INTRODUCTION TO INSECTS

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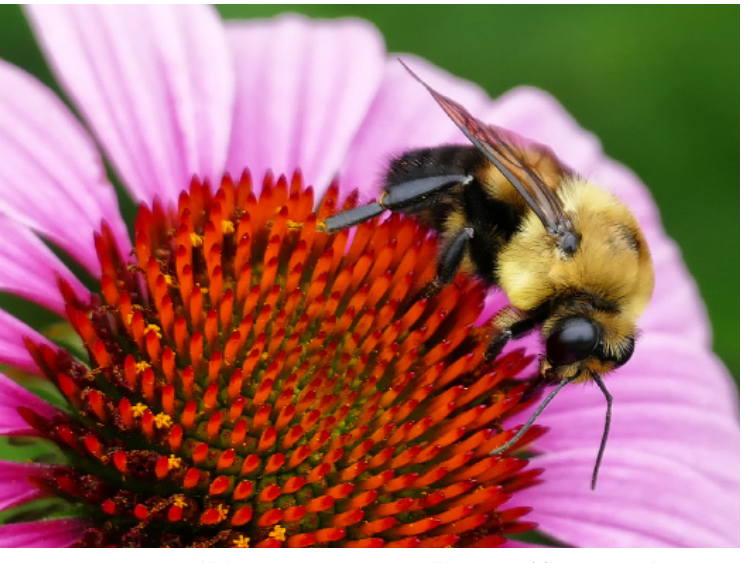
INTRODUCTION

Insects are essential to the functioning of all ecosystems. As the dominant herbivores of most terrestrial communities in Pennsylvania, insects move energy from plants up the food chain, supporting a critical link in the food web. Insects are a major food source for many species of fish, amphibians, reptiles, birds, and mammals. Birds rely on insects during the nesting season to provide their young with adequate nutrition. This resource is so valuable that many bird species will migrate thousands of miles from the tropics to take advantage of the seasonal bounty of insects in temperate regions.

When insects feed and break down both live and dead material, they return nutrients to the soil. Thus, insects are efficient and crucial players in nutrient cycling.

The majority of pollinators in Pennsylvania are insects such as bees, flies, beetles, butterflies, and moths. Because many native plants require insect pollination for reproduction, invertebrates help to perpetuate ecosystems and the services they provide to human society, as well as produce food for wildlife.



8. Bumblebees are important pollinators of flowering plants in Pennsylvania

Other insects are valuable as agents of Integrated Pest Management (IPM). Insect predators and parasitoids can keep pest populations at low levels and reduce dependency on pesticides. The pollination and pest management services provided by insects can have significantly positive economic and ecological impacts.

59. Some parasitic wasps lay their eggs under the skin of insect hosts (such as this tomato hornworm), which will kill the host and naturally suppress pest populations in agricultural fields

Some non-native insects are unfortunately very detrimental to native ecosystems. Some non-native insect pests in Pennsylvania include the gypsy moth, emerald ash borer, hemlock woolly adelgid. These insects are extremely damaging to oaks, ash, and hemlock respectively, all of which are native to Pennsylvania.

38. The Emerald Ash Borer is an invasive beetle whose larval stage feeds on, damages, and kills native ash trees throughout the United States and Canada

CLASSIFICATION

All life is organized using hierarchical classification, where each larger group can be broken down into smaller groups, somewhat similar to computer folders and subfolders. All animals, including insects, fall into the kingdom Animalia. Within Animalia are a number of phyla, including Chordata (animals with backbones, including all fish, birds, and mammals such as humans), Mollusca (including squid, octopods, slugs, snails, clams, etc), and Arthropoda, which includes insects and related animals such as shrimp, crabs, millipedes, centipedes, and spiders.

Arthropods are characterized by having a segmented body that is groups into larger units called tagma (plural: tagmata), jointed legs, compound eyes, and a hardened exoskeleton. The number of tagma, legs, and eyes can vary between different arthropod groups – for example, spiders and other arachnids have eight legs while crabs and other decapods have ten legs.

