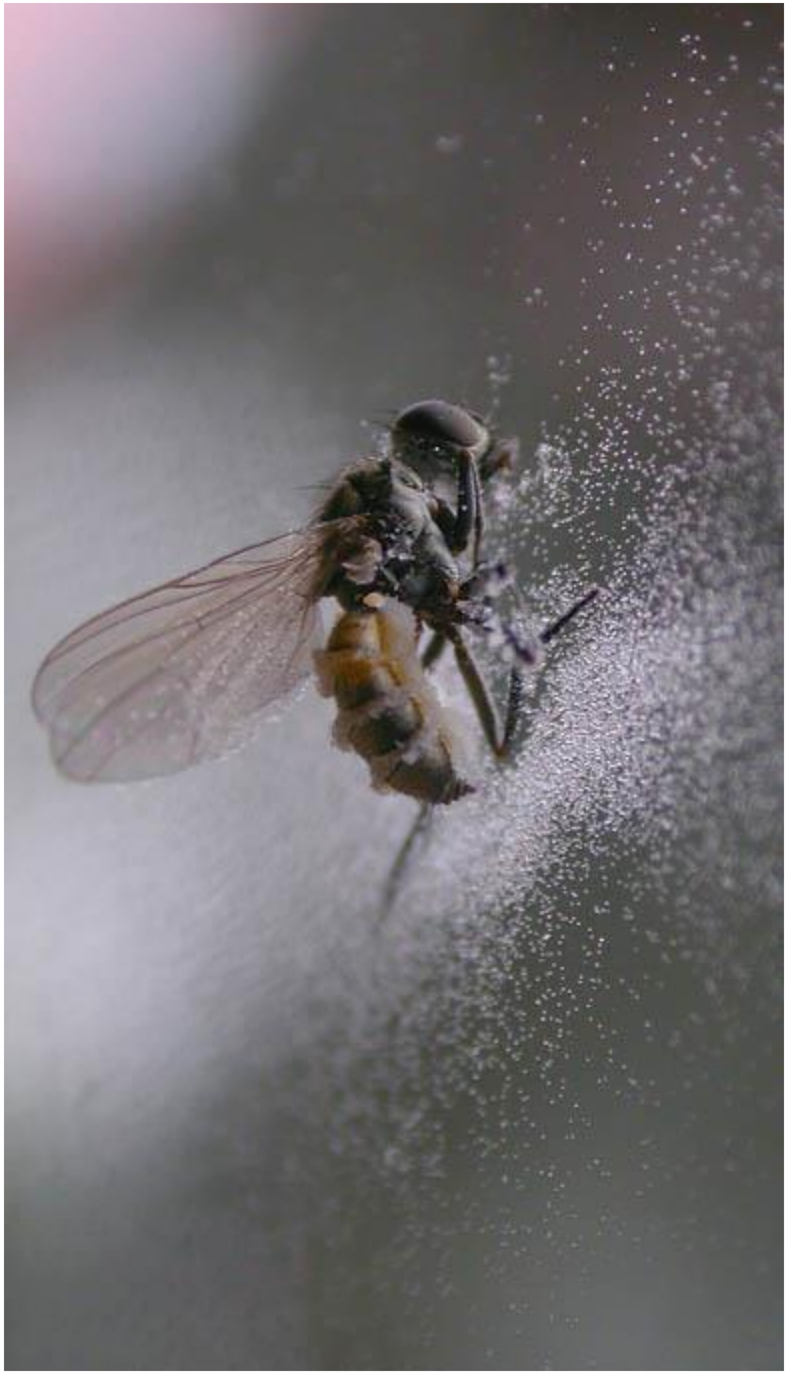
- ***Metarhizium anisopliae*:** infects a broad range of hosts, including corn rootworms, white grubs, and root weevils.
- A commercial cockroach bait station uses *M. anisopliae* to kill cockroaches.

Fungi that kill insects

- ***Beauveria bassiana***: (white muscardine fungus) kills a wide range of insects including European corn borer, Colorado potato beetle, and tussock moths.
- Mycotrol, a product recently registered for use in the United States, contains *B. bassiana*; many products are in use in other countries.

Fungi that kill insects

- ***Entomophthora muscae* (and *E. grylli* and others):** *E. muscae* kills flies -- house flies, seed and root maggot adults, and others.
- The fungus sporulates from the intersegmental membranes of dead and swollen adult flies. House flies may die on a window pane and be surrounded by a ring of spores.



