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Natural Enemies in Your Garden: A Homeowner's Guide to Biological Control

MICHIGAN STATE
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EXTENSION

Cover Photos

Front cover, clockwise from top left

- Ladybug larva, *Coccinella septempunctata* (USDA).
- Green lacewing adult (Karim Maredia).
- Ladybug, *Hippodammia parenthesis*[1].
- Tachinid fly adult (Dave Smitley).

Back cover, from top

- Tomato hornworm covered with braconid parasitoid cocoons[1].
- Carabid beetle adult, *Calosoma* spp. (Dave Smitley).
- Virus infected cabbage looper[1].

Text Illustrations

- Pages 21 '*Orius*', 23, 25, 26, 28, 29, 32, 33, 35, 38, 44-46, and 48 (Michelle Schwengel, Midwest Biological Control News).
- Pages 15-20, 21 'true bug', 24, 33, 36, 40, and 42 (Jana Lee).
- Page 29 'Multicolored Asian lady beetle' (William F. Lyon, O.S.U. Extension factsheet HYG-215-94: Multicolored Asian lady beetle).
- Page 37 (J.J. Culver, 1919, USDA Bulletin 766, plate 1).
- Page 47 (P. Berry, 1938, USDA Circular 485).
- Pages 34, 41[1].

[1] (Michael P. Hoffman and Anne C. Frodsham, 1993, "Natural Enemies of Vegetable Insect Pests", Cornell University).

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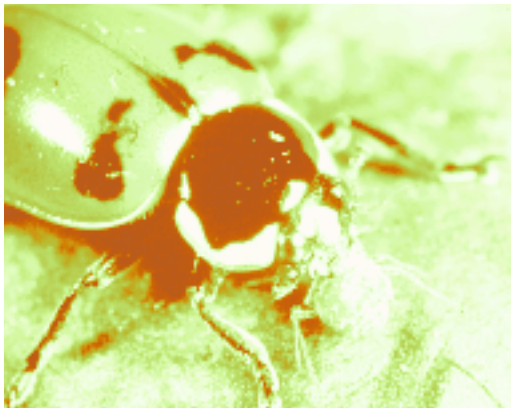

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Acknowledgements

This book summarizes information from the Midwest Biological Control News that is of interest to homeowners and gardeners. The newsletter source and contributing authors are given at the end of each section. If you are interested in learning more about a particular topic, you many find the original article and other articles of interest to you in the newsletter online index at <http://www.entomology.wisc.edu/mbcn/mbcn.html>

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Introduction

The home landscape is a complex habitat possibly consisting of vegetables, flowers, turf, woody ornamentals and other desired, and in some cases, undesired plants. For most of us, our garden is a relaxing place where we tailor the environment to our aesthetic and physical needs. Yet the garden is also home to creatures we consider pests when we find them in our broccoli or apples or on our prized rose bushes. As a result, the home landscape has become the repository of nearly 11 percent of the conventional pesticides used in this country. Indeed, acre for acre, your cousin Vinny's tomato patch has more pesticides than farmer Joe's soybean field! Fortunately, the garden is also home to our friends, the natural enemies of pests.

Most gardeners learn a great deal about their plants' growth needs, but they often know little about the insects in their gardens. Most of the insects in a garden are not harmful pests. The vast majority of insect species in North America are either beneficial or harmless to humans and garden plants. To take advantage of the work that natural enemies do (kill pests), we must first know which ones we have and help them flourish. Using natural enemies to control pests reduces your need to use pesticides and lets you take a bite from cousin Vinny's tomatoes, right off the vine!

— MBCN, v.4, n.4, Bryan Schmeiser and Bob O'Neil, Purdue University.

Who are Our Friends in the Garden?

Most of us are familiar with spiders, ladybugs and praying mantids and know they eat a lot of bad bugs. Luckily, many other natural enemies are also taking care of pests. There are three major groups of natural enemies: predators, parasitoids and pathogens.

Predators, such as ladybugs and spiders, eat many prey in a lifetime. Often they are larger and stronger than their prey and the most visible natural enemies in our garden. Some are quick running hunters, while others sit and wait for a victim to pounce on.

C. maculata

Wasp on an egg

Parasitoids are specialized insects that develop as young in one host, eventually killing it. Unlike predators, they usually kill only one prey during their immature stage. Many flies and wasps are parasitoids, but they are usually small and therefore go unnoticed.

nematode

Pathogens — nematodes, viruses, bacteria, fungi and protozoans — cause diseases. Many of these naturally occur in our gardens; others need to be introduced. Commercial companies have begun to develop many of these pathogens as bait or spray formulations, making them easier for us to use.

Making Biological Control Work for Us

Biological control uses natural enemies to keep unwanted pests at low levels.
To practice biological control in the yard, you should know the three basic approaches.

Classical biological control is used when pests are exotic in origin and exotic natural enemies are imported and released to bring about control. This is conducted by federal and state agencies. Although we homeowners will not be importing natural enemies into our backyards, some of the natural enemies described in this book were brought from other countries and established here. The importation of parasitic wasps to control alfalfa weevil in the Midwest has been a widely successful classical biological control program.

Conservation biological control encourages existing natural enemy populations to flourish in the area and suppress pests. This involves reducing practices that harm natural enemies as well as implementing practices that improve natural enemy longevity, reproductive rate and effectiveness.

Augmentation biological control is the release of natural enemies into the environment in high numbers. This is done when natural enemies do not thrive well in the environment or are not active during the time of pest activity. Conservation and augmentation of natural enemies are the home gardener's tools to subdue pests, so let's get started!

Conserving Natural Enemies

Conservation Step 1: Don't Reach for the Pesticide Spray

To conserve natural enemies in the home landscape, first and foremost, we need to reduce insecticide use. The chemicals we spray to get caterpillars off broccoli also kill or reduce the livelihood of natural enemies. Natural enemies take longer to re-establish themselves than pests do. Using pesticides may also create new pests because it kills natural enemies that are suppressing minor pests without our knowledge. When the natural enemies are killed by a pesticide, these minor pests can become major problems.

Kinder Options

Home gardeners have many insect pest management options other than insecticides. Adopting these options with attention to the life cycles of pest and beneficial insects is a key component of integrated pest management (IPM). Some IPM practices include preplant cultural operations, such as selecting insect-resistant varieties, crop rotations and companion plantings. After the garden has been planted, harmful insects can be managed in a variety of ways.

- If the garden is relatively small and insect pests are few, hand picking remains one of the most effective means of insect control for a gardener.
- Traps or barriers can be useful for some pests, and biological control agents that are commercially available can be very effective against specific insect pests. A word of caution: not all traps are effective (see section on electric traps).
- When all other measures have failed, very selective and well timed spot treatments of individual plant parts with a low-impact insecticide (such as insecticidal soaps or horticultural oils, which are relatively safe compounds for beneficials) may be considered.
- Tolerating a modest level of insect feeding on your garden vegetables will reduce the need for chemical inputs. If cabbageworms eat part of your cabbage head, you can always cut off the nibbled part and use the rest.

— MBCN, v.2, n.4, John Obrycki, Iowa State University, and Susan Mahr, University of Wisconsin - Madison.

Conservation Step 2: Making a Home for Natural Enemies (Habitat Manipulation)

Natural enemies require more than just food (pests to eat) to complete their life cycles. Predators and parasitoids may need an overwintering site, protection from heat and desiccation, plant food sources and early-season prey to sustain them if pests are not present. Managing the garden habitat to meet the needs of predators and parasitoids is an excellent way to conserve these garden friends and minimize the harmful effects of crop production on them.

Overwintering sites — Most pests are generally better at dispersal than their natural enemies, so a garden may get colonized by pests long before natural enemies arrive. For

this reason, it is all the more important that overwintering sites, such as flowering borders, hedges and other perennial habitats be provided for natural enemies. These vegetative sites insulate natural enemies from the winter chill. While some natural enemies may overwinter in the bare ground, we later prepare the ground for planting and disrupt their homes, sometimes killing them. When parts of the garden include undisturbed perennial plantings, natural enemies are more likely to survive the winter.

Mulches — Using mulches can reduce weed growth while providing humid, sheltered hiding places for nocturnal predators such as spiders and ground beetles. Also, the mulch may make it harder for flying insects such as aphids and leafhoppers to see the crop by reducing the visual contrast between the foliage and the soil surface.

Flowers — Having certain flowering plants available can greatly increase the longevity and fertility of many natural enemies. A study in Canadian apple orchards showed that parasitism of orchard pests was four to 18 times higher in orchards with many wildflowers than in orchards with few flowers. A number of plant species have been shown to encourage natural enemies (see Table 2). Ladybug and lacewing adults often feed on pollen. Many natural enemies that benefit from floral nectar are small

Electric Traps Get Good Insects But Miss Mosquitoes

Have you or someone you know bought an electric insect trap to keep the mosquitoes and other biting flies at bay? The snap, crackle and pop of fried arthropods may seem to confirm their effectiveness, but are these traps really doing much good? The traps in question use ultraviolet light to lure in flying insects, but many species of mosquitoes are not attracted to light, and many other non-target insects are attracted to lights and are inadvertently destroyed.

Researchers in Delaware tracked the insects caught in the electric traps of six homes near lowland, wooded sites rich in aquatic breeding habitats and, therefore, close to lots of mosquitoes and no-see-ums. These traps were good at catching insects, they found 13,789 insects, but only 31 were biting flies (a mere 0.22 percent). Nearly half of the insects collected were non-biting aquatic insects such as caddisflies and midges. More importantly, the traps destroyed 1,868 insects from 27 families of predators and nine families of parasitoids. Ground beetles, rove beetles and braconid wasps were particularly common victims. Predators and parasitoids accounted for 13.5 percent of the trap catch.

By their calculations, the traps needlessly destroy 71 billion to 350 billion non-target insects in the United States each year without achieving any effective control of nuisance insects. The heavy toll on beneficial insects suggests that electrified traps may actually be counterproductive for insect control.

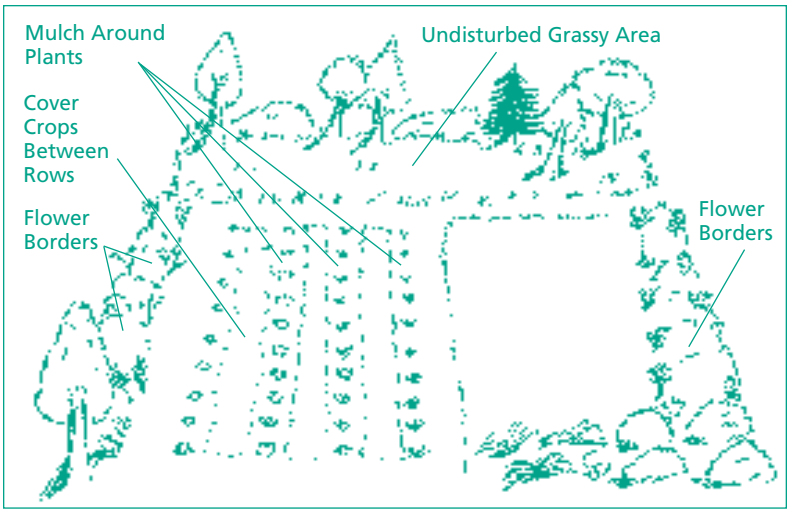
— MBCN, v.3, n.10; T.B. Frick and D.W. Tallamy, 1996, Density and diversity of non-target insects killed by suburban electric insect traps, Entomology News, 107(2): 77-82.

Maximizing Biological Control with Selective Insecticides

Biological control can be used as part of an integrated pest management program to maintain the appearance, health and structural integrity of your valued plantings. The following guidelines will help you maximize the potential for biological control:

- Monitor your plants regularly to record plant health, pest and natural enemy abundance, and habitat disturbance.
- Use your records and experience to develop situation-specific action thresholds and particular control strategies.
- When managing pests that occur early in the season, consider the impacts of natural enemies on late-season pests.
- When thresholds are exceeded, use pesticides most compatible with biological control. Some chemicals can be used without significantly affecting natural enemies, but most of the common insecticides are broad-spectrum and have relatively long residual activity. Consult Table 1 for specific information.

parasitic wasps, often smaller than a mosquito. Consequently, flowers that are good for them are usually small, not overly tubular and relatively open. In addition, flowers ought to synchronize with natural enemy activity. Planting a mixture of plants that bloom for long periods and overlap in time will ensure that food sources are available when natural enemies are active.



Garden showing types of habitat manipulation to benefit natural enemies.

Perennial plants often have shorter blooming periods than annuals, so particular attention should be given to plant diversity and blooming times in perennial borders designed for natural enemies. Sequential plantings of dill, coriander and caraway can be made to provide a continuous source of valuable flowers.

Ground covers — Leguminous cover crops improve soil fertility and provide shelter, floral food sources and alternate prey for a wide variety of natural enemies. In cover crops, non-pest prey may be present and sustain natural enemies if their favorite pest has not invaded the area.

It should be apparent that a single recipe for success using habitat manipulation does not exist. Consider altering gardening practices such as planting times, selecting cultivars and mixing crops together to thwart pests and enhance natural enemy survival.

— MBCN, v.3, n.4, Shawn Steffan and Paul Whitaker, University of Wisconsin - Madison.

Table 1. Pesticide Use Compatibility with Biological Control.			
Class	**Names**	**Compatibility**	**Comments**
Organochlorines	Lindane	not compatible	very long residual, broad-spectrum
Organophosphates	Orthene® (acephate)	not compatible	broad-spectrum
	Dursban®, Lorsban® (chlorpyrifos)	not compatible	long residual, broad-spectrum
	Spectracide® (diazinon)	not compatible	long residual, broad-spectrum
	Cygon® (dimethoate)	not compatible	long residual, broad-spectrum
Carbamates	Sevin® (carbaryl)	not compatible	broad-spectrum; repeated use may stimulate spider mite reproduction
Pyrethroids	Ambush®, Pounce® (permethrin)	not compatible	long residual, broad-spectrum
Botanicals	Pyrethrin	somewhat compatible	short residual but very broad-spectrum
	Azatin®, Margosan-O® (azadirachtin)	compatible	insect growth regulator derived from seeds of neem tree; kills immature stages; pupal stage parasitoids not affected
Insect growth regulators	Dimilin® (diflubenzuron)	somewhat compatible	moderate residual; kills immature stages pupal stage parasitoids are not killed
Microbial insecticides (pathogen biological control agents)	*Bacillus thuringiensis* var. *kurstaki* Dipel®, Thuricide®, Javelin® (bacteria)	highly compatible	targets caterpillars
	Bacillus thuringiensis var. *tenebrionis* (bacteria)	highly compatible	targets beetle grubs
	Beauveria bassiana (fungus)	compatible	kills some soft-bodied predators; short residual, broad-spectrum
	Steinernema carpocapsae Biosafe® (nematode)	highly compatible	very low toxicity to humans and non-targets, wasp parasitoids with silken cocoons are not killed
Others	Horticultural oil (petroleum oil)	compatible	inactive when dry; kills soft-bodied insects; pupal stage parasitoids not killed
	Safer®, M-Pede® (insecticidal soap)	compatible	inactive when dry; kills soft-bodied insects; pupal stage parasitoids not killed

— MBCN, v.6, n.3, Cliff Sadof, Purdue University, and Michael Raupp, University of Maryland.

