Our Islands' Insects and Their Relatives

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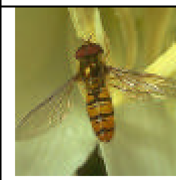
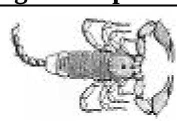
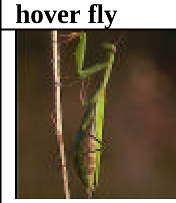
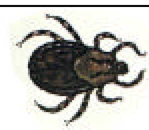
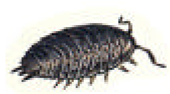
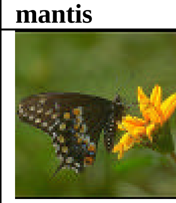
Insect Biology

What are Insects?

Insects are a class of small animals belonging to a large group of **invertebrates** (animals without backbones) called the **arthropods**. The word arthropod comes from two Greek words "arthro" and "poda" which loosely translated means jointed limbs. Having jointed limbs separates the arthropods from other invertebrates such as snails and worms which don't have legs. Another feature common to all arthropods is that they have a hard external skeleton or **exoskeleton** which they wear like a knight's suit of armor to protect their internal organs. Table 1 shows several arthropods which you are likely to see in the Marianas.

Table 1. Examples of insects and insect relatives you are likely to see in the Marianas.

Phylum	**Arthropoda**				
Class	**Arachnida**	**Crustacea**	**Diplopoda**	**Chilopoda**	**Insecta**
Common Groups	spiders, scorpions, mites, ticks	crabs, lobsters, amphipods, sowbugs	millipedes	centipedes	beetles, flies, wasps, moths
Examples	 **garden spider**	 **hermit crab**	 **millipede**	 **centipede**	 **hover fly**
Examples	 **scorpion**	 **land crab**			 **preying mantis**
Examples	 **dog tick**	 **sowbug**			 **swallowtail butterfly**

Insect Diversity: How Many Kinds of Insects are There?

More than half of all the **species** (different kinds of life forms) on our planet are insects. **Entomologists**, scientists who study insects, think that there may be as many as 30 million species of insects. Only a small part, about 1 million of these have been collected and described. To get an idea of how many insect species there are compared to other animals, have a look at the pie chart in Figure 1. Locate the small segment with the fish in it. The size of this piece represents the **chordates** or animals with backbones. This group contains all of the organisms we commonly refer to as "animals": all the mammals, birds, reptiles, amphibians, as well as all the fish. Now compare this to the segment for just one group of insects, the beetles. The insects do not have to wait for a catastrophe such as a nuclear war to take over the world, they already did so millions of years ago.

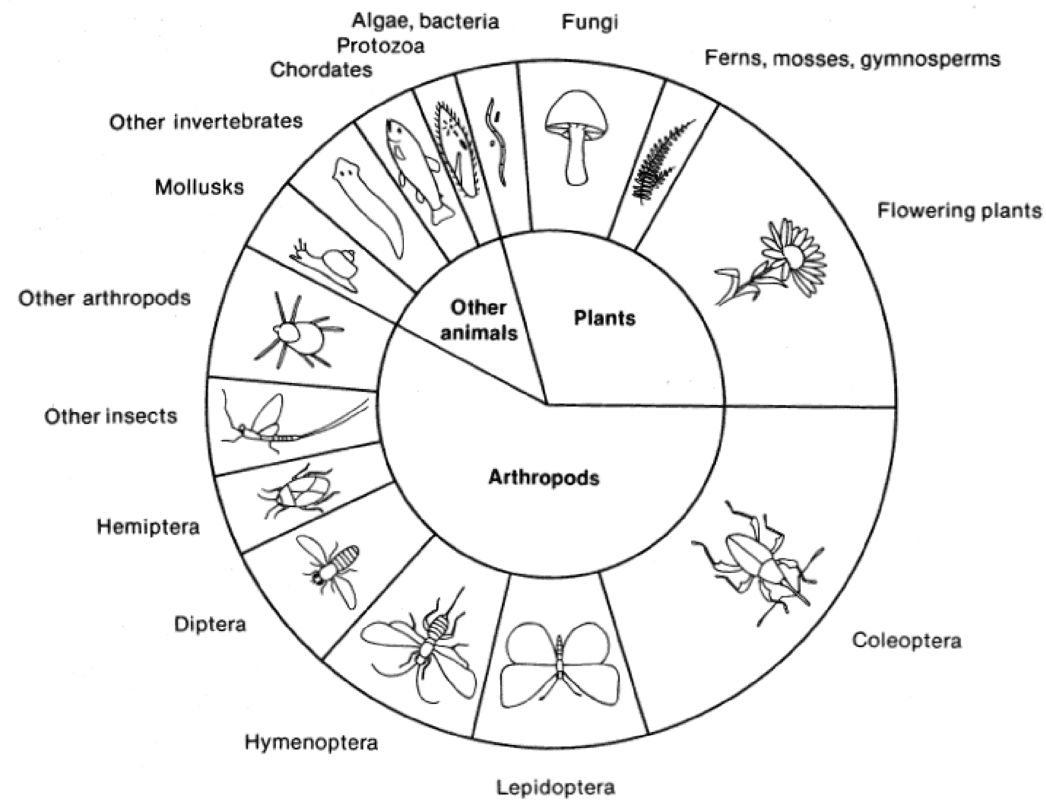


Figure 1. Relative numbers of arthropods, other animals, and plants. Each degree equals 4,200 species. [From (Daly 1978)

Although insect **species diversity** on a global scale is mind boggling, there are relatively few species on our small islands. (Gressitt 1954) estimated that there are "only" about 10,000 species of insects in all of Micronesia with about 2,000 of these occurring on Guam. Table 2 shows how many insect species have been collected on Guam for each major group or **order**. Note that only about half of the estimated number of insect species on Guam have been collected. Insects in the Northern Marianas have not been collected as extensively as on Guam, but the number of species in each order is probably similar to what is found on Guam.