Arthropods are the most diverse group of animals, with 1.7–30 million species estimated to exist. Because it is so diverse, the phylum Arthropoda includes a number of subphyla, including Chelicerata (spiders, scorpions, mites, etc), Mandibulata (millipedes and centipedes), Crustacea (crustaceans such as crabs and lobsters, although this is not a natural, or monophyletic, group), and Hexapoda (insects, springtails, and relatives).

Hexapoda contains 2–4 classes, depending on the classification: Insecta (insects), which includes the vast majority of hexapod diversity, and the non-insect hexapods Collembola (springtails), Protura (coneheads) and Diplura (two-pronged bristletails), which are much less diverse. Because they are closely related to insects, and are found in the same habitats, and have similar morphology, non-insect hexapods are often included with insects. Insects and other hexapods can be distinguished from other arthropods by a number of features including the presence of three main body regions or tagmata (head, thorax, and abdomen), one pair of segmented antennae, three pairs of segmented legs attached to the thorax, and one pair of compound eyes. Insects are also the only arthropods that can have wings (although some "primitive" insects are wingless as adults).

Historically, non-insect Hexapods were organized into the class Entognatha, which contained three orders: springtail (Collembola), coneheads (Protura), and two-pronged bristletails (Diplura). Recent research has suggested Entognatha is not a natural group, so some scientists have raised the old orders to classes (for example, class Collembola instead of order Collembola), which then each contain a number of orders. This change is not yet fully recognized, so for easy of understanding and to be consistent with older references, the non-insect hexapods are included as orders here.

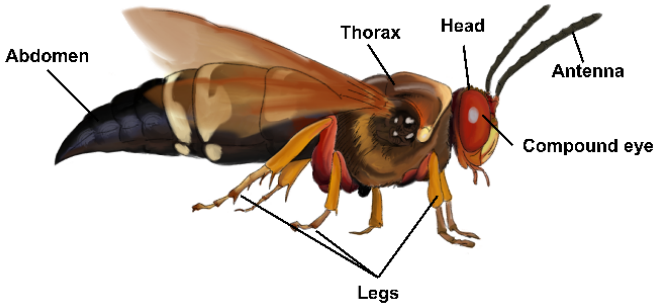
Insects are divided into 27 orders, which includes many groups such as beetles, flies, and butterflies that are recognizable to most people. The non-insect hexapods as considered here contain three orders.

ORDER	COMMON NAMES	NUMBER OF DESCRIBED SPECIES
Blattodea	cockroaches, termites	7,314
Coleoptera	beetles	387,100
Collembola	springtails	8,130
Dermaptera	earwigs	1,978
Diplura	Diplurans	800
Diptera	flies	155,477
Embioptera*	webspinners	463
Ephemeroptera	mayflies	3,240
Hemiptera	true bugs, leafhoppers, aphids	103,590
Hymenoptera	bees, wasps, sawflies, ants	116,861
Lepidoptera	moths and butterflies	157,338
Mantodea	mantids	2,400
Mecoptera	scorpionflies	757
Megaloptera	dobsonflies, alderflies	354
Microcoryphia	jumping bristletails	513
Neuroptera	lacewings, antlions	5,868
Notoptera*	ice crawlers, rock crawlers	49
Odonata	dragonflies, damselflies	5,899
Orthoptera	grasshoppers, crickets, katydids	23,846
Phasmatodea	walking sticks	3,014
Plecoptera	stoneflies	3,743
Protura	proturans, coneheads	804
Psocodea	parasitic lice, book lice, bark lice	10,822
Raphidioptera*	snakeflies	254
Siphonaptera	fleas	2,075
Strepsiptera	twisted-wing parasites	609
Thysanoptera	thrips	5,864
Trichoptera	caddisflies	14,391
Zoraptera	zorapterans	37
Zygentoma	silverfish, firebrats	561

Table 1. *Scientific and common names of insect orders. Groups indicated with an asterisk (*) do not occur in Pennsylvania. Species counts modified from Zhang (2011).*

INSECT STRUCTURE

Insects have three main body parts: the head, thorax, and abdomen. The head contains sensory organs such as the eyes and antennae, as well as the mouthparts. The thorax bears appendages used for locomotion, including three pairs of legs and, if they are present up to two pairs wings. The abdomen contains the majority of the digestive tract, as well as internal and external organs used for reproduction.