Table 2. Good Flowers for Predators and Parasitoids.

Umbelliferae (carrot family)

caraway	*Carum carvi*
coriander (cilantro)	*Coriandrum sativum*
dill	*Anethum graveolens*
fennel	*Foeniculum vulgare*
flowering ammi or bishop's flower	*Ammi majus*
Queen Anne's lace (wild carrot)	*Daucus carota*
toothpick ammi	*Ammi visnaga*
wild parsnip	*Pastinaca sativa*

Compositae (aster family)

blanketflower	*Gaillardia* spp.
coneflower	*Echinacea* spp.
coreopsis	*Coreopsis* spp.
cosmos	*Cosmos* spp.
goldenrod	*Solidago* spp.
sunflower	*Helianthus* spp.
tansy	*Tanacetum vulgare*
yarrow	*Achillea* spp.

Legumes

alfalfa	*Medicago sativa*
big flower vetch	*Vicia* spp.
fava bean	*Vicia fava*
hairy vetch	*Vicia villosa*
sweet clover	*Melilotus* spp.

Brassicaceae (mustard family)

Basket-of-Gold alyssum	*Aurinium saxatilis*
hoary alyssum	*Berteroa incana*
mustards	*Brassica* spp.
sweet alyssum	*Lobularia maritima*
yellow rocket	*Barbarea vulgaris*
wild mustard	*Brassica kaber*

Other plant families

buckwheat	*Fagopyrum sagittatum*
cinquefoil	*Potentilla* spp.
milkweeds	*Asclepias* spp.
phacelia	*Phacelia* spp.

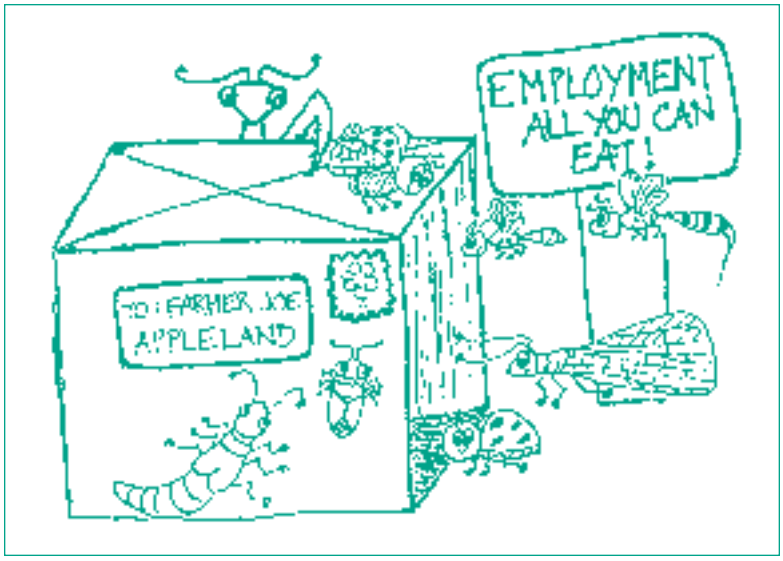
Augmenting Natural Enemies

If naturally occurring predators and parasites are not sufficient to control garden pests, augmenting them with releases of commercially available natural enemies may be effective. Insect pathogens are often produced as formulations called microbial insecticides for use in the yard. Not all natural enemies are available because rearing them may be difficult or costly.

Natural Enemies for Hire

What is available? Green lacewings are commonly sold and are a good option for aphid control. These predators can be purchased and released early in the growing season for earlier and more effective control. The eggs are shipped in small containers mixed with bran (or another filler, such as vermiculite) that protects the eggs during shipping. All you have to do is sprinkle the contents of the container on the plants. Other very popular natural enemies are *Trichogramma* wasps to control cabbageworms, cabbage loopers, tomato hornworms and other caterpillars, and beneficial nematodes to control a wide variety of garden pests. The most commonly used microbial agent is a bacterium, *Bacillus thuringiensis*, or *Bt*. Microbial insecticides are sold by many chemical companies and common in stores. If you are interested in purchasing predators or parasitoids, this is a good free source of information:

— *Suppliers of Beneficial Organisms in North America by C. D. Hunter, from: California Environmental Protection Agency Department of Pesticide Regulation Environmental Monitoring and Pest Management P.O. Box 942871 Sacramento, CA 94271-0001 http://www.cdpr.ca.gov/docs/ipminov/bensuppl.htm*



What to Consider When Ordering Natural Enemies

Ask the supplier for specific information and recommendations for your particular situation. Ordering and releasing natural enemies can be successful if you:

- Know the specific pests you need to control.
- Know the best natural enemies, either singly or in combination, for the target pest or pests. Make sure companies

provide the exact name of the natural enemy that they are selling.

- Know the proper time to release the natural enemy. Timing should be based upon the life cycles of the pest and the natural enemies.
- Know the proper release rate for each natural enemy.
- Calculate the number of natural enemies needed on the basis of release rate, area to be covered and severity of pest infestation.
- Know the recommended frequency of release if multiple releases are necessary.
- Provide a safe delivery address, one where the shipment will be cared for **as soon as it arrives** and where it will not be exposed to temperature extremes.
- Understand proper release practices so that you will be prepared to make releases when the shipment arrives.
- Understand proper storage requirements if releases are not to be made immediately after arrival.

— MBCN, v.2, n.3.

Making Augmentation Successful

Releasing loads of natural enemies in the garden will take money from your pocket, but will it guarantee success? Sometimes predators and parasitoids will leave the area or will not survive long enough to have an impact on pests. Maintaining a suitable habitat, as discussed in conservation biological control, is critical to improving the natural enemy's efficacy. Be very judicious

What About Releasing Ladybugs and Praying Mantids?

Ladybugs are good biocontrol agents, but what about the ones you buy? Chances are these ladybugs are *Hippodamia convergens*. Many convergent ladybugs overwinter in huge aggregations in the Sierra Nevada mountains. This makes it easy for suppliers to scoop them up, box them and sell them. Unfortunately, when you release these convergent ladybugs in your backyard, they behave as they do in the mountains — they fly away looking for the valley, their normal feeding grounds. Some suppliers are now preconditioning ladybugs, letting them fly around before you receive them so the ladybugs will be less likely to fly away. If you're interested in testing ladybugs in your backyard, look for the activity box in the ladybug section.

What about praying mantids? Though they certainly do prey on pests, mantids are extreme generalists — they will eat virtually anything they can catch, including their siblings and other beneficials. Large mantids, such as the commercially available Chinese mantid, will even catch and eat bees and other pollinators. Adult mantids are very mobile, so they usually won't remain in the release site for long. Nevertheless, they are interesting. Because of their large size, big and seemingly inquisitive eyes, and their "praying" stance, we seem to have an affinity for them. If you wish to purchase them, do so as a source of education or interest, but don't expect them to provide much benefit in pest management.

- MBCN, v.2, n.4, Dan Mahr, University of Wisconsin - Madison.

with insecticide use when releasing natural enemies. Commercially reared insects will likely find it just as hard to survive insecticide exposure as your normal yard insects. Also, a diversity of plantings (flowering plants, ground covers) will help maintain an adequate food supply and shelter so released natural enemies will remain in your garden doing what you paid for them to do.

Looking for the Silver Bullet

We often look to biological control to work like chemical controls. It would be nice if one natural enemy was the silver bullet and took care of the pest. Yet natural enemies often do not work that way. Releasing a fantastic predator and having it become established in the system requires effort. We need to know what the predator needs and make sure alternative food sources and protective shelter are provided. As you look through this book, you will notice that some natural enemies eat a variety of pests and others are very specific. Both are usually needed to obtain effective biological control. Some specific natural enemies can be very good at locating pests at low densities and keeping them low, while other specifics may be good at bringing down pest outbreaks. Generalists are important because they can feast on a variety of pests and are more flexible in where they can live. When a particularly bad pest arrives, the generalist natural enemies are already in your garden ready to do their share of eating away the pest population. Biological control of pests may take many natural enemies and more effort on your part, but it can work in your garden!

Discovering Natural Enemies in Your Backyard — How to Sample

Your garden contains a wealth of small critters. We tend to notice the bad or pretty ones, but there are plenty more out there — we just need to keep an eye open for them. Here is how you can discover the wonderful diversity of insects and other critters.

- Spend an hour or two outside sitting quietly and observing. When flowers are in bloom, there is a lot of activity — many flower feeders and pollinators come by. If you are lucky, you might see a predator that was hiding in the flower leap out and attack its unsuspecting prey. If the plant has aphids, you may notice a ladybug or other predator feeding on them. Sometimes you may see ants taking care of the aphids. The aphids provide ants with honeydew, so the ants will guard them against any predator.
- Dig up some soil and spread it out on a white surface. You'll probably see earthworms, a good sign. Perhaps there are little things jumping about. These springtails are important decomposers and relatively harmless to crops. You may also see less mobile pupae and grubs as well as adult ground beetles that run frantically when disturbed.
- Put bright yellow cards covered in petroleum jelly in various areas — in tree foliage, above grasses and in your vegetable planting. Why bright yellow? This color is attractive to many pest and beneficial insects. The traps will kill them, so it is advisable not to keep them out for long. Adult parasitoids, small wasps, often fly into these traps, and you never knew they were there before in your garden.
- Fill yellow plastic pans with soapy water and place them on the ground. Many aphids and flies will find their way into the pans.
- Make pitfall traps by inserting plastic cups into the soil with the rim just below the soil surface so that any strolling insects will fall in. Leave them out overnight and you may be surprised by the number of ground dwellers active at night. Spiders and ground beetles, both good predators, will dominate the traps. If there are insect remains, they may have been feasting on one another through the night.
- Place a white sheet under a tree or bush. Beat the branches with a stick or shake them with your hands. You will find that spiders, true bugs, caterpillars and sawflies come tumbling down.

Natural Enemies of Common Pests

With this table, you can quickly identify the particular natural enemies that can help control common pests in your garden and home landscape. Look in the left column for the pest you want to control. The right column will guide you to the pages for more information.

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	Damsel bugs (predator)	24
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	Hover flies (predator)	34
	Beauveria bassiana (pathogen)	52

Beetles	Natural Enemies of Beetles	Page
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	Nematodes (pathogen)	50

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Caterpillars	Natural Enemies of Caterpillars	Page
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Predators

Predators kill more than one prey in their lifetime. Birds, mice, frogs, insects and other arthropods all eat insect pests. For pest management, the six-legged and eight-legged creatures, insects and arachnids, are the most important control agents.

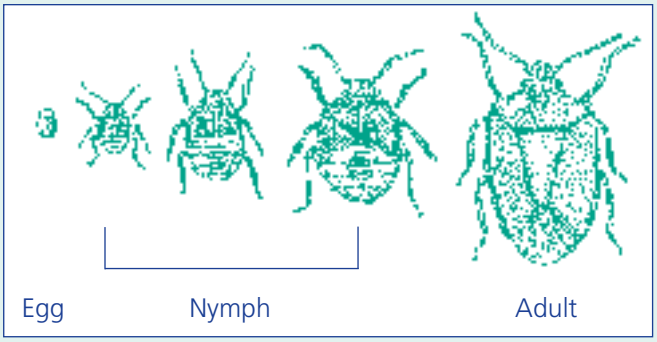
Predators may be stronger and larger than their victims. Some ground-dwelling predators have long running legs and use speed to catch prey. Others are camouflaged and strike when prey are in close range. Some really smart predators build traps to bring them dinner. Have you seen cone-shaped pits in sandy ground? At the bottom of the pit is a young ant lion waiting for an ant to stroll by. When an ant walks near, the young ant lion throws up sand to get the ant to tumble down into the pit. Using strength, speed or trickery, predators can catch and eat a lot of prey, and that is good news for us.

Development

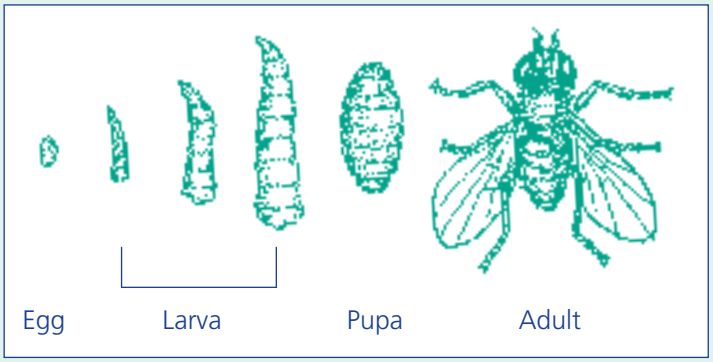
Insects develop in two major ways, and the type of development will influence the natural enemy's lifestyle and how you recognize it. While, all adult insects have six legs, two antennae and a three-part body plan: head, thorax and abdomen, immature insects may look different depending on their type of development.

Hemimetabolous insects: the young insects look like the adult insects without wings.

Both nymph and adult tend to eat the same things. Predaceous true bugs are hemimetabolous. Arachnids, including spiders and mites, develop similarly to hemimetabolous insects.



Holometabolous insects: the young insect looks drastically different from the adult.



The larva and adult may feed on different foods and live in different habitats. Beetles, lacewings, wasps and flies are holometabolous. Beetle larvae are often called grubs, and fly larvae are called maggots.

True Bugs, Blood Suckers of the Insect World

All true bugs (order Hemiptera) have piercing-sucking mouthparts. These mouthparts extend into a long "beak" known as a rostrum. Most true bugs are plant feeders, but many are predaceous, drinking the blood of other insects, and a rare few can attack humans. True bugs have their own tricks of the trade for catching insects. The stink bugs and small flower bugs often attack less mobile victims such as caterpillars, slow larvae and aphids. Assassin bugs may lie hidden and jump when a good-looking dinner crosses their path. Some bugs emit attractive odors to lure bees in. Once a victim is seized, the sharp teeth at the tip of the bug's rostrum busily cut a hole. The bug then sticks its rostrum inside the prey, pumps enzyme-laden saliva and sucks up the partially digested insect cocktail through its own personal straw.

Should we be wary of these blood suckers? Well, the human blood suckers, such as bedbugs, are relatively uncommon. The ones we find in our yard prefer to feed on other insects, though they can poke you if you bother them. Large bugs can deliver painful bites that may cause blistering, so be careful if you handle them.