Table 2. Number of insect species in each order collected on Guam. Data from Gressitt 1954.

Insect Order	Common Names	Species Collected
Coleoptera	beetles	260
Lepidoptera	butterflies; moths	240
Diptera	flies	230
Hymenoptera	wasps; bees	150
Hemiptera	true bugs	99
Homoptera	aphids; psyllids; scales; whiteflies; mealy bugs	95
Thysanoptera	thrips	25
Orthoptera	grasshoppers; crickets; roaches	24
Psocoptera	booklice	18
Mallophaga	bird lice	12
Odonata	dragonflies; damselflies	11
Neuroptera	lacewings; antlions	6
Apterygota	silverfish	6
Isoptera	termites	4
Dermaptera	earwigs	4
Anoplura	sucking lice	3
Siphonaptera	fleas	3
Trichoptera	caddisflies	1
TOTAL		**1191**

There are two reasons for the relatively low number of insects in the Marianas. First of all, our small islands do not have as many different habitats as larger islands and continents. In general, the smaller the island, the fewer the species. For example, imagine going on an insect collecting trip to a little offshore sandbar with a single coconut tree growing on it. There are basically only two habitats here, sand and coconut tree. You will probably collect only a few species of insects: those that live in coconut trees, and those that live by eating stuff washed up on the sand. The second reason why we don't have more insect species is **geographical isolation**. On islands, insects and other organisms either **immigrate** from elsewhere, or **evolve** from these immegrants, over millions of years, into new, local forms called **endemic species**. (Gressitt 1954) estimates that **endemicity**, that is the proportion of species that evolved on our islands, is about 45%. There are many species of insects on our islands that do not occur anywhere else in the world.

The rate of immigration of new species was very slow for millions of years after the formation of the Mariana Islands about 45 million years ago because this island chain is surrounded by thousands of miles of open ocean. When the early Chamorros arrived about 3,500 years ago, they undoubtedly brought many new insect species along with their personal belongings, plants, and animals. In the past 500 years, many new species have been carried here with cargo on ships. However, as we will see later, the immigration rate of new species has risen very sharply within the last few decades due to the frequent arrival of jet aircraft.

Insect Morphology: What do Insects Look Like?

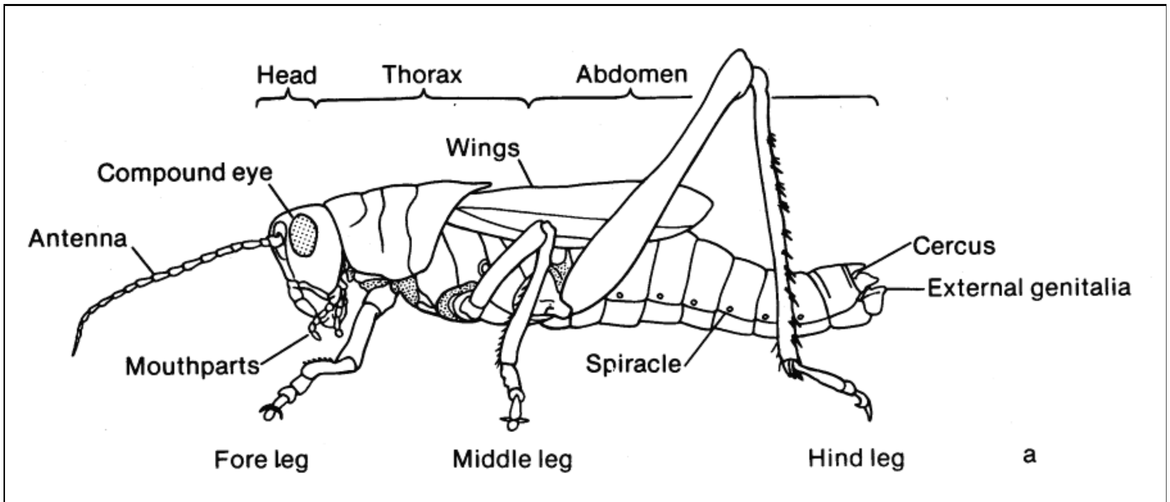


Figure 2. Insect body parts. From (Daly 1978).

Because there are so many different types of insects, it is very hard to come up with a general description of their **morphology**, or what they look like. The following description is a good one for most adult insects. Insects have three major body parts: head, thorax, and abdomen (Figure 2).

Head

The head contains the eyes, antennae, and mouthparts. Most insects have large **compound eyes** which they use to see images of their surroundings. Many also have two or three simple eyes called **ocelli** located on the tops of their heads. Ocelli do not produce images. They simply sense how much light there is. Some people refer to insect **antennae** as feelers. However, their main function is to smell and taste chemicals in the environment. Insects use their antennae to locate food sources. Some insects communicate with others of their species by producing special chemical scents called **pheromones** which are sensed by the antennae.

There are several kinds of insect mouthparts. Dragonflies, mantids, grasshoppers, beetles, caterpillars, ants and wasps have **chewing mouthparts**. Unlike humans who chew with an up and down motion, insect **mandibles**, or jaws, operate side to side to bite off chunks of food and grind them up before swallowing. Other insects have mouthparts that are modified into a **sucking** or a **piercing and sucking** tube. Butterflies and moths suck their food through a long, coiled tube called a **proboscis**. Mosquito and aphid mouthparts work like tiny hypodermic needles that pierce an animal or plant so that liquid food can be sucked out. Houseflies have **sponging** mouth parts to dab up such delightful substances as liquefied manure and decaying plant and animal material before sampling our fiesta plate.