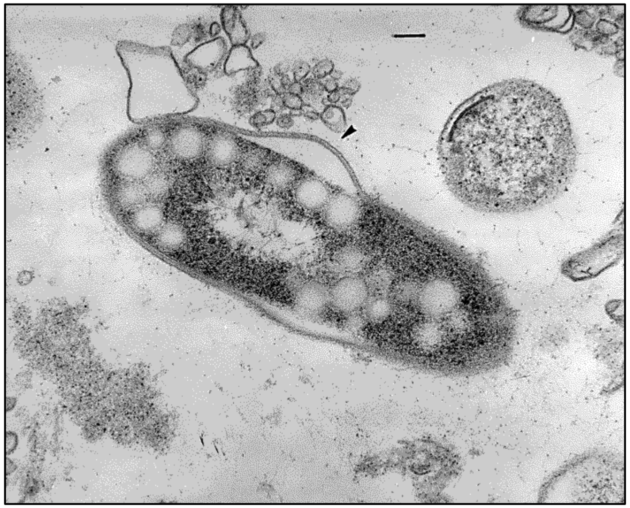
Cordyceps: ZOMBIE FUNGUS

Not biocontrol. Occurs and kills without human involvement: natural biotic control

Pathogens: Microsporidia

- An important Midwestern example is ***Nosema pyrausta***, a pathogen of the European corn borer.
  - Infections usually do not cause rapid death
  - Slows development, females lay fewer eggs (many of which die)
- *N. pyrausta* causes periodic collapses in European corn borer populations in Illinois and neighboring states.

- Microsporidia have not been commercialized as biopesticides except for *Nosema locustae*, a species that attacks grasshoppers.

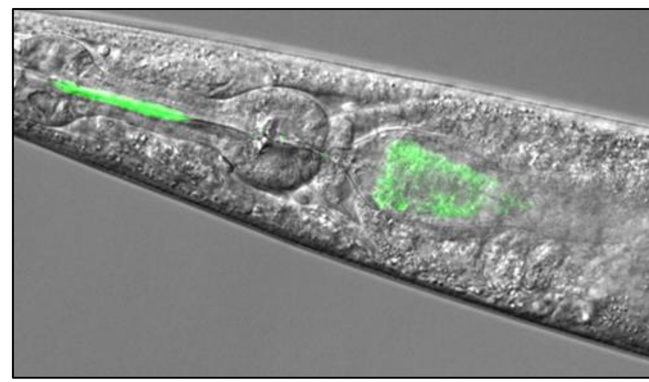


Pathogens: Insect-parasitic nematodes

Enter an insect's body through the mouth, anus, or spiracles, move into the body cavity, and release symbiotic bacteria that multiply within the host insect.

Infection by these bacteria is what kills the insect host.

The nematodes feed on the bacteria, complete their development, and reproduce, yielding thousands of progeny that then seek another host.



Symbiotic bacteria in a nematode

Pathogens: Insect-parasitic nematodes

Two genera have been cultured for sale as "biopesticides"

Steinernema

Heterorhabditis

Nematodes for sale!

Pathogens: Insect-parasitic nematodes

Nematodes can be effective against soil insects, particularly in settings where irrigation can be used to maintain soil moisture.

- Effective against: Root weevil larvae, seed and root maggots, fungus gnat larvae, and others.

- NOT effective against wireworms, corn rootworms, grape phylloxera, or several other key pests.

Microbial insecticides: benefits

- Nontoxic to wildlife and humans
- Toxic action is specific to a single group and does not directly affect beneficial insects
- Can be used in conjunction with synthetic insecticides because the pathogens are not damaged or deactivated by the pesticides
- Residues are not harmful to humans, so pathogens can be applied close to harvest
- Pathogenic organisms can become established in a population of the pest species and therefore affect subsequent pest generations

Microbial insecticides: limitations

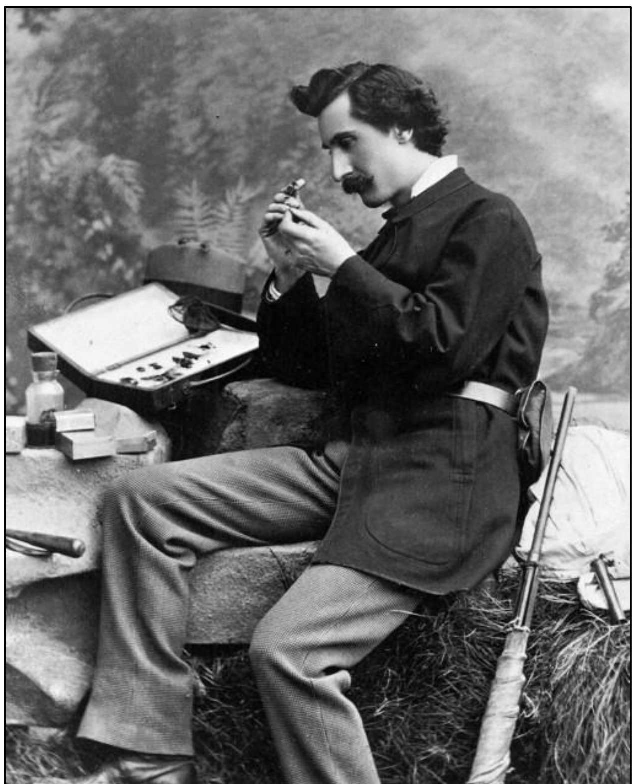
- Because they target specific species or groups, may control only a portion of pests in a given area
- Heat, dessication, or exposure to UV reduces effectiveness of some microbial insecticides
- Special formulation and storage procedures are sometimes needed
- Pest-specific means a smaller market for the insecticide, resulting in lower availability and higher cost of the product

Predators & Parasites: Importation

- The classic example of successful importation ... **Vedalia beetle** for control of **cottony cushion scale** in citrus
- 1868 & 1870s: cottony cushion scale was introduced to California from Australia and became a serious pest of citrus and ornamentals.