Minute Pirate Bugs

Order: Hemiptera, true bugs
Family: Anthocoridae

Pirate bugs are common insect predators found in many habitats, including agricultural crops, pastures and home landscapes. Both immature stages (nymphs) and adults feed on a variety of small prey, including **spider mites, insect eggs, aphids, thrips, scales** and **small caterpillars**.

What you will see: Adults are very small — 1/8 inch long — somewhat oval-shaped and black with white wing patches. Females lay tiny eggs within plant tissues where they are not easily seen or eaten by other predators. These eggs hatch into immature nymphs. Nymphs are small, wingless insects, yellow-orange to brown, teardrop-shaped and fast moving. Growing from egg to adult takes at least 20 days under optimum conditions. Several generations may occur during a growing season.

Minute Pirate Bug

***Orius* spp.** The most common species in the Midwest is *Orius insidiosus*. Another species, *Orius tristicolor*, is more common in western states. Both immature and adult *Orius* can consume 30 or more **spider mites** per day. They also eat **potato aphids** and **potato leafhopper nymphs**. Occasionally, *Orius* may even bite humans, but the bite is only temporarily irritating.

Giving them a boost: Grow a variety of spring- and summer-flowering shrubs and plants — pirate bugs will feed on pollen and plant juices when prey are not available. Insecticides can greatly reduce their numbers. Even soil-applied systemic insecticides may reduce their numbers because they may ingest them by sucking plant juices for moisture. Diversified cropping systems or use of selective products such as microbial insecticides will maximize the natural biological control from minute pirate bugs.

If you would like to give your garden an extra boost of minute pirate bug activity, you can buy *Orius* from commercial suppliers. These bugs are shipped as adults in a carrier such as vermiculite along with a food source. Shake the carrier onto your plants and the bugs will readily disperse and locate prey.

— MBCN, v.1, n.1, Bob Wright, University of Nebraska - Lincoln.

Stink Bugs

Order: Hemiptera, true bugs
Family: Pentatomidae

If you have picked up a stink bug, you may recall the unpleasant smell of your hand afterwards. Stink bugs are quite distinguishable by their broad, shield-shaped bodies.

Many stinkbugs are plant feeders, but some are important predators. The spined soldier bug and the two-spotted stink bug feed on a variety of pests and are particularly famous because they feed on **Colorado potato beetle**.

Spined soldier bug (*Podisus maculiventris*) — This stink bug can feed on more than 50 types of prey, primarily the **larvae of beetles and moths**. The largest, most sustained attempt at releasing spined soldier bugs in a biological control program against Colorado potato beetle occurred in eastern Europe and the former Soviet Union (see MBCN, v.4, n.1). Millions of spined soldier bugs were reared and released, with very promising results.

What you will see: Adult spined soldier bugs are brownish and about 1/4 inch long with a prominent spine on each "shoulder." (This is not the origin of the name spined soldier bug . . . "spined" refers to spines on the legs.) They overwinter as adults, hiding in leaf litter in woods around fields, and begin emerging around mid-April. Females can lay up to 500 eggs and live up to 125 days. Males are slightly smaller than females and live up to 180 days.

Females begin depositing eggs four to seven days after emerging. The number of eggs a female lays depends on how well she is fed and what she fed on. The eggs are deposited in masses of 15 to 70 and range from cream-colored to black. Eggs hatch in four to seven days, depending on temperature. The brick-red first instar spined soldier bugs are not predaceous (they eat nothing at all); the remaining four instars (nymphal stages) are predaceous. Development from newly hatched nymph to adult takes 25 to 30 days. There are one to three generations per year.

egg mass nymph adult

Spined soldier bug

Two-spotted stink bug *(Perillus bioculatus)* —These bugs eat **caterpillars** as well as **Colorado potato beetle eggs and larvae**. Two-spotted stink bugs feed more specifically on Colorado potato beetle and prefer smaller larvae than the spined soldier bug.

What you will see: Two-spotted stink bug adults are black with yellow or red markings. A distinctive black Y appears on their back or shield. Adults emerge in early spring and feed on plant sap before prey are available. The life cycle is similar to that of the spined soldier bug. The first instar feeds on plant sap; later instars are predaceous.

Giving them a boost: Having year-round ground cover present in your garden will provide them an overwintering home and plant sap for supplemental food when prey are scarce. Commercial suppliers have spined soldier bugs and two-spotted stink bugs on hand. If nymphs are purchased, be aware that they are delicate and need to be released soon, and that transporting them onto potato foliage is time consuming. Eggs are easier to handle but should be placed in protective screened containers on the soil to prevent them from being eaten by others.

— MBCN, v.2, n.8; v.3, n.5, Bob O'Neil, Purdue University; J. Hough-Goldstein, J. A. Janis and C.D. Ellers, 1996, Release methods for *Perillus bioculatus* (F.), a predator of the Colorado potato beetle, Biological Control, 6: 114-122.

Two-spotted stink bug

Assassin Bugs

Order: Hemiptera, true bugs
Family: Reduviidae

The more than 160 species in the family Reduviidae in North America include assassin bugs, ambush bugs and thread-legged bugs. Most assassin bugs are medium to large predators of crop pests, but the family does contain a few blood-sucking species. These beneficial insect predators can inflict a painful bite if handled carelessly, resulting in an inflammation that can persist for a few days. Most assassin bugs are generalist predators in gardens, fields and forests.

Assassin bug

They sit in wait for prey and are most likely to attack **small flying insects**, though they can subdue and kill **medium-sized caterpillars**. Prey in vegetable plantings can include **aphids, leafhoppers** and **asparagus beetle eggs and larvae**. Assassin bugs may feed on beneficial species as well as pests.

What you will see: Adult assassin bugs are usually 1/2 to 3/4 inch long. Many species are brownish or blackish, but some are brightly colored. The elongated head is narrow with a distinct "neck" behind the often reddish eyes. The long beak or rostrum is carried beneath the body, with the tip fitting in a groove on the underside of the body. The middle of the abdomen is often widened, so the wings don't completely cover the width of the body. The female lays eggs in tight, upright clusters on leaves or in the soil. Nymphs resemble miniature, wingless adults.

Wheel bug *(Arilus cristatus)* — This is one of the largest and most easily recognized assassin bugs. The adult is about 1 1/4 inches long and gray with a striking semicircular crest on the upper back that looks like a cogwheel. Wheel bugs feed on **aphids** as young nymphs. Later they attack caterpillars such as the **fall webworm** and other pests such as the **locust borer**.

Giving them a boost: Assassin bugs are not often manipulated for pest control, but judicious use of insecticides can help increase their activity.

— MBCN, v.3, n.5, Susan Mahr, University of Wisconsin - Madison.

Damsel Bugs

Order: Hemiptera, true bugs
Family: Nabidae

These generalist predators are commonly found in many crop and garden situations. They are predators of **aphids, moth eggs** and **small caterpillars**, including **imported cabbageworm** and some **armyworms**. Other prey may include **leafhoppers** (including beet and potato leafhoppers), **small sawfly larvae, mites, tarnished plant bug nymphs**, and **asparagus beetle**

Damsel bug

and **Colorado potato beetle eggs and larvae**. Though they can survive for up to two weeks without food, they become cannibals if no other prey is available.

What you will see: Damsel bugs are slender, tan-colored bugs that resemble small, smooth-looking assassin or other plant bugs that feed on crops. Some damsel bug species are black. Most species of damsel bugs overwinter as adults and can have one to five generations per year, depending on location.

Giving them a boost: Maintain low-growing grasses or ground cover in your garden; damsel bugs prefer to take shelter in these environments. Damsel bugs are currently not available from commercial suppliers.

— MBCN, v.4, n.2, Susan Mahr, University of Wisconsin - Madison.

Bigeyed Bugs

Order: Hemiptera, true bugs
Family: Lygaeidae, seed bugs
Genus: Geocoris spp.

Bigeyed bugs, *Geocoris* spp., are generalist predators commonly found in a variety of crops, home gardens and lawns. Many bigeyed bug species are found throughout the United States feeding on **insect eggs, aphids, mealybugs, spider mites, leafhoppers, plant bugs, whiteflies**, and **small caterpillars** or **beetle larvae**. Each nymph may consume up to 1,600 spider mites during its immature stages and as many as 80 mites a day as an adult. Bigeyed bugs are fun to watch — they attack prey by extending their beak and quickly inserting it into the prey. These small bugs may lift prey into the air to prevent it from escaping.

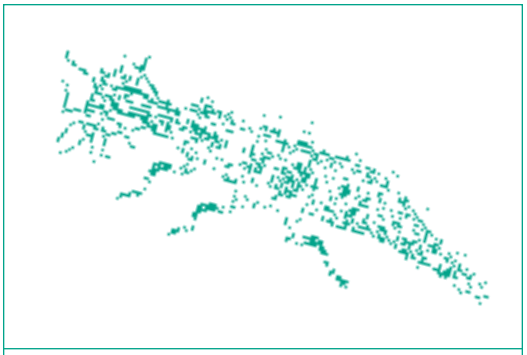
What you will see: As the name implies, bigeyed bugs have rather large, protruding eyes. The adults range in color from black and white to tan. The nymphs resemble

Bigeyed bug

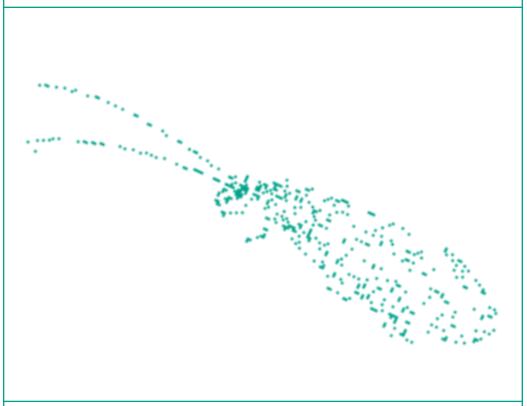
miniature grayish adults. They are small, about 1/8 to 3/16 inch long. Most bigeyed bugs go through five nymphal stages. Under laboratory conditions, nymphs develop into adults within 30 days at 77 degrees F and 60 days at 68 degrees F. Bigeyed bugs overwinter as adults or as eggs, depending on the species and location.

Giving them a boost: Bigeyed bugs prefer weedy areas of gardens. They feed on plants and survive best when they have a mix of plant and insect food. Be aware that their plant-feeding habit makes them also susceptible to systemic insecticides. The good news is that their omnivorous feeding habits allow them to survive in a variety of habitats, and there is no evidence that their plant feeding causes significant injury to plants.

— MBCN, v.4, n.12, Bob Wright, University of Nebraska.



Lacewing larva



Lacewing adult

Green Lacewings

Order: Neuroptera
Family: Chrysopidae

Green lacewings are found in most environments throughout North America. The larvae of green lacewings, called aphidlions, are voracious predators in many biocontrol programs. Aphidlions can consume up to 200 **aphids** per week. They also eat **mites, insect eggs, thrips, mealybugs, immature whiteflies, scales** and **small caterpillars**. Adult green lacewings are generally not predaceous, consuming plant nectar, pollen and honeydew.

What you will see: The light green lacewing adult has long, slender antennae, golden eyes, and large, veined, gauzelike wings that are 1/2 to 1/3 inch long. It is a slow-flying nocturnal insect that feeds on nectar and pollen. It emits a foul-smelling fluid from special glands if captured. The female lacewing lays eggs in groups on leaves, each egg held away from the leaf surface on the end of a slender stalk. A female can lay 300 eggs over a period of three to four weeks, but the eggs often do not survive that long in the field. The aphidlion larva resembles a green-gray alligator with mouthparts like ice tongs. An aphidlion seizes and punctures its prey with long, sickle-shaped jaws, injects a paralyzing fluid and sucks out the body fluids. After

feeding and growing to 1/2 inch in length during a two- to three-week period, the larva spins a spherical, white silken cocoon to pupate. The adult emerges in about five days. It overwinters as a pupa within its cocoon or as an adult.

Giving them a boost: Have flowering plants blooming throughout the season — adult lacewings need nectar and pollen to feed on and stimulate egg laying. Green lacewings are widely available from many commercial suppliers, generally offered as eggs. Aphidlions will travel 80 to100 feet in search of prey. For control of moderate aphid infestations in home gardens, release five to 10 lacewing eggs per plant or 1,000 eggs per 200 square feet. Two or three successive releases made at two-week intervals are better than a single release. These insects are extremely effective under certain conditions, especially in protected or enclosed areas such as a greenhouse, but they may fail to survive and provide control when conditions are not favorable. Providing a suitable habitat for adults will encourage released lacewings to remain in your garden. Otherwise, you will need to make additional releases to maintain a continuous supply of larvae.

— MBCN, v.1, n.3, Susan Mahr, University of Wisconsin - Madison.

Ladybug, Ladybird, Lady Beetle

Order: Coleoptera, beetles
Family: Coccinellidae

Ladybugs have been appreciated for centuries. During the Middle Ages, farmers prayed to the Virgin Mary when aphids were attacking their crops. When these beetles arrived and consumed the aphid problem, they were called "Our Lady", hence the

Sibling Rivalry

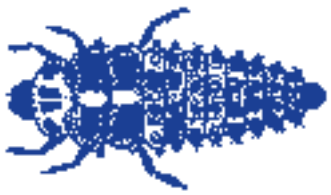
Ever noticed insect eggs on a slender stalk? Why would a mother lay her eggs that way? It is not to let the wind gently blow on them but to prevent them from being eaten. The predaceous green lacewings are mighty good predators, and once hatched, they are so determined to eat that they would eat their own siblings. The mother lays her eggs on a stalk to keep them out of reach of hungry brothers and sisters.

Fun for Kids

Purchase a praying mantid egg case or find one in your backyard. Place the egg case in a jar. Put lots of very small insects and their plant food inside. Wait for eggs to hatch. Watch the young brother and sister mantids hunt the small insects. About how many mantids hatched? How many mantids are left after a week? Where did the rest go? Place the remaining mantids in the garden.

name "ladybug". The family of ladybugs contains more than 4,000 species. Nearly all are predators, and they feed on many kinds of soft-bodied insects: **aphids, mealybugs, whiteflies** and **scales**. As early as the late 1800s, lady beetles were being used in biological control programs in the United States. The importation of the predaceous vedalia beetle, a scale-feeding species, saved the citrus industry in California from the cottony cushion scale.

What you will see: Many of us are familiar with adult ladybugs. They are shiny, convex, round, sometimes red-orange or black, and with and without spots. Larvae are less well known but also very important predators. The size and coloration of the larval stages vary among species, but generally larvae are soft-bodied and shaped like miniature alligators. Newly hatched larvae are gray or black and less than 1/8 inch long. Later stage larvae can be gray, black or blue with bright yellow or orange markings.