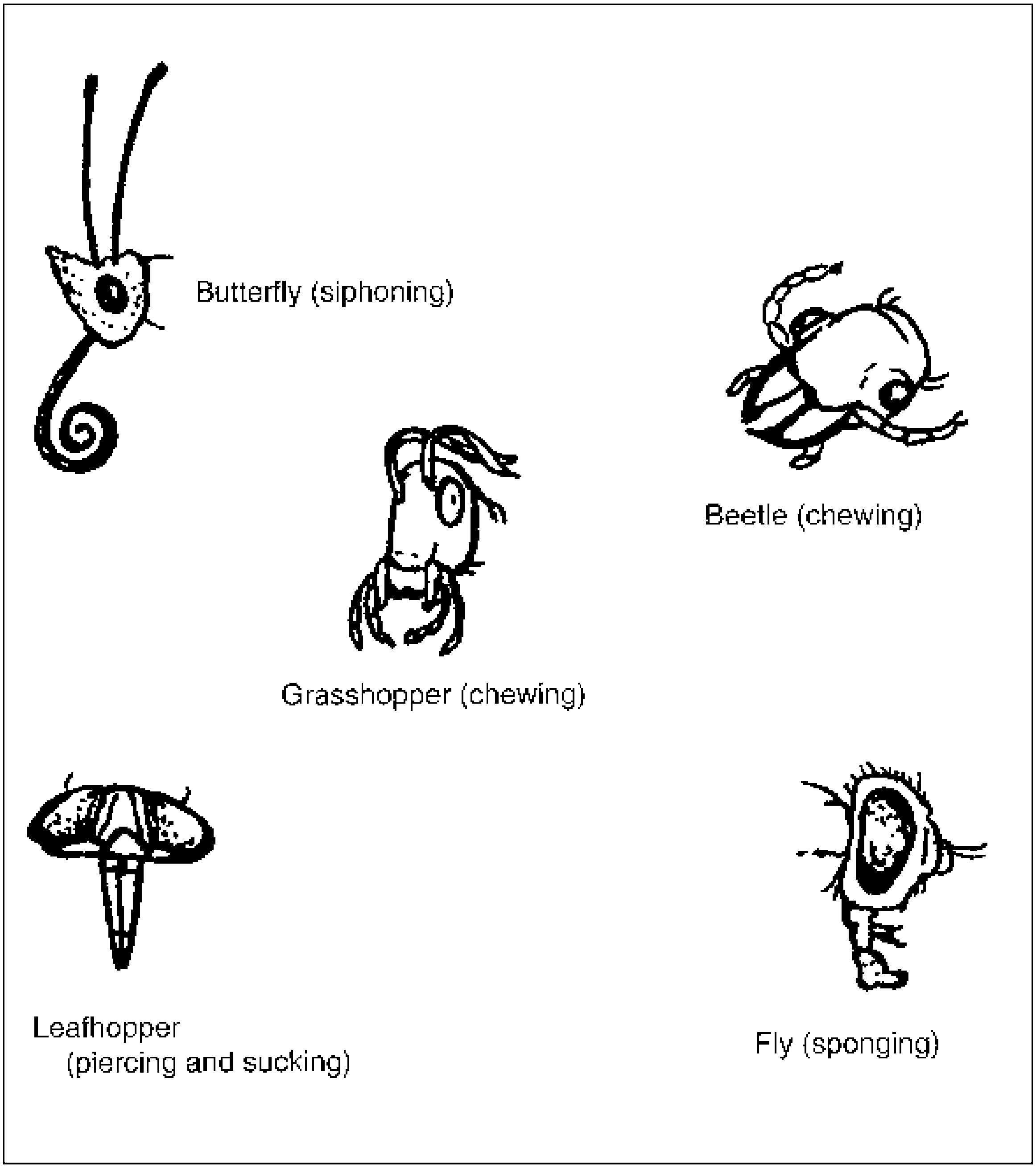


Figure 3. Different kinds of insect mouthparts.

Thorax

The thorax contains three pairs of segmented legs, and usually one or two pairs of wings. Legs may be modified for crawling, jumping, digging, or catching prey. The last leg segment of the leg, the insect's foot, is called a **tarsus**. The tarsus is equipped with claws to hold onto things and chemical sensors which are used to “taste” whatever the insect is standing on. Insect wings are different from those of birds and bats in that they are not modified forelimbs. Most winged insects, except for the flies, have two pairs of wings. Flies have only one pair: the hind wings of flies have been modified into club shaped structures called **halteres**. (The scientific name for flies is Diptera (di=two; ptera=wings)). Only adult insects have wings. Those little houseflies you see are not baby flies. They are adults and they will not grow any bigger.

Abdomen

The abdomen contains the digestive and reproductive organs. External reproductive organs are called **genitalia**. Female genitalia are often modified into a long, pointed egg laying tube called an **ovipositor**. In some species of Hymenoptera (bees, wasps, and ants), the ovipositor has been modified into a **stinger** used for defense and for paralyzing or killing prey. Because only females have ovipositors, males cannot sting. Some insect abdomens have a pair of appendages called **cerci** which are used as feelers (cockroach) or pinchers (earwig).