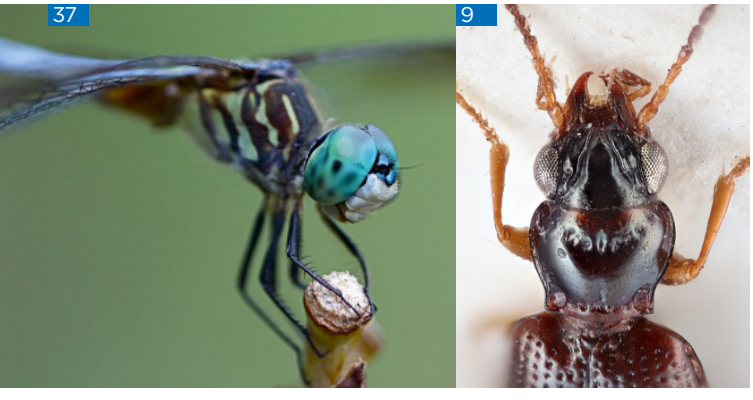
48. All insects possess a body plan that can be divided into three parts: the head, the thorax, and the abdomen

HEAD

The head is the front-most (anterior) part of an insect's body and includes the antennae, eyes, and mouthparts.

EYES

Most adult insects have compound eyes made up of tiny facets, although some subterranean species may lack eyes altogether. Compound eyes are used to see the world around the insect, so visually oriented insects such as dragonflies can have large compound eyes of many thousands of facets while subterranean insects may have compound eyes made of a few or even one facet, if they are present at all. Because each facet sees a slightly different image of the world, insects can see movement and moving objects much better than vertebrate eyes (which is why it's so hard to kill a house fly!).



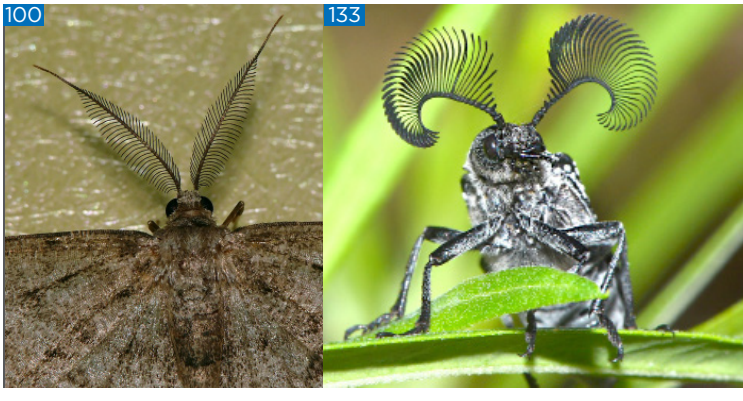
Insects' compound eyes range in size and are used to view the world around them. Dragonfly eyes (left) are very large and composed of thousands of individual facets, while some insects, like ground beetle (right) have relatively smaller eyes

Many insects also have 1–3 simple eyes called ocelli (singular ocellus) on the top of their heads. Ocelli are composed of a single lens and cannot form images like compound eyes can. Rather, they are used to detect light and are associated with light-dark cycles, circadian rhythm, and determining the season.

151. Ocelli are also called 'simple eyes' and are used to detect light and shadows. You can see three of them sitting on the top of this wasp's head, centered between her two compound eyes

ANTENNAE

Most insects have one pair of antennae at the front of the head (unlike some other arthropods, such as crayfish and lobsters, which have two pairs). Antennae are sensory organs that are used to detect touch and chemicals that we perceive as odors or taste. Some insects also use their antennae to detect sound. The size and shape of the antennae and the number of antennal segments vary greatly between insect groups and can be used for identification.