Ladybug larva

In the Midwest, several very common lady beetle species are aphid predators.

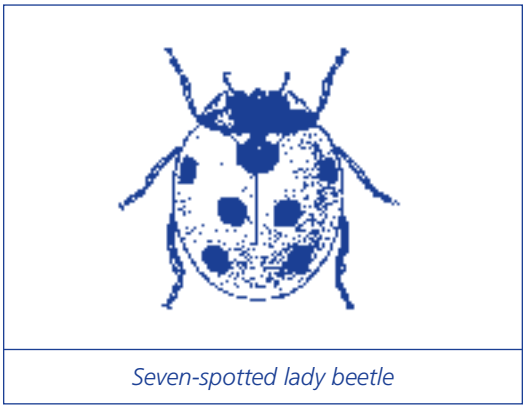
C. maculata

Twelve-spotted lady beetle *(Coleomegilla maculata)* — Adults are about 1/4 inch long and have pink to light red wing covers with six black spots on each wing. Both adults and larvae feed on **aphids, mites, insect eggs** and **small larvae** of many insect pests. Plant pollen and fungal spores are also important components of their diet. Females lay clusters of 10 to 20 yellow eggs on plants. This species has two to three generations per year in the Midwest and overwinters as large groups of adults in the litter at the bases of trees or next to buildings.

Convergent lady beetle *(Hippodamia convergens)* — Adults are about 1/4 inch long with orange wing covers, typically with six small black spots on each wing cover or sometimes with no spots.

Convergent lady beetle

The section of the body behind the head is black with white margins and has two converging white lines; this is why it is called the convergent lady beetle. Adults and larvae feed primarily on **aphids**. Females lay clusters of 10 to 20 yellow eggs on plants infested with aphids. The larvae grow and molt through four stages. This species probably has one to two generations each year in the Midwest. Large aggregations of convergent lady beetles in the Sierra Nevada mountains of California are collected for commercial sale.



Seven-spotted lady beetle

Seven-spotted lady beetle *(Coccinella septempunctata)* — The seven-spotted lady beetle was introduced into North America from Europe. Adults are large — about 3/8 inch — with red wing covers with seven black spots. Females lay clusters of 15 to 70 yellow eggs on plants that are infested with their **aphid** prey. Larvae grow and molt through four stages as they feed on aphids. The large fourth instar consumes more aphids than the previous three larval stages combined. Adult seven-spotted lady beetles overwinter in small groups in hedges or in leaf litter on the ground near the bases of plants.

Two-spotted lady beetle

Two-spotted lady beetle (Adalia bipunctata) — As one might expect from its common name, these red beetles have two black spots. The 1/4-inch-long adults are commonly found in trees and bushes. They overwinter in or around buildings or in other protected locations and emerge in early to midspring.

Multicolored Asian lady beetle

Multicolored Asian lady beetle *(Harmonia axyridis)* — Adults are yellow to orange and often seen in large congregations on buildings around the end of October. This lady beetle was introduced from Japan to control tree-inhabiting aphids. It feeds on various **aphids, certain scales** and a few **other insects**. It is an effective predator of aphids on pecans, pine trees, ornamental shrubs, roses and other plants. In the South, many pecan growers no longer need to spray their trees for pecan aphids

because this lady beetle has done such a good job of biological control.

The adult multicolored Asian lady beetle is quite variable in appearance. Individuals can be any color from a pale yellow-orange to a deep orange-red with no spots or up to 20 black spots. They are very prolific and may live up to three years. The bright yellow eggs are laid in clusters of about 20 on the undersides of leaves. The eggs hatch in three to five days, and the larvae feed up in the trees for 12 to 14 days. They then pupate on the leaves. Adults emerge in five to six days.

Giving them a boost: Reduce insecticide use or pick selective insecticides. Plant a variety of crops so that ladybugs have a variety of prey available throughout the season. Adults need nectar and pollen, so make sure flowering plants are around. Though ladybugs are available for sale, augmentative releases have not been highly successful.

— MBCN, v.2, n.4, John Obrycki, Iowa State University; MBCN, v.2, n.10, Susan Mahr, University of Wisconsin - Madison.

The Scientist in You:

How Do Ladybug Releases Affect Aphids in Your Garden?

Ladybugs are often offered for sale for controlling aphids in home gardens. As mentioned, releases have not often been successful. Nevertheless, you may be curious about buying ladybugs and testing them.

- Select several plants (or branches of a tree) that have aphids on them for your test plants. Mark eight to 12 branches with tags so you can easily locate them. Count or estimate the number of aphids on each branch, and record this information.
- Enclose half of the branches in cages and leave the rest exposed. You can make simple cages with mosquito netting or other mesh fabric. Cut out a square piece of netting and fold it in half. Sew the long side and the bottom shut. Or, if the branches are small, try pantyhose. Insert your aphid-infested branch into this "sleeve cage" and tie it closed with a piece of string. Do remove any natural enemies that might be on the branches before putting on the cages.
- Release about five ladybugs on half of the exposed branches and half into the cages. The remaining exposed and caged branches will be your controls. You now have four treatments: exposed branch with ladybugs, exposed branch without ladybugs, caged branch with ladybugs and caged branch without ladybugs.
- Inspect the branches for ladybugs and count the number of aphids on the branches again in three days, a week and two weeks.

Now that you have run your backyard science experiment, what happened? How have the aphid populations changed? Were any ladybugs still on the exposed branches? If not, where do you suppose they went? Do you think the exposed aphids were eaten by the ladybugs you released or were they destroyed by other naturally occurring

biological control agents? Did caging the ladybugs to keep them from flying away improve aphid control? Do you think it is worth the cost to buy ladybugs to release in your garden?

– MBCN, v.2, n.6, Susan Mahr, University of Wisconsin - Madison.

Ladybugs: Friends in the Home?

Have you noticed that, when the weather grows cold, you start finding ladybugs on your table, on the windowsill or in your cup? Even though the multicolored Asian lady beetle is an important biological control agent, it can become a nuisance when large numbers aggregate in homes or other buildings. For several days during autumn, they typically hang out on sunny, southwest sides of light-colored rock outcroppings or structures where nearby crevices serve as overwintering sites. Outdoor clusters may leave after a few days or weeks.

The best way to prevent beetles from becoming uninvited houseguests is to seal cracks around windows, doors, siding, utility pipes or other openings with a good quality caulk. Replace or repair damaged screens, and install screens over roof vents. Indoor visitors can be removed with a vacuum cleaner equipped with a crevice tool. They can also be swept up with a broom and dustpan and be deposited outside well away from the house. It is not a good idea to kill them with insecticides, squash them or handle them, as this may result in orange stains on walls and fabric. When stressed, the lady beetles secrete a harmless but staining orange substance.

— MBCN, v.2, n.10, Susan Mahr, University of Wisconsin - Madison.

Fun for Kids: How Ladybugs Defend Themselves

Collect some ladybugs. Hold them and poke them gently. Notice how they pull their legs into their bodies and an orange liquid comes out. This liquid is blood that comes out of the joints of the legs in a phenomenon called reflex bleeding. All lady beetles do this when threatened. Their blood is distasteful to birds and other prospective predators. Afterwards, free the ladybug so it can relax again.

Rove Beetles

Order: Coleoptera, beetles
Family: Staphylinidae

There are about 2,900 species of rove beetles in North America. Some species are predaceous as both adults and larvae; the larvae of other species are parasitoids; many others are probably scavengers. They are often found in agricultural soils and home gardens. Predaceous rove beetles may consume root maggot eggs and larvae, mites, small insects, snails and insect eggs on the ground or sometimes on foliage.

What you will see: Adult rove beetles are generally less than 3/4 inch long. They are easily recognized by their slender, usually black or brown body and shortened front

Rove beetle

wings (elytra) that may look like pads on the abdomen. They may curl the tip of the abdomen upwards when disturbed or running, like a scorpion. Adults are usually strong fliers. The mobile larvae of non-parasitic rove beetles may be distinctly segmented. Rove beetles may be seen under debris or rocks, in compost piles or on plants.

Aleochara bilineata rove beetles have a dual lifestyle — as larvae, they are parasitic on cabbage maggot pupae, and as adults they become hunting predators of **cabbage maggots**. The 1/8-inch-long adults are glossy black except for the short wing covers, which are a reddish brown. Adults emerge in spring and deposit eggs in the soil near the roots of maggot-infested plants. When larvae hatch within five to 10 days, they search for host puparia in the surrounding soil. They gnaw holes in the puparia, enter and feed on the maggot pupae for about three weeks. After their long meal, these rove beetles pupate within the host puparia, and adults emerge after a month or more. *Aleochara* adults then destroy eggs or young maggots near the soil surface and maggots in the plant roots. They may consume up to five root maggot larvae and 23 eggs per day.

Giving them a boost: Make sure an area of your garden has grassy cover during the winter — rove beetles hibernate in these sites in great numbers. Be selective with chemicals — they are very sensitive to insecticide exposure. In some cases, as with *Aleochara bilineata*, the beetles do not often emerge early enough in the spring to prevent early-season root damage. Augmentative releases may provide early-season maggot control. As of now, *A. bilineata* is not commercially available in North America, but it has been mass reared in Europe and Canada, and in time they may be commercially available.

— MBCN, v.4, n.4, Susan Mahr, University of Wisconsin - Madison.

Ground Beetles

Order: Coleoptera, beetles
Family: Carabidae

Ground beetles are very abundant in most agricultural and garden settings. "Why haven't I seen them?" you might ask. Well, most are nocturnal predators and spend the day hiding under rocks, at the bases of plants and in soil crevices. Some species also climb into trees, shrubs and crop plants looking for prey. Adult ground beetles run quickly when disturbed but don't often fly. The adults and larvae are fierce predators that chew up their prey with their large, sharp mouthparts. **Caterpillars, grubs and adults of other beetles, snails, aphids, fly maggots and pupae, earthworms** and other **small soil dwellers** are common prey

Ground beetle

Ground beetle

for many ground beetles. They can consume their own body weight or more in food daily.

What you will see: Pick up a rock, sift through leaf litter or garden mulch, and you might surprise some ground beetles, which will rapidly try to scurry away. Hundreds of species of ground beetles occur in the Midwest. Adults have hard wing coverings and vary in size from less than 1/4 inch to more than 1 1/2 inches long. Most adults are dark brown or black, shiny and somewhat flattened, with slender legs for running. A few are an iridescent blue or green. The larvae are brownish, black with a large head and mandibles (jaws) and tapered. Ground beetle larvae spend most of their time belowground — you will be unlikely to encounter them. Their eggs are deposited either on objects aboveground or in cavities made in the soil. Ground beetles may overwinter as larvae or adults in soil. Typically, it takes one complete year to develop from egg to adult, and they may live for two to three years.

Caterpillar hunters: Ground beetles in the genus *Calosoma* are called caterpillar hunters. They are large, usually 1 1/2 inches. *Calosoma sycophanta*, a large, bright metallic green beetle, was imported from Europe to New England for the biological control of the gypsy moth in 1905. The larva feeds day and night, consuming 50 caterpillars during its two-week developmental period. The adult will eat several hundred caterpillars during a life span of two to four years.

Giving them a boost: Ground beetles are highly susceptible to soil insecticides and fumigants. Because they need an overwintering home, perennial plants (e.g., grassy areas) will give them an insulated place to burrow during the cold. During the hot summer, ground beetles must avoid water loss. They prefer to be in clover ground covers and mulches that provide a humid microclimate. Ground beetles are not commercially available but can easily be encouraged with garden mulches.

— MBCN, v.3, n.4, Susan Mahr, University of Wisconsin - Madison.

Fun for Kids: Ground Beetle Homes and Dinner Time

Put some soil in a fairly large container, about shoebox size. Put some rocks in one corner and leaves in another; leave the middle part with only bare soil. Now collect some live ground beetles with pitfall traps (see section on sampling) and add them to this box. Leave them alone for a while and then check where they are. Where do they like to be? Check them at night — are they acting differently?

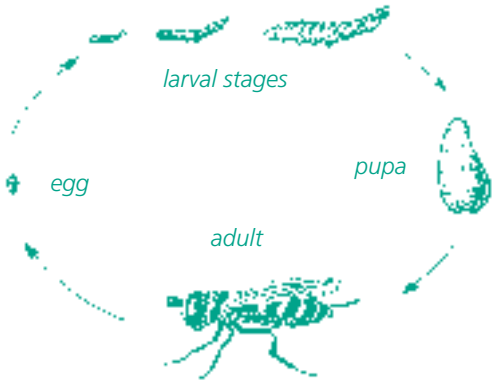
Feed the ground beetles caterpillars or pupae. If these are not available, throw in small bits of cat food. Watch the ground beetles eat. Notice the jaws, called mandibles, cutting away the food. Are they eating more than their body size?

Hover Flies

Order: Diptera, flies
Family: Syrphidae

Hover flies are common and important natural enemies of aphids and other small, slow-moving insects. As their name implies, the adults are often seen hovering around flowers. Adults are not predaceous but feed on nectar and pollen and are important plant pollinators. Hover fly larvae feed mainly on **aphids** and also eat **small caterpillars, thrips** and other **small insects**.

What you will see: The adults may resemble bees or wasps with black and yellow stripes on the body, but they have only one pair of wings (wasps have two pairs). Other hover flies are hairy with a long, thin abdomen. All have short antennae. There are many species which range in size from less than 1/4 inch to more than 3/4 inch long.



Hover fly life cycle

Females lay hundreds of tiny, white eggs singly on leaves or shoots near or among aphid colonies through midsummer. Larvae hatch in three days and are small, legless maggots that range in color from creamy-white to green or brown. They may be mistaken for pests — they look somewhat sluglike and are tapered towards the head. The larvae complete their development in two to three weeks while consuming up to 400 aphids each. Depending on species, they may pupate on the foliage or in the soil. The smooth, tan puparia are often teardrop-shaped. During the growing season, adults emerge in one to two weeks. Generation time depends on temperature, species and availability of food; there may be five to seven generations per year. Hover flies overwinter as pupae.

Giving them a boost: Hover fly adults are particularly attracted to Queen Anne's lace, wild mustard, sweet alyssum, coriander, dill and other small-flowered herbs. Having these plants will encourage females to lay

eggs in your garden area. At this time, hover flies are not commercially available.

— MBCN, v.2, n.11, Susan Mahr, University of Wisconsin - Madison.

Robber Flies

Order: Diptera, flies
Family: Asilidae

Robber flies get their name from their ferocious manner of pouncing on their prey in the air. Adults are aggressive, generalist hunters, attacking butterflies, wasps, bees, dragonflies, grasshoppers, beetles and other flies. Some of the larger species can inflict a painful bite if handled carelessly. Certain species frequently capture hornets or paper wasps, which are aggressive fighters. At least six species in North America feed principally on grasshoppers. Most species, however, tend to feed more or less indiscriminately, destroying many destructive insects but also beneficial ones such as honeybees and other pollinators. Robber fly larvae pierce the body of their prey and suck the body fluids from the wound. They generally feed on **eggs** or any **soft-bodied insects** that they encounter, though some seem to specialize on **grasshopper eggs** or **white grubs**.