Insect Classification

Because there are so many different kinds of plants and animals, scientists have devised a system of classification. The process of giving a name to a plant or animal is called **taxonomy**. The taxonomic hierarchy for the honey be is as follows:

KINGDOM Animalia (animals)

PHYLUM Arthropida (arthropods)

CLASS Insecta (insects)

ORDER Hymenoptera (ants, wasps, bees)

FAMILY Apidae (honey bees, bumble bees)

GENUS Apis

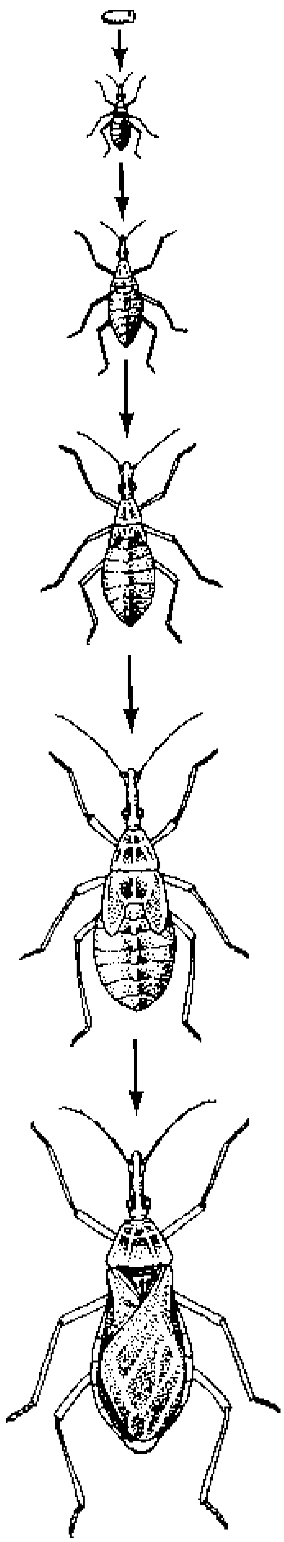
SPECIES ***mellifera***

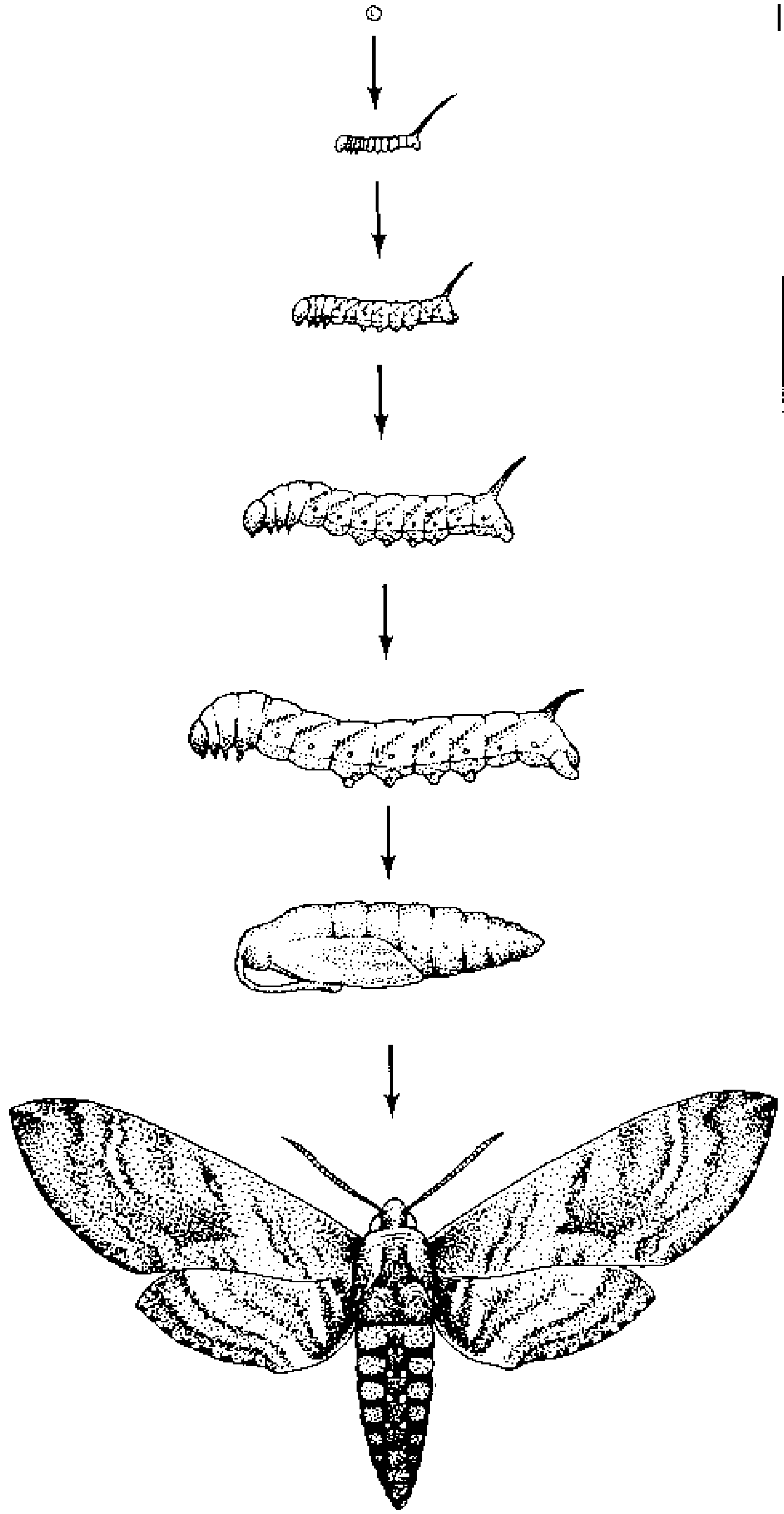
Figure 4. Honey bee (*Apis mellifera*).