Predators & Parasites: Importation

- 1887: **C.V. Riley** convinced the California Fruit Growers' Convention to pressure the U.S Congress to provide $2,000 for the covert collection of natural enemies in Australia.
- He sent **Albert Koebele** to Australia (presumably to represent the California citrus growers at the world agricultural exposition).
- Koebele returned with parasites (*Cryptochaetum iceryae*) and *Rodolia cardinalis* (the Vedalia beetle!)



Predators & Parasites: Importation

- **Result:** Fantastic control of cottony cushion scale until DDT was used in orchards in the late 1940s (and still important now).
- The Vedalia beetle was extremely easy to establish at new locations.
  - For example, only 4 adults were taken to Peru, and successful populations developed! Imported predators are usually more difficult to establish.

Predators & Parasites: Importation

Other successful introductions (examples):

- *Cryptolaemus* – mealybug destroyer
- Larval parasites (Hymenopteran) of cereal leaf beetle
- Parasites of the alfalfa weevil
- Carabids for gypsy moth suppression
- And many more…




Predators & Parasites: Importation

Difficulties with introductions:

- Finding a "guild" of natural enemies that together provide adequate control (of not only one but most of the pests in a system.)
- Natural enemy survival in pesticide-treated crops or habitats
- Quarantines, production of high numbers for release, fitness, climate, more

There are many natural enemies "in place" in any region. Read your handout to become familiar with several groups and species, including:

- **Carabids** (ground beetles)
- **Coccinellids** (C-7, convergent lady beetle, spotted lady beetle, twice-stabbed lady beetle, *Stethorus* (mite eater), Asian multicolored lady beetle) ... most eat aphids, but some specialize on scales or mites
- **Staphylinids** (rove beetles)
- **Syrphid flies** (larvae eat aphids)
- **Lacewings** (Larvae are generalists but prefer aphids; adults of the common green lacewing feed only on pollen and nectar.)
- **Hemipteran predators** (*Orius* [a minute pirate bug], *Nabis* [a damsel bug],*Geocoris* [big-eyed bug], *Podisus* [spined soldier bug])
- **Mantids** (usually not very beneficial because of prey choice and cannibalism)
- Many **predaceous mites**

(Not all predaceous or parasitic insects are beneficial ... some kill the natural enemies of pests instead of pests.)

More natural predators!

- Hornworms vs braconids (2min)

- Cockroach vs. Emerald Jewel Wasp

- Native to Asia, Africa, and some Pacific islands.

- Unsuccessful introduction to control cockroaches in Hawaii

Parasitoid wasps (and other native predators) are important!!

Predators & Parasites: Conservation

- What steps are involved in conservation?
  - Recognizing beneficials
  - Minimizing insecticide applications
  - Using selective insecticides or treating in selective manner
  - Maintaining ground covers, standing crops, and crop residues
  - Providing pollen and nectar sources or artificial foods

Be aware ... Cultural practices influence pests and beneficials simultaneously. For example, ground cover plants that provide nectar and pollen for beneficial insects may also attract and serve as a food source for cutworm moths and their larvae.

Predators & Parasites: Augmentation

- Natural enemies that are available for purchase and release include:
  - **Convergent lady beetle** (fly away, fly away ...)
  - **Mealybug destroyer** (good in greenhouses)
  - **Green lacewings** (best of general purpose and aphid predators; larvae that hatch on the ground often die)
  - **Spined soldier bug** (fun to watch, feeding rate & pop dynamics don't allow a purchase of these bugs to keep up with pests)
  - **Praying mantids** (ditto but worse; often eat nonpest insects)
  - **Predaceous mites for spider mite control** (some good results in greenhouses, dependent on conditions; possible benefit to re-inoculating orchards)
  - **Mites that prey on thrips** (good stories from greenhouses, dependent on conditions)
  - ***Encarsia* for whitefly control** (many successes in greenhouses, often complicated by other pests)
  - **Parasites of fly pupae** (successes in poultry have been difficult to match in other livestock facilities)

Biological control can be integrated with other IPM tactics

The following can be manipulated to enhance populations of natural enemies…

- Cultural controls
  - Management of cropping patterns, soil, and non-crop vegetation
- Mechanical or physical controls
  - Tillage, etc.
- Plant breeding and transgenic crops
- Pesticide use (see next slide)

Integration of biological control and pesticide use

- Reduce pesticide use
- Use selective pesticides and apply them selectively
- Modify biocontrol agents to survive pesticide applications
- Combine biocontrol agents and pesticides for increased effectiveness

- **An especially useful web site:**

Biological Control: A Guide to Natural Enemies in North America, from Cornell University at: http://www.nysaes.cornell.edu/ent/biocontrol/