Antennae are important sensory organs and range widely in their size and structure. Insects like this moth (left) and cedar beetle (right) use long, fringed antennae to smell and locate mates

MOUTHPARTS

Insect mouthparts, like their antennae, vary greatly between orders of insects and species. The mouthparts of comprised of four parts that are derived from leg-like appendages – the labrum, mandibles, maxilla, and labium – that work together to process food. Insect mouthparts are grouped by function, including chewing, piercing, siphoning, and lapping mouthparts, and are usually indicate what an insect eats.

Chewing mouthparts are used to tear, cut, or crush food and deliver it to the mouth opening. Some insects have large chewing mouthparts that they also use when competing against other males of the same species.

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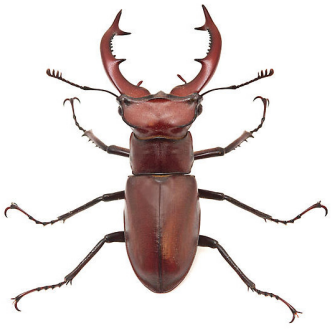

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Many beetles, such as these two pictured, use their mandibles to tear and cut food. Stag beetle males (left) rely on showing off their oversized mandibles to find a mate

Insects with piercing mouthparts have the same basic components as insects with chewing mouthparts (i.e., labrum, mandibles, maxilla, labium) except the parts are modified into long, thin stylets that form a hollow tube. Piercing mouthparts have evolved multiple times within insects, and how and which parts of the mouthparts are modified varies between groups. Piercing mouthparts allow the insect to insert the mouthparts into plants or animals on which they feed.

1. Mosquito saliva is directed into the host as they are feeding, which includes a mix of proteins that prevent blood from clotting and are anesthetic so that you don't feel their stylet when they are probing you

Siphoning mouthparts are similar to piercing mouthparts. The basic parts of the mouthparts have been modified to form a tube which enabling the insect to draw in fluids such as nectar. In general, siphoning mouthparts are not stout enough to pierce into other plants or animals.

160. This bumblebee is using siphoning mouthparts to access the nectar deep inside of this thistle flower

Lapping mouthparts have been modified to act like a sponge to lap up liquids. For example, this is how houseflies and fruit flies eat.

THORAX

The thorax is the middle section (tagma) of an insect's body and is located behind the head and in front of the abdomen. The thorax of adult insects contains the appendages used for locomotion, including three pairs of legs and the wings (if they are present). The thorax is often stiff with many internal folds that the muscles used to control the legs and wings attach to.

LEGS

The three pairs of jointed legs originate from the thorax. Insect legs differ based on their mode of movement and are often useful in identifying insects. Some examples of different types of legs based on the insect's movement include walking, jumping, and swimming. Some legs are adapted for specific uses such as carrying pollen or capturing prey. The feet of insects often have small claws or pads depending on their type of movement and the environment they inhabit.

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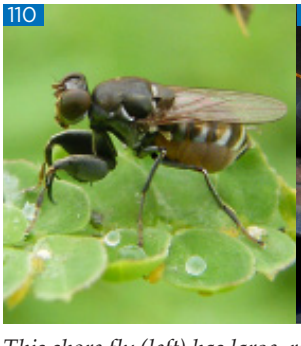

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This shore fly (left) has large, raptorial forelegs that aid in the capture of live prey. For grasshoppers (right), large, elongated hindlegs are used for hopping and jumping

WINGS

The wings, like the legs, originate from the thorax. Many, but not all, adult insects have wings. Wings vary greatly between orders and species of insects and the venation of insect wings can aid in identification. Some wings are highly modified for uses other than flying. For example, the front wings of beetles, which are called elytra, are hardened for protection of the hind wings and body. The hind wings of flies are modified into halteres, which act like gyroscopes and aid in balance during flight. The wings of moths and butterflies are covered with minute scales which give the wings their color.