The scientific name for the honey bee is ***Apis mellifera***. Scientific names are the genus and species written in Latin, once regarded as the universal scientific language. All scientific names are unique and are accepted and understood by biologists worldwide. The honeybee has many common names, but only one scientific name. Insects within the same species are able to mate and reproduce. Insects are grouped into higher **taxa**: genus, family, and order based on morphological similarities. Taxonomists look for similarities and differences in mouthparts, wing venation, numbers of tarsal segments, and other morphological characters when deciding in which group to put different species. Taxonomy is not an "exact science". For example, some taxonomists place roaches, mantids, and termites in an order called Dictyoptera, while others place roaches and mantids with the grasshoppers and crickets in order Orthoptera, and put termites in their own order, Isoptera. It can get very confusing!

Insect Life Cycles

Insects change form or **metamorphose** as they grow from egg to adult. In order to grow, insects must shed their exoskeletons. This process is called **molting**, and most insects molt several times as they grow. Insects with **incomplete metamorphosis** have three life stages. Eggs hatch into **nymphs**, also called **naiads** if they are aquatic (such as dragonflies). Nymphs look like miniature adults and usually, but not always, feed on the same food as the adults. Insects with **complete metamorphosis** have an additional life stage and the young do not resemble the adult. Eggs hatch into larvae that grow and molt several times. When fully grown, the larvae molt into the **pupal stage**, which allows them to transform themselves into completely different-appearing adults. Lacewings, beetles, butterflies, moths, mosquitoes, flies, bees, fleas, ants, wasps, and others experience complete metamorphosis. Insect larvae have various names, depending on the group to which they belong, such as **grubs** (beetles), **maggots** (flies), **caterpillars** (butterflies and moths), and **wrigglers** (mosquitoes). It is important to note that that most larvae do not rely on the same food source as the adults. Thus, if the insect is a pest, damage to our crops or to us usually occurs during only one stage of the insect's life.





Insect Pests and Pest Control

What is a Pest?

"A pest is any organism (plant or animal) that occurs where we do not want it (weeds in the garden, cockroaches in the house), annoys us (bites or stings), destroys something we need or desire (our crops and our houses), or causes disease (malaria, encephalitis)." (Hodgins 1995)

Only a small percentage of insects are pests. Of the nearly one million insect species that have been described, only about 3,500 (0.35%) are considered to be pests. Of the estimated 10,000 insect species in Micronesia, only about 400 (4%) are considered to be pests. Some of the most important ones are listed in Table 3. Many non-pest insects are actually benefit man either directly or indirectly: bees pollinate crops, insect predators and parasites control populations of pest insects and weeds, and many species provide "**ecosystem services**" by helping to recycle dead plants and animals.

Table 3. Important insect pests in the Marianas.

Structural Pests	**Agricultural Pests**
termites	silverleaf whitefly
	melon aphid
Household Pests	Chinese rose beetle
cockroaches	Philippine lady beetle
	melon fly
Medical Pests	diamondback moth
mosquitoes	fruit piercing moth

Pest Control

Quarantine

Nearly all of the important insect pests in the CNMI are aliens. They arrived on our islands from other parts of the world by hitchhiking in cargo or in passengers' baggage. The number of insects, both pests and non-pests, arriving on our islands has increased dramatically since the advent of frequent jet traffic. "Aircraft provide quick trips and therefor allow more organisms to survive the trip. A hitchhiker may have no food on board, so a species that could not live long enough to make the voyage on a ship may survive on a plane" (Schefter 1997). When aircraft are loaded at night, insects may be attracted to lights in the cargo bay.

In an attempt to prevent new alien insects from invading the Commonwealth, the Department of Land and Natural Resources, Division of Agriculture operates the Plant Pest Quarantine Service (PPQ). PPQ officers inspect cargo and baggage arriving at the airports and cargo at the seaports. Local and federal regulations give PPQ officers the authority to confiscate, treat, or destroy any cargo or plant parts which they suspect is infested with alien insects.

Insecticides

Insecticides are poisons that kill insects. There are several broad classes of insecticides. **Botanical** or **organic** insecticides are made by extracting chemicals from plants. Many plants have evolved the ability to make chemicals which protect them from being eaten by insects and other animals. One of the first organic insecticides to be used was nicotine sulfate extracted from tobacco leaves. **Nicotine sulfate** is extremely toxic to people as well as insects, and for this reason, it is no longer used. The adjective "organic", when applied to a pesticide, does not mean "safe" or even "environmentally friendly", it simply means that it is a natural product. Other organic insecticides are much safer that **nicotine sulfate**. **Pyrethrum** is made from the chrysanthemum flowers. This chemical, or similar compounds called

pyretheroids which have been synthesized by chemists, are very safe for animals other than insects, provided they used according to directions on the label. Because of this low **mammalian toxicity**, **pyrethrums** and **pyrethroids** are often used in household sprays, for treating animals, and for spraying fruits and vegetables. An organic insecticide of local interest is **rotenone**. This chemical is made from the roots of the **derris** plant. It has a very low mammalian toxicity, but is very poisonous to fish as well as insects. Derris has been used by Chamorros and Carolinians for killing fish for many years. A research teem at the Northern Marianas College (agricultural extension agents Ray MacDuff and Marcello Romolor, plant pathologist Dr. Diana Greenough, and chemist Linwood Seaver) are currently investigating the use of extracts from locally grown **neem** trees for insect and fungus control.