Robber fly

What you will see: Robber fly adults are medium to large, hairy flies with an elongated, humped body and a slender, tapering abdomen. Most are gray, brown or black, but a few species resemble bumble-bees. Adults live about three months. These fast and powerful fliers may produce a loud buzz. They are able to capture in flight insects much larger than they are. Adults never seem abundant because males are quite territorial. Any stray male that wanders into another's territory is either chased or captured.

Females deposit small, cream eggs on grass or other plants, soil, bark or wood. Eggs may be laid singly or in large masses covered with a soft, chalky-white material. The small, cream-colored, cylindrical larvae live in the soil or in decaying wood, migrating to locate prey. They overwinter as larvae and pupate in the soil. The pupae come to the surface of the soil just before the adult emerges, leaving the pupal skin sticking out of the soil. Common species require one to three years to complete their development.

Giving them a boost: Adults require sugar as well as protein before egg laying, so they may be encouraged by planting nectar-producing flowers. Robber flies have not been used in biological control programs. Their role in natural control of pest species has not been well studied, even though they are common in some areas.

— MBCN, v.6, n.6, Susan Mahr, University of Wisconsin - Madison.

Spiders

Class: Arachnida
Order: Araneae

Spiders may not be well liked, but they are highly beneficial. About 15 families of spiders are frequently found in crops, where they are natural control agents. Virtually any active stage of an insect's life cycle can fall prey to a spider, though each spider species is more likely to catch a certain prey type, because of its method of prey capture. For example, orb weavers are more likely to capture adult flying insects than crawling insects.

How they find dinner: Many spiders construct a web of some sort to capture prey. Common families of web spinners are the orb weavers (family Araneidae); the sheet web spiders (family Linyphiidae); the comb-footed spiders (family Theredíidae), which construct a very haphazard type of web; and the funnel web spiders (family Agelenidae). Other spiders are known as hunters. These do not construct a web to capture their prey, though they may construct a silken refuge. These spiders are very active and often run down their prey to capture it. Their good vision helps them detect movement of their prey. Examples of hunting spiders include the wolf spiders (family Lycosidae), the jumping spiders (family Salticidae), the lynx spiders (family Oxyopidae) and the two-clawed hunting spiders (family Clubionidae). One large family, the crab spiders (Thomisidae), exemplify the ambush method of prey capture. These spiders are common on flowers and vegetation and sit motionless until their prey comes within easy grasp.

Giving a them a boost: Chances are that many spiders are already present in your garden. You can help maintain their populations by not using broad-spectrum insecticides. Insecticides not only directly kill spiders but also kill many non-pest insects that the spiders use for food during periods of low pest numbers. Spiders also need an overwintering site; grassy perennials give them a winter home.

No spiders have been successfully used in natural enemy importation programs (classical biological control), and none are commercially available for augmentative releases. However, there are a few examples of human manipulation of spider populations for improved natural control. In China, bundles of straw are placed in fields with high spider populations. The straw provides refuges, and the bundles can be moved to relocate the spiders to other areas.

— MBCN, v.3, n.10, Dan Mahr, University of Wisconsin - Madison.

Crab Spider

Parasitoids develop as larvae within the body of the host. Generally, the adults are free living and their main job is to mate, find hosts and then lay eggs in or near hosts. Adult parasitoids are often short-lived; they may feed on plant sources. Some also feed on the hosts, which means they kill more pests in a lifetime.

The most important parasitoids are mainly flies and wasps. These wasps are not like the yellow jackets that may come to mind. They are often very small, some no bigger than the period at the end of this sentence. The females may have long, slender tubes at their hind end. These are ovipositors, special tubes for laying eggs.

You will notice that the physical descriptions of the parasitoids are not very detailed. Most entomologists have a hard time telling them apart! Nevertheless, anyone can spot their activities. Parasitized aphids often turn black or brown and develop a hard casing. Parasitized eggs may also become much darker. You may find a caterpillar with cocoons on its back. They are the unwitting factories for making more helpful parasitoids.

Tachinid Flies

Order: Diptera, flies
Family: Tachinidae

The tachinid flies are by far the largest and most important group of fly parasitoids, with more than 1,300 species in North America. Many species of tachinids were introduced into North America from their native lands to suppress populations of alien pests. Most tachinids attack **caterpillars** and **adult and larval beetles**. Other species kill **sawfly larvae**, various types of **true bugs, grasshoppers** or other types of insects.

What you will see: Tachinid flies differ in color, size and shape, but many somewhat resemble house flies. They usually are either gray, black or striped, and they often have many distinct abdominal bristles. Most if not all tachinid fly larvae are internal parasites feeding within their hosts. Most species are solitary, but some are gregarious, with anywhere from two to a dozen or more capable of developing within a single host. Egg and larval development is rapid for most tachinids, and pupation often occurs within four to 14 days after egg laying. Many species are capable of several generations per year, but others are restricted to only one generation, especially if their hosts have only a single generation.

Voria ruralis —This tachinid fly attacks the **cabbage looper caterpillar**. Females lay eggs on a caterpillar and one or more maggots develop within the host. Death does not occur until the caterpillar is fully grown, so the parasitoid reduces the next generation's population and future pest damage.

Tachinid Fly

Myiopharus doryphorae — This bristly, gray-black, 5/16-inch-long parasitoid inserts live larvae into second, third or fourth instar **Colorado potato beetle larvae**. The larval parasitoids complete their development inside larval potato beetles that enter the soil to pupate. Though parasitism can be high — up to 75 percent of the beetle population — it is usually late in the season after the potato crop has already been damaged. In Colorado, however, this fly is quite numerous early in the season and causes high rates of parasitism, and the Colorado potato beetle rarely reaches damaging levels. Researchers are not sure why high rates of early-season parasitism occur there and not elsewhere. Nevertheless, *M. doryphorae* does contribute to beetle mortality and may be useful as one of a group of natural enemies that, together, can keep Colorado potato beetle populations below damaging levels.

Feather legged fly *(Trichopoda pennipes)* — This tachinid parasitoid attacks members of the stink bug and leaf footed bug families, including the **squash bug** and **green stink bug**. This distinctive and conspicuous fly is about the same size as a house fly but is bright orange with a velvety black head and thorax (middle body part). It has dark legs with a fringe of short, black hairs on the hind legs; yellow feet; large, brown eyes; and brown and black wings. The tip of the female fly's abdomen is black.

Each female fly lays on average 100 eggs. Most of the small, white or gray, oval eggs are placed on the underside of the thorax or abdomen of the bug. Many eggs may be laid on the same host, but only one larva will survive in each bug. The young larva that hatches from the egg bores directly into the host body and then feeds on the body fluids of the host for about two weeks. It

T. pennipes maggot in host

dramatically increases to a size almost equal to that of the body cavity of its host! When it has completed its development, the third instar maggot bursts out from the bug between the last abdominal segments. Strangely the bug does not die from the parasitoid feeding but from the mechanical injury caused by the parasitoid's emergence. The maggot pupates about an inch down in the soil, and an adult fly emerges two weeks later. There can be three generations per year, depending on location. The fly overwinters as a larva within the body of the overwintering host bug.

Compsilura concinnata — This tachinid fly is a parasitoid of **gypsy moth** and more than 100 other moth and butterfly species. It is one of more than 45 species of natural enemies introduced for control of gypsy moth over a period of more than 50 years, beginning in 1906. The blackish adult fly is 5/16 inch long with four deep black stripes on the thorax and lots of bristles.

The females are fun to watch. A female approaches a host, moving closely around it for a few seconds. She then darts at its

middle, pinches the host's body between spines on the underside of her abdomen, and with her sharp larvipositor, she injects a young maggot into the wound in about 1/2 second. She often examines and attacks the same host a number of times. Each female produces about 100 maggots (fly larvae). The maggot develops within the intestine or body cavity of the caterpillar, and after consuming the contents, it bursts out of the host. Leaving the remnants of the caterpillar behind, the maggot pupates in the soil, host web or crevices in the bark of the tree. The transformed adult emerges in about 10 days. There are up to four generations per year.

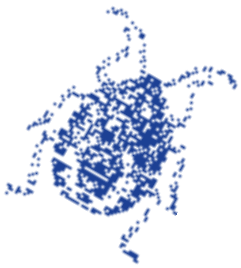
C. concinnata overwinters as a maggot in living caterpillars of various species. It does not overwinter in gypsy moth because this host overwinters in the egg stage. The abundance of *C. concinnata* in the spring — and consequently the degree of parasitism of gypsy moth — is influenced by the abundance of its hibernating hosts. Parasitization of gypsy moth by this parasitoid is generally low (less than 5 percent) during gypsy moth outbreaks but tends to be higher when pest populations decline. *C. concinnata* may have impacts on native species, however, and this points out why people carrying out classical biological control programs should be cautious about introducing generalist natural enemies.

Istocheta (=Hyperecteina) aldrichi — This tachinid fly parasitizes **adult Japanese beetles**. It was introduced in the United States from Japan in 1922. The adult flies appear from mid-June to mid-July, feeding on aphid honeydew and nectar. Females attach an egg on the thorax of newly emerged beetles, busily laying up to 100 eggs over a two-week period. The egg hatches in 24 hours, and the maggot burrows into the body cavity of the beetle to feed. This feeding kills the beetles in about five to six days; unparasitized Japanese beetle adults live four to six weeks. Also, parasitized beetles bury themselves in the ground.

I. aldrichi kills so fast that a large portion of the female Japanese beetle population is killed before they are able to deposit their first eggs. However, the fly is not well synchronized with its host in the United States — it emerges several weeks before the beetles do. As a result, *I. aldrichi* usually affects the first emerging beetles and disappears long before the peak beetle emergence.

Giving them a boost: Adult tachinid flies feed on nectar, especially from plants such as Queen Anne's lace and meadowsweet. Adults also depend on aphid honeydew, so having non-crop plants with some aphids is welcomed. Though many tachinid flies have been introduced for classical biological control programs, they are not augmentatively released.

— MBCN, v.2, n8; v.4, n.9; v.6, n.5; v.6, n.9; v.5, n.8, Susan and Dan Mahr, University of Wisconsin - Madison; Deborah McCullough, Denneth Raffa and Chris Williamson, 1999, "Natural enemies of Gypsy moth: the good guys!" Michigan State University Extension bulletin E-2700.



What Tachinid Mothers Do

Tachinid mothers have a variety of ways to secure their children with food.

- In some species, mothers lay eggs near the host insect. The maggots hatch from the eggs and are happy when a caterpillar gobbles them up along with the foliage. Then the maggots start their own feast and develop inside the host.
- In other species, mothers glue their eggs to the body of the host. These white eggs up to 1/20 inch in size can sometimes be seen on the head or body of a caterpillar. After the eggs hatch, the maggots penetrate into the host's body.
- Some adult female tachinids possess a piercing ovipositor and insert the eggs inside the host body. Once maggots hatch, they have all that they need — their mom placed them in the right spot.
- In many tachinid species, eggs mature within the mother fly. She gives birth to living young, inserting them into hosts with a special larvipositor.

Fun for Kids: Parasitoid Factories Inside Caterpillars

Scout tomatoes in the garden for hornworm caterpillars with cocoons on their backs. Give them a nice home in a large container with plenty of their favorite food. Count how many cocoons are present. How long does the caterpillar feed? Keep an eye on what comes out of the cocoons. Do they come out at the same time?

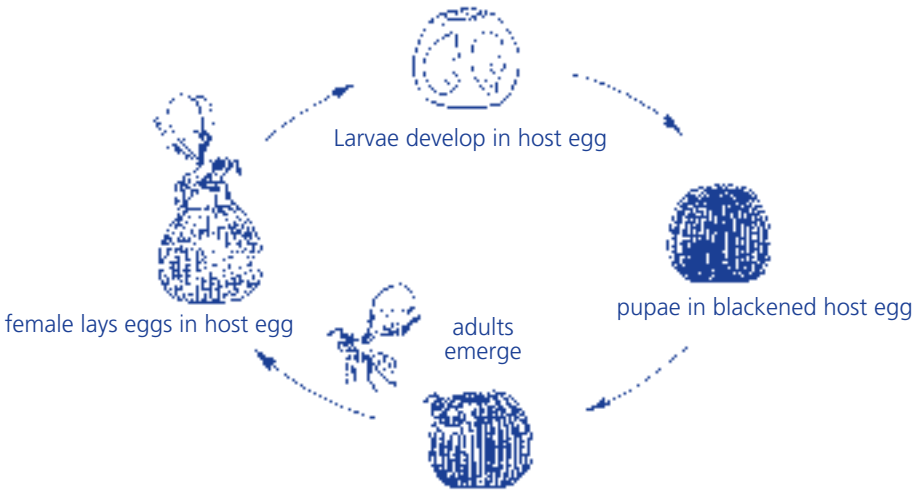
Trichogramma Wasps

Order: Hympenoptera, wasps
Family: Trichogrammatidae

Trichogramma wasps attack the **eggs of more than 200 species of moths and butterflies**. These almost microscopic parasitoids are very important in preventing crop damage because they kill their hosts before the insects can damage the plant. These wasps are harmless to people, animals and plants. Though *Trichogramma* wasps occur naturally throughout the United States, they usually do not occur in high enough numbers to effectively suppress pest populations. Also, *Trichogramma* **do not** attack gypsy moth eggs.

What you will see: You probably won't see them at all — adults are 1/25 inch long, or about the size of the period at the end of

Trichogramma wasp on a host egg



Trichogramma life cycle

this sentence. The female *Trichogramma* lays an egg within a new host egg; as the wasp larva develops, the host egg turns black. Each female parasitizes about 100 eggs and may also destroy additional eggs by feeding on them. The short life cycle of eight to 10 days allows wasp populations to increase rapidly.

Giving them a boost: *Trichogramma* are readily available for augmentative releases in large quantities from commercial suppliers. Determining the best species or strain to release may be difficult. Most suppliers provide detailed instructions for strain selection, release and rates to use, but their recommendations may not always be accurate. Frequent releases made over several weeks result in better parasitism and control than a single large release. Releases should begin at the time of the first moth flight before pest populations have built up. Regular scouting to determine the appearance of caterpillar eggs is a good way to determine when hosts for *Trichogramma* are present.