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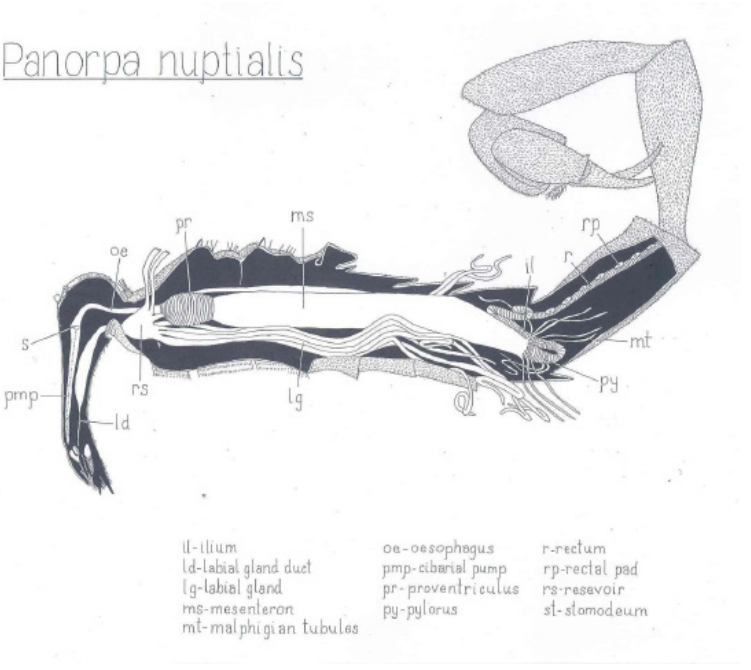
Beetle, fly and butterfly wings vary dramatically in form and function

ABDOMEN

The abdomen is the rear-most main section of an insect's body located behind the thorax. The abdomen is sometimes hidden by the insect's wings while moving or at rest. Much of the digestive system is located within the abdomen, along with the insect's internal and external reproductive organs. Adult females of many groups of insects have an ovipositor located at the rear of the abdomen that is used to lay eggs. In other groups, the last few segments of the abdomen are modified into an ovipositor. Glands are common on the abdomen used to produce various chemicals that aid in communication.

INTERNAL ANATOMY

The internal anatomy of insects differs greatly from the vertebrates we are most familiar with. A short description of the respiratory, circulatory, digestive, and nervous systems is below.



134. The internal anatomy of a scorpion fly. Most insects share the same basic internal structure, but this can vary depending on their lifestyle

RESPIRATORY SYSTEM

Unlike mammals, birds, and other vertebrates, insects lack lungs and do not use blood to transport oxygen. Instead, insects almost exclusively rely on the passive diffusion of air through a network of hollow, internal branching tunnels (known as the tracheal system) to acquire oxygen. The tracheal system extends throughout the insect's body and even into the wings. The openings of the tracheal system in the exoskeleton are called spiracles. Spiracles are found on the thorax and abdomen, although the number of spiracles may be reduced in some insects or completely lost (as is sometimes the case with aquatic insects that have gills). The spiracles can be selectively opened or closed depending on the specific activities or behaviors an insect is engaging in.

CIRCULATORY SYSTEM

Insect circulatory systems are located along where a backbone would be in animals with internal skeletons. The circulatory system is an open system with bodily fluids flowing throughout the body, bathing the muscles and organs (unlike the closed circulatory systems of mammals and other vertebrates, where blood is routed through veins and arteries).

Instead of having 'blood', insects transmit nutrients, hormones and cells through a fluid called hemolymph. He-

molymph is mostly made of water but also includes a small percentage of ions, carbohydrates, lipids, amino acids, cells and other materials. The hemolymph flows freely throughout the body cavity to deliver nutrients and remove waste from the insect. It also has important immune response functions, allowing for wounds to be sealed by clotting, or by defending against internal parasites or other invaders. Insects don't have a centrally located heart like we do – instead, the hemolymph flows from the efforts of a tunnel-shaped dorsal vessel, or heart, in the abdomen, that pulls hemolymph in and pulses it forward towards the thorax and the head of the insect. From here, hemolymph spills out of the aorta, kind of like a hose, before sloshing back toward the posterior end of the body again.