During and after the second world war, chemists invented several classes of **synthetic insecticides**. The first of these, the **chloronated hydrocarbons**, is typified by DDT. DDT became after the publication of Rachel Carson's book, Silent Spring. Up until this time, DDT was regarded as an ideal insecticide for two reasons. Firstly, contrary to current popular belief, it was not poisonous to mammals. In fact, its first use was as a delousing powder during the war. It could be sprayed liberally on crops without the risk of poisoning anybody. Farmers got used to using insecticide applications as the one-and-only method for protecting their plants from insect damage. Secondly, treatments lasted for a long time. Houses sprayed with DDT would remain mosquito free for months; protecting people from malaria and other diseases transmitted by mosquitoes.

At first, DDT was seen as a perfect solution to most insect problems. However, it was soon realized that its use was effecting the environment in subtle ways. The title, Silent Spring, refers to the fact that populations of birds were disappearing due to the accumulation of DDT and other log-lived pesticides. Many bird species, especially those high up in the food chain, had difficulty in reproducing because DDT in their bodies interfered with the formation of egg shells. Shortly after publication of Silent Spring, the use of DDT and other long-lived pesticides which accumulate in the ecosystem were banned in most developed countries. Even before DDT was banned, farmers and entomologists noticed that its effectiveness for killing insects was rapidly decreasing. Large-scale use of DDT was killing most insect pests, but a few, genetically **resistant** individuals could tolerate high doses of the poison and survived. These individuals mated, passing on their resistance genes to their offspring. It got to the point where some populations of insect pests could not be killed at all by DDT. Other insecticides could be used, but after a many generations, insect populations became resistant to these chemicals as well. This phenomenon is called **insecticide resistance**. Development of insecticide resistance has become a worldwide problem. Many classes of insecticides are no longer effective in controlling resistant populations of insects.

A new class of insecticides, the **organophosphates**, filled the gap created by the banning of DDT. **Organophosphates** were originally developed for chemical warfare. They are extremely powerful poisons but, unlike DDT, they quickly degrade into nontoxic components which greatly reduces their long-term impact on the environment.

Insecticides are currently the major tool for insect pest control in the Commonwealth. Modern insecticides are safe to the applicator, the general public, and the environment if used properly. To ensure that insecticides are used properly, the Division of Environmental Quality enforces regulations which determine how pesticides are to be used and stored. The Division, with the help of NMC, also holds pesticide applicator workshops which are free to the public. Completion of a pesticide applicator workshop entitles the participant to apply for a private pesticide applicator license which is necessary for purchase of restricted-use pesticides.

Biological Control

The sizes of animal populations, including those of insect pests, are controlled by other organisms including birds, lizards, toads, spiders, and other insects which use them as food, as well as bacteria, fungus, and viruses which cause diseases. This type of natural population control is commonly referred to as the **balance of nature**. Insect populations are controlled by other insects: **predators** which hunt them for food, and **parasitoids** which develop inside them.

Parasitoids are very important in controlling insect pests, so we will describe their function in some detail. Insect parasitoids are typically small wasps. An adult female parasitoid will fly around hunting for its insect **host species**. She will use her ovipositor to lay one or more eggs in each individual host that she finds. Most parasitoids are very specialized: they will lay eggs only in a particular life stage (egg, larva, or pupa) of a particular host species. Many are **species-specific**, meaning that they have only one host species. The parasitoid egg will hatch inside the host, and begin feeding. The developing parasitoid will eventually kill its host by eating its internal organs, and emerge as an adult. (Remember the parasitoid in the movie “Aliens”?.) The word parasitoid means parasite-like. This differentiates them from true parasites which usually do not kill their hosts.

Biological control, often shortened to **biocontrol**, is very important in the islands due to the high rate of new pest introductions. Many of the new pests that become established here undergo population explosions because there are no predators or parasites to attack them. Several years ago, a small insect called the leucina psyllid arrived in the CNMI and started feeding on the tangan-tangan (*Leucana leucocephala*). Before long, all the tangan-tangan was without leaves and was starting to die off. Can you imagine what would happen if all the tangan-tangan died? What would stop our soil from washing into the ocean and killing the reef? A solution to the psyllid problem was needed urgently. One of us (JAT) knew that the leucina psyllid had also invaded Hawaii but had not become much of a problem there. A field study by JAT in Hawaii showed that the psyllid was being attacked by a small blue-green lady bug, *Cerinus cerelius*. This predator had been introduced in Hawaii in the early 1900’s to help control another insect pest. Several hundred of these ladybugs were collected, brought back to the CNMI, and released throughout the islands. To this day, they are doing a good job of controlling the leucina psyllid, which is still here, but no longer a problem.

In recent years, NMC entomologist Dr. Chou-hon Chiu has released several species of predators and parasitoids to control pests in the CNMI. These were purchased from companies on the United States mainland have established **insectaries** which rear large numbers of **biocontrol agents** for sale.

Integrated Pest Management

We have just described two tactics used for controlling insect pests: insecticides and biocontrol. Other tactics can be used:

- Plants can be protected by excluding insects using fine netting.
- Insects can be trapped using visual attractants (yellow sticky traps), powerful chemical attractants (pheromone traps), or trap crops.
- Plant varieties resistant to insect damage can be selected for planting.
- Large numbers of sterilized insects can be released into the environment. Insects that mate with these will produce no offspring.
- Insect diseases (bacteria, viruses, and fungi) can be used as **biological insecticides.**
- Repellants can prevent pests from attacking host plants or animals.