The wasps are shipped as immatures inside moth eggs glued to small cards that can be attached by hand to infested plants. Keep the cards in a warm, humid place out of direct sunlight until the emerging adults can be seen as small dots moving around in the closed container. When most of the adults have emerged, place the containers in a shaded spot upwind of the areas where moths are suspected or egg laying is occurring. The adult wasps will fly onto plants in search of new host eggs to attack. Do not put the cards out before the wasps have emerged because ants and other predators may eat them. The emerging wasps will have the best chance of finding and parasitizing eggs when the weather is moderate. The best time to release is early morning or evening, when direct sunlight will not hit the cards. Avoid making releases under extremely hot, cold, rainy or windy conditions.

— MBCN, v.1, n.4, Susan Mahr, University of Wisconsin - Madison.

A Mother's Travels

Finding hosts is a challenge to all female parasitoids. Some *Trichogramma* mothers attach themselves to adult females of their host species. They go where the host goes, and when the host finally lays some eggs, the mother parasitoid is in the right spot. She now has homes for her many children. Other female parasitoids locate hosts by smell. They may know the scent of their host. In many cases, plants release odors when they are being attacked by herbivores. The mother parasitoid picks up on these plant odors and follows them in hope of finding that the herbivore is her host species. Sometimes hosts are hidden under the leaf surface or bark layer. The female can detect these hosts by feeling for vibrations created when the host is eating plant material.

Aphidius Wasps

Order: Hymenoptera, wasps
Family: Aphidiidae

Aphidius wasps are internal parasitoids that provide natural control of **aphids** in gardens, commercial fields and urban landscapes. In addition to killing aphids directly, the searching behavior of these wasps causes many aphids to fall off the plants and die.

What you will see: *Aphidius* wasp adults are small, less than 1/2 inch long. The slender abdomen is usually longer than the head and thorax combined. Females lay eggs singly in aphid nymphs, and hatched wasp larvae consume the aphids from inside. As

Aphidius wasp

larvae mature and aphids are killed, the aphids turn into golden or tan mummies, which are readily seen on plant foliage. After the larvae pupate, each adult wasp emerges through an exit hole cut in the mummy.

Giving them a boost: Have nectar sources and plants that provide shade on hot summer days available. Some *Aphidius* wasps — including *Aphidius matricariae, A. colemani* and *A. ervi* — are available commercially and generally used in greenhouses to control green peach aphid, melon aphid and cotton aphid. Releasing these wasps may not be compatible with use of microbial natural enemies such as fungal pathogens (e.g., *Beauveria bassiana*), which kill wasp larvae inside the aphid.

— MBCN, v.5, n.2, Susan Mahr, University of Wisconsin - Madison.

Fun for Kids: Mummies in the Garden

Find some aphid colonies. They are just about everywhere: on rosebushes, trees or broccoli. Some aphids may be tan and have a hard casing — they are parasitized. With a magnifying lens, take a closer look. Is there an exit hole? That means the parasitoid already left. Put some mummy aphids without holes in a jar and watch what comes out of them.

Cotesia glomerata

Order: Hymenoptera, wasps
Family: Braconidae

Cotesia (=Apanteles) glomerata is a braconid wasp that develops within larvae of **imported cabbageworm**. Parasitized cabbageworms continue to feed, consuming approximately 1 1/2 times as much as unparasitized caterpillars before they are killed by the emerging parasite larvae. *C. glomerata* populations often have very little effect on the first generation of imported cabbageworm because their initial numbers are low in the spring. Parasitism by *Cotesia* increases over the season and does reduce the overwintering population and, therefore, the spring population next year.

What you will see: The adults are black and 1/8 inch long, and they feed on nectar of flowers and juice of cabbage leaves. Females lay eggs in mostly first instar cabbageworms. Each cabbageworm becomes the home of 16 to 52 wasp larvae. The caterpillar continues its own development until the wasp larvae emerge from its body to spin their yellow-orange cocoons in a group.

A new competitor: A related species, *Cotesia rubecula*, is a solitary parasitoid — only one larva develops in the caterpillar instead of many. It kills the host sooner and so is a more efficient parasitoid than *C. glomerata*. A strain of the species imported from Yugoslavia has been established in Michigan. It has displaced *C. glomerata* in these areas and has spread at least 20 miles from the original site. If this species does become established, additional releases may be necessary to provide economic control.

Giving them a boost: These parasitoids need plant fluids and sugars, so a steady supply of plants with floral nectaries can help them out. Currently, neither wasp is commercially available.

— MBCN, v.3, n.3, Susan Mahr, University of Wisconsin - Madison.

The Battle

What is a host to do when parasitoids are so keen on laying eggs or larvae in it? Most defend themselves with an active immune response similar to the way our bodies defend against microbes. Any invading egg or larva is greeted by large numbers of specialized defensive cells, which accumulate and eventually form a shield that encloses the unwelcome guest, a process called encapsulation. Encapsulation does not normally occur when a parasitoid attacks its usual host because the parasitoid has developed ways to fight back. In some cases, a parasitoid lays its eggs only in areas of the host (brain, nerve cells, gut) where they are not in contact with host blood and therefore free from an immune attack. Other parasitoids are a wolf in sheep's clothing — they coat themselves with hostlike proteins and trick the host into believing that they are a part of its body. Some may feed heavily on the host and render the host incapable of launching a defense. Also, some mother parasitoids inject specialized helper viruses while laying eggs — these subdue the host's defensive system but are harmless to the parasitoid. With these sneaky strategies to overcome host defenses, parasitoids are quite successful and thus very helpful to us as biological control agents.

Cotesia melanoscelus

Order: Hymenoptera, wasps
Family: Braconidae

This braconid wasp was first brought from Italy in 1912. Now this species is widespread and abundant where gypsy moth is established, and it attacks early instar **gyspy moth larvae** in North America.

What you will see: The shiny black adults are 1/8 inch long. There are two generations per year, each taking about two to three weeks. *C. melanoscelus* overwinters as full-grown larvae in their sulfur-yellow cocoons. Adults emerge when gypsy moth caterpillars start hatching from their overwintering eggs. Each female lays 500 to 1,000 eggs, which she places singly in first and second instar gypsy moth larvae. Oviposition itself may be enough to kill small caterpillars. When *C. melanoscelus* larvae complete their development, they tear a hole in the side of the caterpillar and emerge. They spin silken cocoons on the foliage, tree bark or any other objects nearby.

Giving them a boost: The gypsy moths are not the only ones being attacked — the overwintering *C. melanoscelus* parasitoids are attacked by many hyperparasitoids (a parasitoid of a parasitoid). Up to 80 to 90 percent of overwintering cocoons are affected. Winter weather and the ability of third instar gypsy moth larvae to defend themselves against parasitism also limit *C. melanoscelus* populations. To protect parasitoid populations, broad-spectrum chemical insecticides should be avoided in early and midsummer. *Bacillus thuringiensis* microbial sprays may work well with natural enemy activity. Gypsy moth larvae sprayed

C. melanoscelus

with *Bt* take longer to develop. This allows *C. melanoscelus* to attack more caterpillars, mainly because they are in the small, susceptible instars longer. However, Gypcheck®, a formulation of gypsy moth nuclear polyhedrosis virus (NPV), and an insect growth regulator, diflubenzuron (Dimilin®), may interfere with parasitoid activity. Wasps avoid NPV-infected gypsy moth larvae, and wasp larvae developing inside caterpillars infected with NPV or the growth regulator probably cannot complete their development before the host dies. Thus, *C. melanoscelus* populations are reduced in areas treated with NPV or insect growth regulators.

— MBCN, v.5, n.3, Susan Mahr, University of Wisconsin - Madison; Deborah McCullough, Denneth Raffa and Chris Williamson, 1999, "Natural enemies of Gypsy moth: the good guys!" Michigan State University Extension bulletin E-2700.

Pteromalus puparum

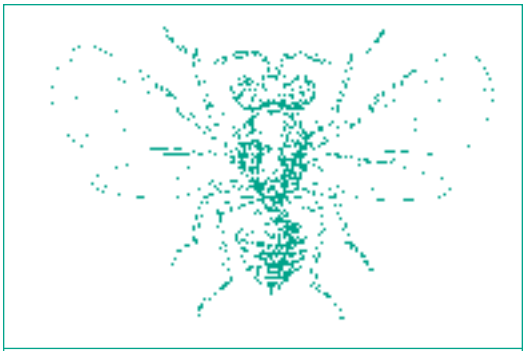
Order: Hymenoptera, wasps
Family: Pteromalidae

Pteromalus puparum is a tiny wasp that makes its home inside pupae of **imported cabbageworm**. The wasps will parasitize other caterpillar species when imported cabbageworms are scarce. Because the wasps attack only the pupae, the benefit of this parasitoid is in reducing the number of adults and thereby reducing the size of the subsequent generation.

What you will see: Adult wasps are 1/8 inch long. Females are shiny black; males are metallic greenish bronze and smaller. The wasps fly short distances of less than an inch, which gives them the appearance of hopping. Females lay eggs in either the prepupae or newly formed pupae of the host. Each female may deposit up to 700 eggs during her life span. More than 200 offspring can burst out of one cabbageworm pupa. A parasitized pupa turns from green or gray to dull brown as the wasp larvae develop over three weeks. A healthy unparasitized pupa changes from green or gray to yellowish white as the butterfly inside reaches maturity. The wasps overwinter as mature larvae within the host pupae.

Giving them a boost: These wasps feed on nectar, so a supply of flowers should be constantly available. This wasp is not available commercially.

— MBCN, v.3, n.12, Susan Mahr, University of Wisconsin - Madison.



P. puparum

Diadegma insulare

Order: Hymenoptera, wasps
Family: Ichneumonidae

Diadegma insulare is the most important parasitoid of the diamondback moth in North America and Canada. It attacks small to medium-sized **diamondback moth larvae**. *D. insulare* pupates inside the cocoon made by the mature diamondback moth larva. Parasitism is often greater than 75 percent in the field.

What you will see: *D. insulare* can be easily monitored by examining diamondback moth cocoons. Normal diamondback moth cocoons will be white inside (green when the

D. insulare

larvae first form the cocoon); developing *D. insulare* wasps will be visible as dark bodies inside the cocoon.

Giving them a boost: *D. insulare* is very sensitive to insecticides, and females require nectar sources. A nectar source can increase *D. insulare* female longevity from two to five days to more than 20 days. With poor nectar sources, females parasitize few or no diamondback moth larvae. With an optimal nectar source however, females can parasitize more than 150 moth larvae. The best nectar sources are flowers with wide or shallow corollas, where *D. insulare* can easily reach the nectar. Queen Anne's lace and members of the cabbage family are good plants to include in the garden.

— MBCN, v.4, n.1, Edward Grafius, Michigan State University, and A.B. Idris, University of Kebungsaan, Malaysia.

Tiphia vernalis and *T. popilliavora*

Order: Hymenoptera, wasps
Family: Tiphiidae

These two tiphiid wasps are among several natural enemies imported from Asia for the biological control of **Japanese beetle**. They did not disperse rapidly, so people had to move these wasps to new areas.

What you will see: The adults are 1/4-inch-long, shiny black wasps. The adults of *T. vernalis* emerge during May and early June and feed on aphid honeydew. The female wasp searches out the overwintering third instar host larva in the soil, stings it to paralyze it temporarily, and then deposits a single egg between the thorax and the

Tiphia wasp

abdomen. Each female may deposit up to 25 eggs in a month. In a week the larva hatches and punctures the Japanese beetle, where it feeds externally for 18 to 30 days. The entire body except the head and legs is consumed. These tiphiid wasps spend their winter as pupae in the soil cell of the host and emerge the next spring as adults. A single generation occurs per year. The biology of *T. popilliavora* is similar to that of *T. vernalis* except that the adults emerge in August and early September.

Giving them a boost: You can help out both species by providing food sources. *T. vernalis* feed on nectar from the blossoms of umbelliferous plants, and *T. popilliavora* feed on honeydew from aphids. The females feed in the morning and then fly relatively short distances to deposit their eggs. This is why parasitism by both species tends to be greatest in grassy areas near flowering borders that contain aphids or wild carrot. You may not welcome an aphid infestation in your yard and hope the ladybugs are taking care of them, but having some aphids present in ground cover will benefit the parasitoids.

— MBCN, v.5, n.8, Susan Mahr, University of Wisconsin - Madison.

Parasitoids Have Enemies, Too

Parasitoids have to battle not only with the host but with one another, as well. Sometimes parasitoids must fight with their own species. If hosts are few, several mothers may lay their eggs into the same host. After that, the kids have to compete for survival. Parasitoids have their own parasitoids, called hyperparasitoids. These hyperparasitoids may sense the odor of the parasitoid, locate it and lay eggs in it. The role of hyperparasitoids is very important in biocontrol control programs. When parasitoids are imported, they are checked for hyperparasitoids, which have reduced their effectiveness in the past.

Elm Leaf Beetle Parasitoids

Order: Hymenoptera, wasps
Family: Eulophidae

The destructive elm leaf beetle came from Europe in the early 1800s and spread from the eastern United States across North America. The elm leaf beetle is a major defoliator of elms in urban areas throughout the United States. It has many natural enemies, including two eulophid wasps in the genus *Tetrastichus*.

Tetrastichus gallerucae — This is an exotic parasitoid that attacks **elm leaf beetle eggs**. It has been introduced into the United States several times in attempts to control the elm leaf beetle. *T. gallerucae* is established in the Midwest, central Missouri and at a few locations in California.

What you will see: The adult wasp is 1/8 inch long with a dark metallic blue thorax and a black abdomen with a faint metallic luster. It is a solitary internal parasite, completing its life cycle in about 17 days. Several generations occur each season, usually twice the number of annual generations of its host. It probably overwinters as adults in sheltered places. The females also destroy many eggs by host feeding; this is considered an important factor in reducing the pest population in Europe. Inoculative releases in areas where it cannot overwinter well might be useful for beetle suppression.

Tetrastichus brevistigma — The other elm leaf parasitoid is somewhat of a mystery. It is apparently native to the northeastern United States and attacks elm leaf beetle pupae. Its only known host is of European origin, yet this parasitoid has never been reported in Europe. In the northeastern United States, *T. brevistigma* commonly parasitizes 50 to 80 percent of beetle pupae in midseason.

T. brevistigma

What you will see: *T. brevistigma* is a 1/8-inch-long, gregarious internal parasitoid (more than one parasitoid develops within a host). Each female can lay up to 100 eggs, and an average of 12 individuals develop in each host. Larval development can be completed in nine to 15 days, but many individuals enter larval diapause and emerge the following spring. They overwinter as full-grown larvae in the pupal skin of their host. These dead elm leaf beetle pupae are found in grass and debris surrounding the bases of the elm trees or on the tree trunks, concealed in crevices or under the bark. The parasitoids emerge from the host pupae in June and July to attack the first generation of the beetle.

Giving them a boost: Augmentative releases might prove effective. Though rearing techniques have been developed, neither *T. brevistigma* nor *T. gallerucae* is currently commercially available.