DIGESTIVE SYSTEM

The digestive tract is relatively simple and goes from the mouth of the insect to the abdomen where waste is excreted. Depending on their lifestyle, insects will have different specialized organs to cope with the digestion of food, the absorption of nutrients and waste excretion. Broadly speaking, however, insect digestive systems include three functional regions - the foregut holds the food, the midgut breaks down the food, and the hindgut processes and excretes the waste.

NERVOUS SYSTEM

The nervous system consists of a series of nerve centers called the ganglia (singular ganglion) running along the bottom (or venter) of the insect, which is different from vertebrate species where the nervous system runs up and down the spine. Primitively, each segment of the insect body has a separate ganglion and associated nerves that act like control switches for that segment. The insect "brain" is really a fusion of the nerves associated with the fused segments of the head, which correspond to the antennae, possibly the eyes, and each of the paired mouthparts.

INSECT GROWTH AND DEVELOPMENT

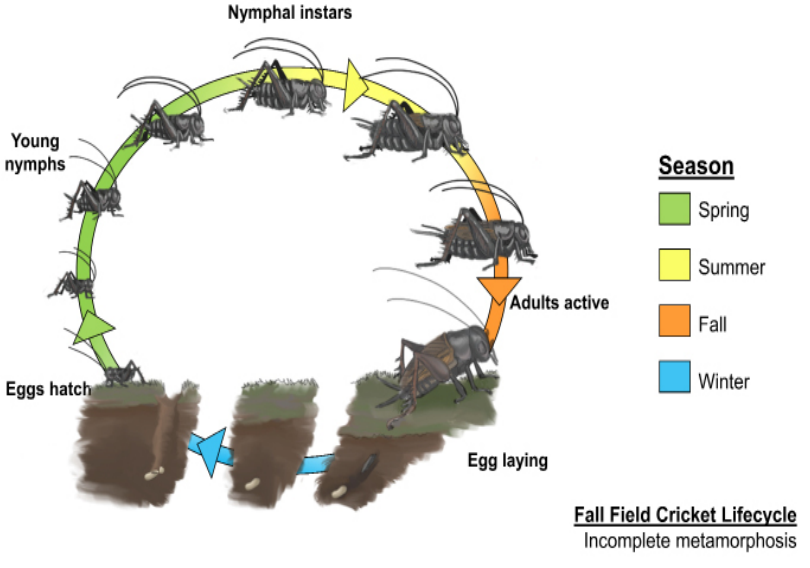
Insect growth and development is distinctive and aids in the classification of insects. There are three main types of insect development: no metamorphosis (ametaboly), incomplete metamorphosis (paurometaboly and hemimetaboly), and complete metamorphosis (holometaboly). Metamorphosis is the term for the transition between stages of insect development. Regardless of the type of development, there is a general theme of progression from egg to immature to adult insect with fully developed legs, wings (if present), mouthparts, antennae, reproductive organs.