Integrated pest management means using the best tactic or combination of tactics from those available. If pest population levels are low, the best tactic may be to do nothing. Spraying insecticide on a crop that contains only small numbers of insect pests may cost more money than the profits lost due to the small amount of damage that may occur. In addition, the insecticide will probably kill any predators or parasites which are helping to control pests in the crop, resulting in a population explosion of pests within a few days, requiring further sprays until harvest. For these reasons, a skilled farmer never uses insecticides unless pest populations are high enough to warrant this tactic, thereby saving a lot of work and money.

Integrated pest management relies on **pest monitoring** to determine when pesticide applications are necessary. Crops under integrated pest management must be surveyed frequently, usually more than once a week, to determine answers to the following questions:

- Which pest species are attacking the crop?
- How many are there?
- Are predators and parasites attacking the pests?

The decision to spray or not to spray is based on the answers to these questions plus other considerations, such as the number of days to harvest. Integrated pest management practitioners need to be able to identify and quantify the major pests, predators, and parasites in the crop the are growing.

One of us (AM) has developed an electronic pest monitor that may some day help farmers keep track of insect population levels in their fields. This monitor uses a photosensor to record sunlight reflected off the wings of insects flying within the field. The recorded signals, which contain insect wingbeat waveforms, are fed into a computer programmed to identify and count major pests as well as their predators and parasitoids.

Insect Natural History

In this section we will study some common island insects in detail.

Aphids and Aphid Hunters

Aphids are small insects belonging to the Order Homoptera and Family Aphidae. There are several s[ecies of aphids in the CNMI that are a major pests of melons, beans, citrus and other crops. Aphids feed by sucking sap out of plants with sharp needle-like mouthparts. Because of this method of feeding, aphids can transmit plant diseases such as viruses. Aphids can easily be identified by a pair of structures on their abdomens called **cornicles**. These are glands which produce chemical messengers called **alarm pheremones**. In the CNMI, all aphids are female. They are very unusual in that they do not need to mate for reproduction, and they give birth to their young instead of laying eggs. Under a microscope, you can often see the eyes of baby aphids within the abdomen of the mother. Aphids reproduce very rapidly. An adult can give birth to several **nymphs** each day. You will usually find aphids in colonies consisting of a mother surrounded by her offspring of different ages. You will often see ants associated with aphid colonies. The ants get **honey dew**, a sticky sugar solution, from the aphids and repay them by chasing away predators and parasites. Aphids undergo incomplete metamorphosis. The adults look and behave just like the immatures, except some are **alate** (=with wings) and some are **apterous** (=without wings). Aphids colonies produce more alates on plants that are under stress or dying. It is the alates that are very good at infesting new plantings. They are often found on the underside of seedlings. If they are not controlled by biocontrol agents or chemicals, aphid colonies may get so large that they suck so much sap out of the young leaves that they curl up. If pesticides are not used intensively, predators will attack and help to control aphids. In the CNMI, hover fly larvae (Order Diptera, Family Syrphidae) and lady beetles (Order Coleoptera, Family Coccinelidae), both adults and larvae, can often be seen eating aphids. There are several species of miniature wasps that parasitize aphids, but these are not very common in the CNMI. One of the authors (AM) is working with entomologists at University of Guam, Washington State University, and the Czech Academy of Science to introduce new species of aphid parasitoids to control aphids in the Marianas.

Figure 5. Wingless (apterous) aphid.

Figure 6. Winged (alate) aphid.

Figure 9. Lady beetle with eggs.

Figure 7. Lady beetle larva hunting aphids.

Figure 8. Lady beetle pupa.

Muddauber

There are several species of muddaubers in the CNMI. These are large black and yellow wasps with very long, thin wastes. They make a nests of mud. These nests are often found on the outside walls of houses in the CNMI, and are considered a nuisance by many homeowners. Depending on which species she belongs to, the muddauber stocks her nest with spiders or caterpillars which she has paralyzed by injecting a small amount of venom using her stinger. If angered, these wasps can sting humans, but they are usually quite shy. Before sealing each cell in the nest, the muddauber lays a single egg, This egg will hatch, and the larva will feed on the live spiders, pupate, and emerge from the nest as an adult.

Figure 10. Muddauber wasp (*Sceliphron caementarium)*

Figure 11. Muddauber wasp emerging from cell.

Fruit Piercing Moth

Eggs of the fruit-piercing moth, *Othreis fullonia*, are moth are laid on coral trees (Erythrina trees). The caterpillars feed on the coral tree leaves. They have large "eye spot" markings on them that may scare away predators. This insect is principally a pest in the adult stage, which is very unusual for a moth. It feeds primarily at night on a wide variety of ripening fruit by piercing the fruit and sucking out the juices. The fruit-piercing uses its long, sharp proboscis to make a round, pinhole-sized puncture is made in fruits through which it sucks juice. The hole serves as an entry point for disease organisms and can result in early fruit drop. A small cavity is left in the fruit in the feeding site. The area of the fruit around the cavity will be dry and spongy. The moth feeds on a wide variety of fruits including citrus, guava, mango, papaya, pomegranate, eggplant, and tomato. Damage is often misdiagnosed as being fruit fly damage. However, fruit damaged by fruit flies will contain eggs or maggots.

Fruit-piercing moth damage is difficult to control with insecticides because the moths spend only a short time on the fruit, do not breed on the affected crops and are strong fliers. The fruit can be protected by covering it with bags shortly before it ripens. Area-wide destruction of coral trees could reduce the moth population but is not likely to be practical. Coral trees, or gaogao trees in Chamorro are very common and are a source of traditional medicine. Unlike many moths, fruit-peircing moths are repelled by strong lights. Placing electric lights or kerosene lamps placed at a height of five feet at 40- to 70-feet intervals downward of fruit trees may protected them.