— MBCN, v.5, n.12, Susan Mahr, University of Wisconsin - Madison.

Ooencyrtus kuvanae

Order: Hymenoptera, wasps
Family: Encyrtidae

Ooencyrtus kuvanae was introduced to the eastern United States in 1909 from Japan as an egg parasitoid for control of the **gypsy moth**, a serious defoliator of hardwood trees. In the 1970s and 1980s, many additional introductions of *O. kuvanae* were made in the northeastern United States, and after spreading naturally, it is currently found nearly everywhere that the gypsy moth is found.

O. kuvanae

O. kuvanae females are good fliers that actively search out gypsy moth egg masses on tree trunks and tree branches. Females may locate the egg masses through scents released from the egg masses themselves, or they may be able to detect pheromones of gypsy moth females. Studies in New Jersey, Virginia, Pennsylvania and Michigan have shown that 20 to 30 percent of the gypsy moth egg population is destroyed annually by these egg parasitoids.

The short ovipositor of *O. kuvanae* restricts parasitism to the outermost layers of eggs in a gypsy moth egg mass. Parasitism is inversely related to egg mass size: parasitism rates are higher on small, thin egg masses that are laid on flat surfaces such as smooth-barked trees. Though it is limited in the number of eggs it can parasitize, *O. kuvanae* complements the activities of other natural enemies that affect the larval and pupal stages of gypsy moth, such as the fungus *Entomophaga maimaiga* and the ground beetle *Calosoma sycophanta*.

What you will see: Adults are 1/12 inch long. Females overwinter in leaf litter and become active around mid-April. Each female lays about 200 eggs into gypsy moth

eggs for about four to six weeks. *O. kuvanae* adults emerge from parasitized eggs between mid-July and early August. This is just about the same time that gypsy moth adult females are emerging, mating and laying their egg masses. The new generation of *O. kuvanae* parasitizes these new egg masses. The third generation emerges between September and November. In warmer areas, a fourth generation of *O. kuvanae* is possible in the fall. Monitoring for this egg parasite is fairly easy: parasitized gypsy moth eggs have a tiny round emergence hole.

Giving them a boost: *O. kuvanae* has been shown to be susceptible to broad-spectrum insecticides. The synthetic gypsy moth pheromone Disparlure, which is used for mating disruption, has no effect on parasitism; nor does *Bacillus thuringiensis* var. *kurstaki*, used to kill larvae. If you plan to scrape off gypsy moth egg masses and destroy them, wait until winter. This allows the third generation of parasitoids to complete development and find an overwintering site below the tree.

— MBCN, v.4, n.6, Amy Christenson, Michigan State University; Deborah McCullough, Denneth Raffa and Chris Williamson, 1999, "Natural enemies of Gypsy moth: the good guys!" Michigan State University Extension bulletin E-2700.

Pathogens

You may have seen a dark and mushy caterpillar or a fly stuck to a window with white threads. These insects have succumbed to pathogens. Many microorganisms — bacteria, fungi, nematodes, protozoans and viruses — can naturally bring down pest populations in the field if certain environmental conditions are right. Pathogens are hard to manipulate because we cannot control the climate. Thus, their use in biological control is mainly augmentative, and some are sold commercially as microbial insecticides.

All pathogens except nematodes are regulated much as chemical insecticides are. This can be a plus for consumers because more information is available about them than other natural enemies. These microbes are more sensitive than chemicals — they have a shorter shelf life and special storage requirements and application procedures.

Microbial insecticides are generally harmless to animals and humans and can specifically target certain pests. They do not persist long outdoors, and this reduces the risk of insects becoming resistant to them. When used as instructed, these microbes can be valuable biocontrol agents themselves and help to conserve predators and parasitoids from more harmful chemical pesticides.

Nematodes

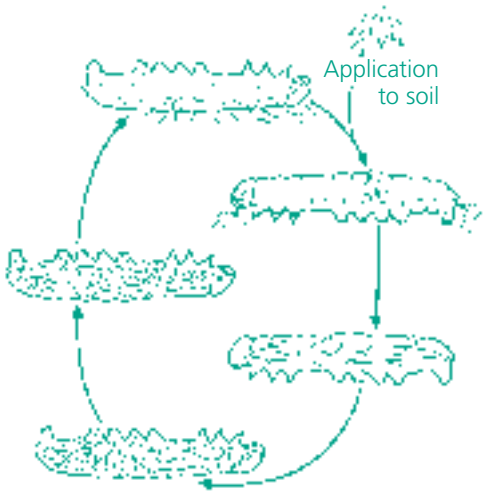
Phylum: Nematoda

Families: Steinernematidae and Heterorhabditidae

Insect-attacking nematodes in the families Steinernematidae and Heterorhabditidae have received a great deal of attention in the past 10 to 15 years because of their potential as biological control agents for a **wide range of insect pests**, especially **those living in the soil**. These nematodes attack many pest insects, can search for and kill their hosts rapidly, and are safe to non-target organisms. Advances in rearing techniques that have made it possible to produce them economically in large numbers have encouraged their commercialization. These nematodes are being used commercially in certain specialized markets (e.g., citrus, turf and ornamentals) and may be used more widely as costs of production decrease.

Many species of these nematodes occur naturally in the soil throughout the world. Fifteen species of steinernematid nematodes and five species of heterorhabditid nematodes have been described. All vary somewhat in their behavior, host range and developmental rate.

Life of a nematode: Insect-attacking nematodes have a life cycle consisting of an egg, four juvenile stages and the adult. Both



Nematode life cycle

steinernematid and heterorhabditid nematodes have a specialized third juvenile stage, the infective juvenile — this is the stage that attacks insects. The infective juvenile can survive in the soil for extended periods until it is able to find a susceptible host.

Nematodes do not have eyes but find hosts by orienting to carbon dioxide and other excretory products of the host. Infective juveniles enter hosts through the mouth, anus or breathing pores (spiracles). These nematodes carry a special species of bacteria in their intestines. When they enter the host, they release the special bacteria, which rapidly multiply. The bacteria release protein-destroying enzymes that kill the host, usually in 24 hours. The nematodes feed on the host remains and complete two to three generations inside the host. When the host is cleaned out, infective juveniles leave and search for new victims.

When a host is infected with steinernematid nematodes, it takes seven to 10 days at room temperature for new infective steinernematid nematodes to burst out. If the host is infected with heterorhabditid nematodes, it takes about 12 to 15 days.

What you will see: Because different species of bacteria are associated with steinernematid and heterorhabditid nematodes, infected hosts look different. Insects infected by steinernematid nematodes are limp and cream to dark brown, while those infected by heterorhabditid nematodes turn brick-red and glow in the dark.

Giving them a boost: When you buy nematodes, you are getting the third stage larva (infective juvenile). This is the stage adapted for host finding and survival in moist soil. Using nematodes effectively depends on providing proper conditions for their survival after application and proper selection of nematode species for the desired target pest. Nematodes depend on available water film for their movement and survival, so they should be watered into the soil. Most nematode species are not very active when soil temperatures are below 60 degrees F. If nematodes are applied to cool soil, they may sun themselves at the soil surface and dry out, be exposed to ultraviolet light and die. To help these sensitive creatures, apply nematodes late in the day and water the area after application so any nematodes on leaf surfaces are washed down to the soil. Life as a nematode is hard; various natural enemies — including springtails, mites and fungi — abound in the soil. Many sources of mortality mean that nematodes often need to be applied regularly.

The many nematode species vary in their behavior and efficacy against various pests. *Steinernema carpocapsae* (sometimes referred to as *Neoaplectana carpocapsae*) is currently the most common nematode sold commercially.

— MBCN, v.2, n.1 and n.2, Bob Wright, University of Nebraska; A. Hom, Future directions for nematodes in biological control, The IPM Practitioner, April 1994; A. Hom, Current status of entomopathogenic nematodes, The IPM Practitioner, March 1994.

Grubs on Grass, Nematodes to the Rescue

Are grubs destroying your lawn and landscape? These white grubs, the larvae of scarab beetles, are eating the grass roots, leaving lawns high and dry in the afternoon sun. One thing to do is to water more. Another option is to spray the lawn with nematodes. *Steinernema glaseri* may take care of Japanese beetle and Oriental beetle grubs. The trick is to get the nematodes through the thatch to the grubs before they dry out. Following the instructed release rates and immediately watering with 1/4 to 1/2 inch of water will bring better control.

— MBCN, v.2, n.11; T. Yeh and S.R. Alm, 1995, Evaluation of *Steinernema glaseri* (Nematoda: Steinernematidae) for biological control of Japanese and Oriental beetles (Coleoptera: Scarabaeidae), J. Economic Entomology, 88:1251-1255.

A Little History: The First Fungus

During the 16th and 17th centuries, the French and Italians put many silkworms to work in the textile industry. Many larval silkworms succumbed to "muscardine" and died. In 1835, the Italian scientist Agostino Bassi de Lodi ("father of insect pathology") found the problem affecting the silkworms was caused by a fungus that multiplied in the body of the insect. This was the first microorganism to be recognized as a contagious agent of animal disease. Yes, indeed, the first animal pathogen to be understood was of insects, not humans! The fungus was later named *Beauveria bassiana* in honor of its discoverer. The very distinctive and noticeable white mummies of infected caterpillars gave rise to the name "muscardine", which is derived from the French word for the bonbons that the mummified specimens resembled. Something to remember when you eat a bonbon.

— *MBCN, v.4, n.10, Susan Mahr, University of Wisconsin - Madison.*

Beauveria bassiana

Fungus

Beauveria bassiana is a common soilborne fungus that occurs worldwide. It attacks a wide range of both immature and adult insects. Besides **silkworm**, the extensive list of hosts includes important pests as **whiteflies, aphids, grasshoppers, termites, Colorado potato beetle, Mexican bean beetle, Japanese beetle, boll weevil, cereal leaf beetle, bark beetle, lygus bug, chinch bug, fire ant, European corn borer, codling moth** and **Douglas fir tussock moth**. Natural enemies such as ladybugs are susceptible, too, and it has even been found infecting the nasal

passages of humans. The many strains of the fungus exhibit considerable variation in virulence, pathogenicity and host range. It occurs in the soil, where it lives on decaying material.

Life of *Beauveria*: Like all insect-pathogenic fungi, *Beauveria* produces spores, the infective stage of the fungal life cycle. The spores, called conidia, are resistant to environmental extremes and infect directly through the outside of the insect's skin. Under favorable temperature and moisture conditions, conidia adhering to the host cuticle (insect covering) will germinate. The fungal hyphae growing from the spore secretes enzymes that attack and dissolve the cuticle, allowing it to penetrate the skin and grow into the insect body. Once inside the insect, it produces a toxin called beauvericin, which weakens the host's immune system. After the insect dies, the fungus unleashes another toxin, an antibiotic (oosporein) that enables the fungus to outcompete intestinal bacteria. Eventually the entire body cavity is filled with fungal mass.

What you will see: When conditions are favorable, the fungus will grow through the softer parts of the insect's body, producing the characteristic "white bloom" appearance. Relative humidity must be 92 percent or more for *B. bassiana* to grow outside the insect. These external hyphae produce conidia that ripen and are released into the environment, completing the cycle.

Giving them a boost: *B. bassiana* is available commercially as a microbial insecticide. Commercial formulations allow the fungus to withstand ultraviolet light and temperature and humidity extremes commonly encountered in the field. It takes three to seven days to kill an insect with *B. bassiana,* so it will take some time to suppress a pest population when using these products. Thorough spray coverage is essential because fungal spores must contact the insect for infection to occur.

— MBCN, v.4, n.10, Susan Mahr, University of Wisconsin - Madison.

Handling Microbial Insecticides

Though *Bt* won't cause our guts to cave in and *Beauveria* won't cause us to bloom white, all microbial insecticides need to be handled cautiously. Bacterial spores, mold spores and virus particles are "foreign proteins" — if they are inhaled or rubbed into the skin, they can cause allergic reactions. The dusts or liquids used to dilute and carry these microorganisms also can act as allergens or irritants. Avoid breathing dusts or mists of microbial insecticides. Wear gloves, long sleeves and long trousers during application, and wash thoroughly afterward. These are common-sense precautions that will help prevent unexpected reactions and minimize any effects from unknown toxicity.

— MBCN, v.2, n.7, Rick Weinzerl and Lee Solter, University of Illinois.

Gypsy moth infected with *Entomophaga*

Entomophaga maimaiga

Fungus

Entomophaga maimaiga is a common disease in **gypsy moth** populations in its native Japan. The fungus was first released in the United States near Boston in 1910 as part of a program to introduce natural enemies of gypsy moth. The fungus did not seem to establish and the project was abandoned. The fungus appeared in several northeastern states in 1989 and caused high mortality in gypsy moth populations. Scientists have found that the fungus is present in at least 11 states. Fortunately, *E. maimaiga* affects gypsy moths and a few other species; it poses little risk to most other insect populations. It will not affect other animals or humans.

Life of *E. maimaiga*: *E. maimaiga* passes the winter as a tough, thick-walled resting spore in the soil or on tree bark. In May or June, resting spores germinate and produce sticky spores at the end of a stalk that grows just above the soil surface. Gypsy moth caterpillars encounter these spores as they search for leaves to feed on. Once in contact, the fungus eats through the skin of the caterpillar and grows inside the body. Infected caterpillars may die within one week.

When young caterpillars are affected early in the summer, the fungus will produce a second type of spore, called conidia. These microscopic spores are spread by the wind and can infect other caterpillars. The cycle of conidia production and infection may occur four to nine times during the summer. When the fungus develops in large caterpillars, it produces the overwintering resting spores.

Weather plays an important role in determining how effective *E. maimaiga* will be. Like most fungi, the spores need moisture and high humidity to germinate. Frequent rainfall during May and June contributes to the start and spread of *E. maimaiga* through a gypsy moth population. Temperatures of 50 to 80 degrees F enhance fungal growth.

What you will see: Caterpillars killed by *E. maimaiga* fungus remain attached to tree stems or branches. Bodies tend to be stiff and straight, and the legs extend stiffly from the body. Some dead caterpillars may have tiny white conidia attached to the hairs on the body. *E. maimaiga* can be distinguished from NPV (nuclear polyhedrosis virus), a viral disease that often causes gypsy moth outbreak populations to collapse. Caterpillars killed by NPV often remain attached to the stem or branches of trees. The bodies of dead caterpillars are soft, filled with a brown liquid and disintegrate rapidly. Usually, they hang limply in an inverted "V" position. NPV is seldom prevalent until gypsy moth populations reach very high levels; *E. maimaiga* may be found even when gypsy moth populations are low.

Giving them a boost: *E. maimaiga* may become an important biological control of gypsy moth in both low and high popula-

tions. Infections may be more common in years with rainy spring weather than in years with dry spring weather. *E. maimaiga* is not commercially available. However, cadavers can be collected and placed in the soil or leaf litter below an oak tree with gypsy moth egg masses. If the weather is right in spring, gypsy moth larvae that move across the soil may become infected with the fungus.

— MBCN, v.3, n.8; Lyle Buss, Deborah McCullough and Dave Smitley, 1996, "*Entomophaga maimaiga* - A Natural Enemy of Gypsy Moth," Michigan State University Extension bulletin E-2604.

Bacillus thuringiensis (Bt)

Bacterium

Bacillus thuringiensis, otherwise known as *Bt*, has been the most widely used microbial insecticide in the United States since the 1960s. Bacterial pathogens in the genus *Bacillus* are spore-forming, rod-shaped bacteria. They occur commonly in soils, and the more effective strains have been formulated as bacterial insecticides. An insect must eat the bacteria to become infected — bacterial insecticides will not kill by contact alone. *Bacillus* species and subspecies vary in their specificity — they may target an entire order of insects or one or a few species.

The bacterial cells usually produce a spore and a crystalline protein toxin, called an endotoxin, as they develop. This toxin is the ingredient that kills insects. Most commercial *Bt* products contain the protein toxin and spores, but some contain only the toxin component.

Life of *Bt*: Case scenario: a farmer applies commercial *Bt* on crop foliage. A wandering caterpillar chews on the leaf and ingests *Bt*. The caterpillar's gut is alkaline and full of enzymes. These conditions activate the protein toxin in *Bt*. The activated toxin

Bt, One Controversial Microbe

Bt insecticides produced by fermenting the bacteria are useful for farmers and gardeners, but recent biotechnological advances have placed *Bt* under a lot of fire. The *Bt* genes responsible for making toxins can be inserted directly into the chromosomes of certain crop plants. You have probably heard of *Bt*-corn and *Bt*-potatoes. This technology may seem ideal — a farmer wouldn't have to worry about timing or repeated application because the *Bt* toxin is always in the plant. However, this seasonlong, high-level control also increases the risk that insects will develop resistance to *Bt* toxin. Insects have developed and are developing resistance to every group of chemical insecticides we use against them. The *Bt* toxin likely will suffer the same fate if it is constantly present in the environment and resistance prevention programs are not followed. Field or laboratory populations of the diamondback moth, Indian meal moth, Colorado potato beetle and tobacco budworm have been reported to show resistance to *Bt*!

attaches to specific receptor sites on the gut wall, paralyzing and destroying the cells. The gut contents enter the caterpillar's body cavity. This toxin may kill the caterpillar quickly or the caterpillar stops feeding and dies in two to three days. The bacteria may multiply in the caterpillar, but because few spores or crystalline toxins are produced, few infective units are released after the caterpillar dies. Consequently, *Bt* products are applied much like synthetic insecticides. *Bt* treatments are inactivated by UV light exposure within one to a few days, and repeated applications may be necessary for some crops and pests.

The victims: Until the early 1980s, commercial *Bt* products were effective only against caterpillars. In recent years, however, additional strains that kill other types of pests have been identified and developed.

Bt formulations that kill caterpillars — The best known and most widely used *Bt* insecticides are formulated from *Bacillus thuringiensis* var. *kurstaki (Btk)* isolates that are pathogenic and toxic only to larvae of butterflies and moths (order Lepidoptera). Many such *Bt* products have been registered by the U.S. Environmental Protection Agency (EPA). These products are available as liquid concentrates, wettable powders and ready-to-use dusts and granules. They are used to control many caterpillars that attack cabbage, broccoli, cauliflower and Brussels sprouts; bagworms and tent caterpillars on trees and shrubs; and larvae of gypsy moth and other forest caterpillars. *Bacillus thuringiensis* var. *aizawai* is another *Bt* that kills caterpillars.

These *Bt* products kill only caterpillars, but they do not kill all caterpillars. Caterpillars that live in the soil or bore into plant tissues do not consume a significant amount of the *Bt* applied to plant surfaces. The peach tree borer in stone fruits, codling moth larvae in apples and cutworms that clip off field crops or garden plants are examples of caterpillars seldom controlled by *Bt* treatments.

***Bt* formulations that kill mosquito, black fly and fungus gnat larvae** — *Bacillus thuringiensis* var. *israelensis (Bti)* kills the larvae of certain flies and mosquitoes. The main targets are the larval stages of mosquitoes, black flies and fungus gnats; it does not kill larval stages of "higher" flies such as house flies, stable flies or blow flies. *Bti* is most effective when used on a community-wide basis by mosquito abatement district personnel. For homeowners, eliminating sites that periodically serve as sources of standing water (such as tires, birdbaths and empty containers) and controlling weeds around stagnant ponds or drainage lagoons is more effective than applying *Bti*. Some *Bti* products are used effectively for the control of fungus gnat larvae in greenhouses and in mushroom culture beds.

***Bt* formulations that kill beetles** — *Bacillus thuringiensis* var. *san diego* and var. *tenebrionis* are toxic to certain beetles. Beetle species exhibit great differences in susceptibility to these strains, presumably because they have variable receptor sites in the gut wall where bacterial toxins attach. *Bacillus thuringiensis* var. *san diego* is used against larvae of the **Colorado potato beetle**, adults and larvae of the **elm leaf beetle** and **willow leaf beetle**. Considerable research effort is now directed to identifying and developing additional *Bt* isolates that are active against more or different beetle species.

What you will see: Insects infected with Bt become sluggish, cease feeding and excrete liquid. Once an insect is dead, the body darkens and softens and degrades into dark, putrid mush.

Giving them a boost: After you have chosen the right *Bt* strain for the target pest, following the right timing and application process is critical for success.

- Keep an eye out for pest activity; apply *Bt* only when pests are present. *Bt* formulations are not long-lived outdoors.
- Try to use *Bt* when pests are still small — they do not eat so much yet and this will minimize feeding damage. Also, *Bt* is often more effective on younger larvae.
- *Bt* sprays should thoroughly cover all plant surfaces including the undersides — insects need to ingest *Bt* to die.
- It is best to treat foliage in the late afternoon or evening because UV radiation deactivates *Bt*. This allows active *Bt* to be ingested by unsuspecting herbivores overnight. Treating on cloudy (but not rainy) days provides similar results.
- Take advantage of technology. Some companies encapsulate *Bt* spores or toxins in a granular matrix (such as starch) or within killed cells of other bacteria, and this provides protection from UV radiation. Spreader or sticking agents are also available that help *Bt* adhere to the smooth surfaces of plants.

— MBCN, v.2, n.7, Rick Weinzerl and Lee Solter, University of Illinois; R. Weinzerl and T. Henn, Alternatives in insect management: biological and biorational approaches, North Central Regional Extension Publication 401.

Scientist in You: What Happens to Insects on Bt?

Do you know what a caterpillar infected with Bacillus thuringiensis (Bt) looks like? Bt is the most common microbial insecticide, yet you may not be aware of what happens to the caterpillar in the two to three days between ingestion of the bacterium and death. You can create an observational chamber to witness the havoc that Bt wreaks on pests.

- Collect some small (less than 1/2 inch long) caterpillars from cabbage plants. *Bt* does not work well against caterpillars that are more than half grown. You could also try to capture cabbage looper moths or imported cabbageworm butterflies, keep them in containers until they lay eggs and use the baby caterpillars a few days after they hatch.
- Cut out 10 equal-sized pieces of leaves from unsprayed cabbage, broccoli or cauliflower plants. If you use leaves that have been sprayed with an insecticide, there may be enough pesticide residue to kill your test insects. Dip five of the leaf pieces in water and five in a *Bt* solution (mixed according to label directions). Let the leaves dry, then place them individually in containers.
- Put one to five small caterpillars on each leaf piece (depending on how many caterpillars you have and the size of the

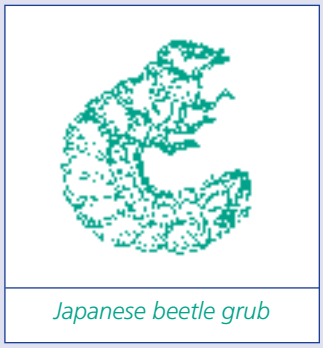
leaf pieces). Let the caterpillars feed for at least 72 hours and look at them every 24 hours.

Are the ones on the *Bt*-dipped leaves still feeding? How much of the leaf did they eat compared with the ones on the water-dipped leaves? On the third or fourth day, note the number active and dead on each leaf piece. Was the *Bt* effective against your caterpillars? Was there much mortality in the water-dipped control? If so, maybe your caterpillars were naturally infected with a disease.

— *MBCN, v.3, n.6, Dan Mahr, University of Wisconsin - Madison.*

Can Milky Disease Control Japanese Beetle Grubs in the Field?

Milky disease, *Bacillus popilliae*, attacks root-feeding grubs. *B. popilliae* infects Japanese beetle grubs when they consume bacterial spores while feeding on roots in the soil. These spores germinate in the gut, allowing bacteria to invade the rest of the grub and kill it over a period of several weeks. At the end of this process, the grub's blood becomes filled with billions of white spores that give the normally clear blood a milky white appearance. Because viable spores persist in the soil, introducing the spores into a population of Japanese beetle grubs can spread the disease and ultimately control the grub problem.



Japanese beetle grub

In the lab, commercially prepared milky spore diseases kill grubs with no mercy. Making commercially prepared milky spore disease work outdoors is currently a challenge for scientists and companies.

— MBCN, v.2, n.12; C.T. Redmond and D.A. Potter, 1995, Lack of efficacy of in-vivo and putatively in-vitro produced *Bacillus popilliae* against field populations of Japanese beetle (Coleoptera: Scarabaeidae) grubs in Kentucky, J. Economic Entomology, 88: 846-854.

Pathogen Against Pathogen

Garden plants face many problems, from six-legged creatures to the smutty mold that spreads on the leaves. Natural enemies of insect pests are primarily described here, but there are natural enemies of smutty mold, too. Natural enemies that are pathogens are fascinating — in their own way, they attack (antibiosis) or just take up space needed by the bad plant pathogens (competition).

Trichoderma harzianum, strain T-22

Fungus

Members of the genus *Trichoderma* are filamentous fungi that can be isolated from many soil types. They are part of a healthy soil environment. Numerous species are found worldwide. A few select strains of *T. harzianum* have been shown to suppress plant pathogens. However, they are limited in the scope of plants they protect and the pathogens they control. For example, one strain can control *Pythium* and grow in cooler soils, while another can control *Rhizoctonia* and colonizes the root system.

A new breed: To overcome these limitations, researchers at Cornell University produced a hybrid strain that enhanced attributes of both parents. The strain, T-22, protects plant root systems against **fungal pathogens *Fusarium, Pythium*** and ***Rhizoctonia***. Protected are a number of crops, including potatoes, tomatoes, beans (green and dry), cabbage, cucumbers, cotton, peanuts, turf, trees, shrubs and other transplants and ornamental crops. T-22 can grow in a range of soil types at temperatures above 50 degree F. Because of its superior attributes, T-22 has been commercially developed as one of the first biofungicides.

Life of T-22: T-22 controls various plant pathogens in two ways. First, T-22 can grow along the entire length of the root system (rhizosphere), where it establishes a barrier against pathogen attack. As long as the root system remains active in its growth and development, T-22 will continue to grow along with it by feeding on the waste products naturally released by roots. Early applications of T-22 protect plant roots by removing secreted nutrients that other pathogens might use. Here the squatter's rights apply. Most importantly, T-22 does not seem to interfere with the activity of mycorrhizae or nitrogen-fixing *Rhizobium* on the roots.

A second line of defense by T-22 against root-rotting fungi is the release of hydrolytic enzymes. Many plant pathogens contain chitin as a component of their cell wall. T-22 releases enzymes called chitinases, which dissolve the cell wall and create holes in the pathogen. Once damaged, the pathogen becomes the prey of other soil microflora. These enzymes work best in an acidic environment. Insects also contain chitin as a constituent of their exoskeleton, but their pH is typically alkaline. Thus, the T-22 chitinases will not work on these non-target organisms. Plants, birds, fish, humans and other organisms are also not affected by T-22.

T-22 maintains the root system, allowing for larger root biomass to develop. Once the plant is harvested, T-22 levels in the soil drop. The levels remaining after harvest will not be high enough for efficacious fungal control on new plantings.

Giving them a boost: Use of T-22 is approved for certified organic production in several states. T-22 can protect plant roots previously not protected by chemical fungicides. It can be used at the time of planting as a seed treatment. The T-22 planter box formulation is compatible with many standard chemical seed treatments and is applied directly over chemically treated seeds at the time of planting. The chemical allows for stand establishment, but that's all. T-22 then kicks in to protect the root system from fungal attack. In addition, T-22 is

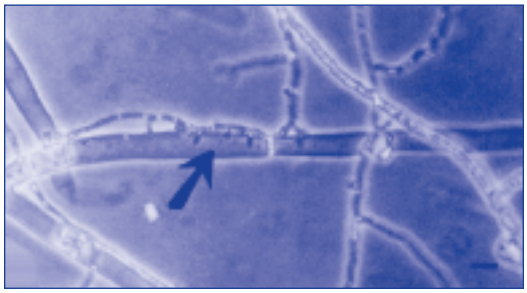
available in a granular formulation for incorporation in soilless potting mixes and as a wettable powder for drenching greenhouse or agricultural plants.

— MBCN, v.5, n.4, Dr. Chris Hayes, BioWorks, Inc., Geneva, NY 14456.

Gliocladium virens

Fungus

Gliocladium virens is a naturally occurring, ubiquitous soil fungus found throughout the United States in various soil types. It has been shown to suppress a variety of **soilborne plant pathogens**, including ***Pythium* spp.**, ***Rhizoctonia solani*** and ***Sclerotium rolfsii***, which cause damping-off and root rot on snapbeans, zinnia and cabbage; southern blight of tomato; and various other seedling diseases. *G. virens* has considerable potential as a biological control agent for many soil diseases.



Gliocladium virens

Life of *G. virens*: *G. virens* reproduces asexually, producing conidia that are held in masses of moist spores. The spores are dispersed only in water or carried in soil or organic matter; they are not airborne. *G. virens* is known to parasitize some soil pathogens such as *R. solani*. It will actually wrap itself around the pathogen and release enzymes that destroy the pathogen's cuticle, leaving the pathogen susceptible to attack.

Giving them a boost: This fungus was one of the first to be registered for biological control of plant diseases. SoilGard™ is an available commercial formulation that controls plant pathogens through a variety of mechanisms, including parasitism, antibiosis and competition. The fungus does not persist at the inoculated high concentrations and declines over a period of a few weeks.

— MBCN, v.5, n.9, Susan Mahr, University of Wisconsin - Madison.

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