Figure 12. Fruit piercing moth (*Othreis fullonia*).

Figure 13. Feeding damage by adult fruit piercing moths.

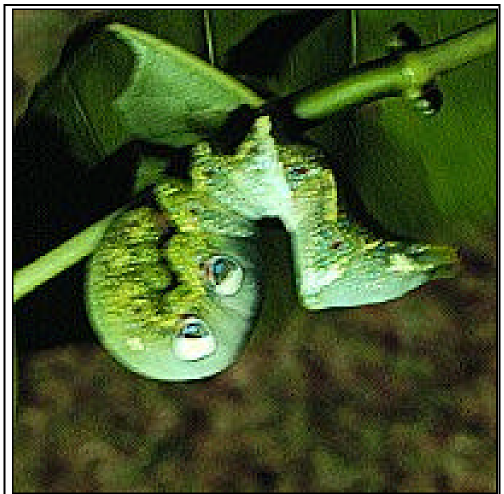


Figure 14. Fruit piercing moth caterpillar (green stage).

Figure 15. Fruit piercing moth caterpillar (black stage).

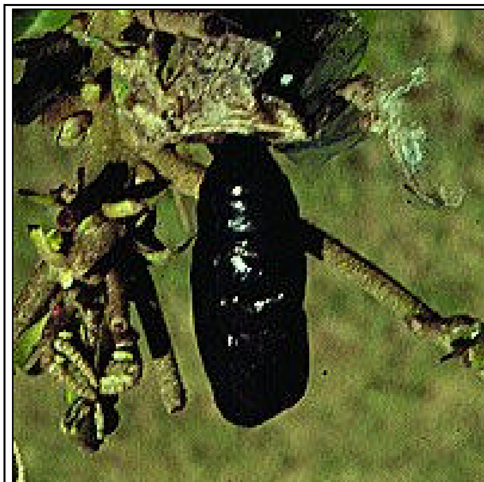


Figure 16. Fruit piercing moth pupa.

Annotated Resource List

Identifying Local Insects

Probably the best field guide available is **Borror, D. J. and R. E. White (1970). A Field Guide to Insects: America North of Mexico. Boston, Houghton Mifflin Company**.
Although this book was written for use on the mainland, it can be used to identify most insect families found in the Marianas. It can be ordered from from www.amazon.com for about $17.

For identifying local butterflies, you can get a copy of **Schreiner, I. H. and D. M. Nafus (1997). Butterflies of Micronesia**, for $10 from the Agricultural Experiment Station,College of Agriculture and Life Sciences, University of Guam, Mangilao, Guam 96923,USA. This book has color pictures and descriptions for over 50 species.

Identification of insects down to the species level can be very difficult. The standard reference for the Marianas is the multivolume series, **Insects of Micronesia**, published by the Bishop Museum in Honolulu. These volumes are very technical and are written for use by professional entomologists. Unfortunately, this series is out of print. NMC on Saipan has a complete set.

The best way to identify insects is to take specimens to the Agricultural and Life Sciences Department at Northern Marianas College on Saipan. The easiest way to kill and preserve insects is to put them in your freezer. The entomology lab is located in building D. College entomologists, in cooperation with the Department of Land and Natural Resources, maintain a large collection of Micronesian insects. Insect specimens can often be identified by comparison to those in the collection. If you have access to the Internet, you can identify crop pests by going to the online insect pest database at **www.nmcnet.edu/Lg/aubweb/bugweb/bugroot.htm**.

For identification and control recommendations for household pests and biting insects, check out **Tenorio, J. M. and G. M. Nishida (1995). What's Bugging Me?: Identifying and Controlling Household Pests in Hawai'I** and **Nishida, G. M. and J. M. Tenorio (1993). What Bit Me?: Identifying Hawai'i's Stinging and Biting Insects and Their Kin**, both from the University of Hawai'i Press in Honolulu.

Insect Videos

Insects (Eyewitness Video Series) is a fascinating overview of insect biology with great photography. A copy is available at the Joeten-Kiyu public library on Saipan. This video can be enjoyed by all levels of students.

The National Biological Control Institute (NBCI/USDA/APHIS/OA, 4700 River Road Unit 5, Riverdale, MD 20737-1229) has put together a mini-course kit on biological control which includes a video:
Biological Control: Learning to Live with the Natural Order
and an accompanying book:
Hodgins, M. R. J. a. A. S. (1995). Pests Have Enemies Too: Teaching Young Scientists About Biological Control, Illinois Natural History Survey. This material is available for free and is suitable for high school level students. Dr. Moore at NMC has a copy of each for loan.

Insect Collecting

Making an insect collection is a fun way for students to learn about biology and the island environment. It is also a fascinating hobby. A company called **BioQuip** (17803 LaSalle Ave., Gardena, CA 90248-3602, USA; bioquip@aol.com) specializes in entomological supplies and publishes a very comprehensive free catalog. Teachers intending to involve their students in insect collecting or beginning amateur entomologists should consider ordering order one or more student insect collecting and mounting kits (Cat # 1138) for about $34 each. These are very complete kits include a nice manual.

World-Wide-Web

Information about local insects can be found at: **http://www.nmcnet.edu/Lg/aubweb/EntRes.htm**

For a huge index to information about insects and entomology go to: **http://www.ent.iastate.edu/List/**

The Entomological Society of America has lots of interesting information for teachers and students at **http://www.entsoc.org/educate.htm.**

References

Daly, H. V. (1978). Introduction to Insect Biology and Diversity, McGraw-Hill.
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Schefter, C. S. L. M. (1997). Tropical Island Environments, University of Guam Press.