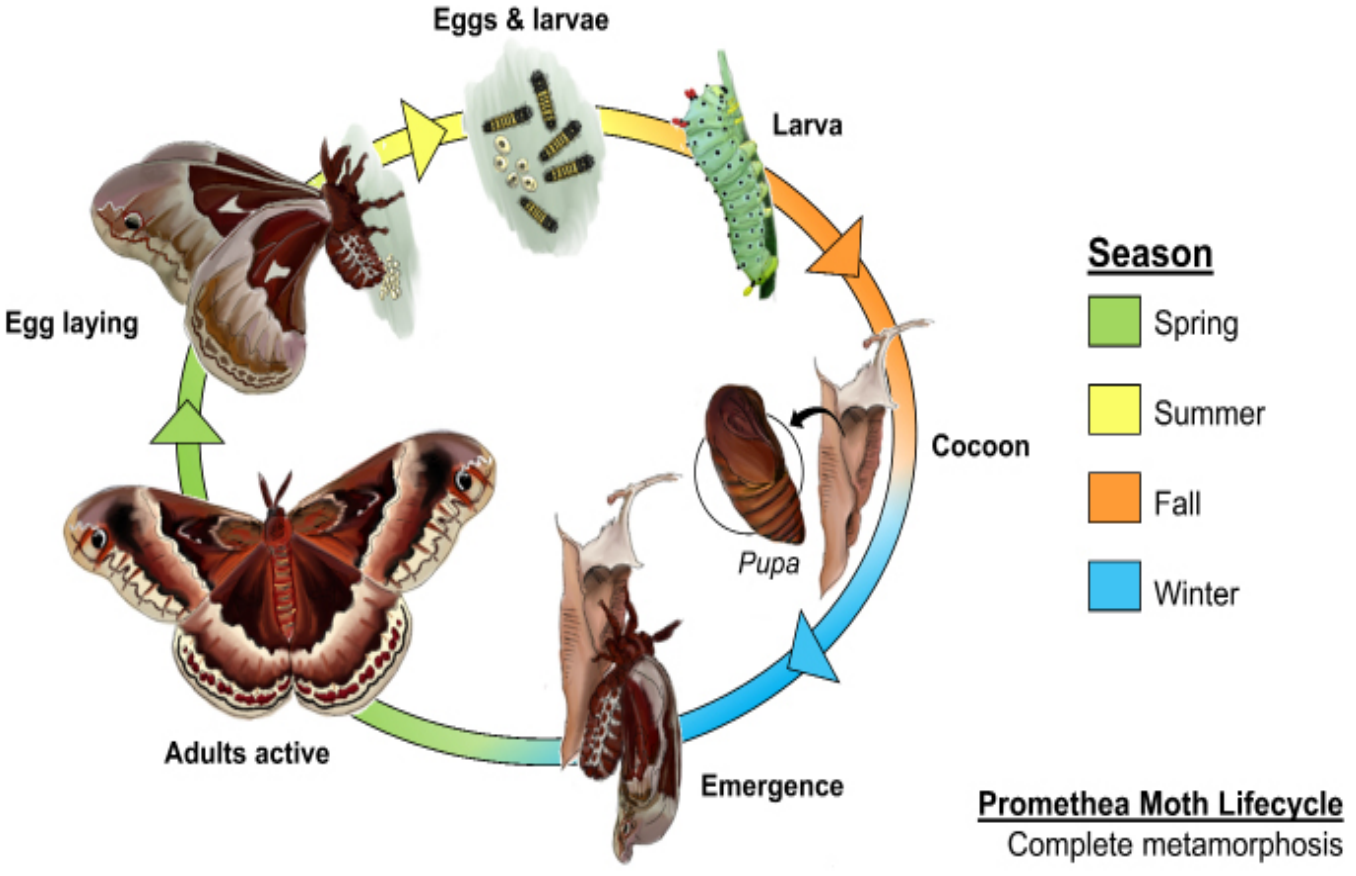
Adult insects can lay anywhere from a few eggs to many thousands of eggs. These eggs can take days to months to hatch, with some eggs enduring the winter before hatching. Insects that have specific hosts as larva are often laid on or near that host. The immature insect's main priority is to eat and grow. Immature insects must molt to grow, with the stages between molts being called instars.

NO METAMORPHOSIS

Some primitive insects develop with no metamorphosis. These insects go from egg to immature to adult with little change from the immature to adult stages other than size. Immature insects that lack metamorphosis look and function like the adults but are slightly smaller and don't have fully developed reproductive organs. Once the insect has functional reproductive organs it is considered an adult, although it may continue to grow and molt. None of the groups that are ametabolous possess wings as adults.

79. Incomplete metamorphosis is a common insect lifestyle reflected in groups such as grasshoppers, cicadas, aphids and stoneflies





77. Complete metamorphosis is common to many insect groups including beetles, bees, butterflies, and flies.

INCOMPLETE METAMORPHOSIS

Incomplete metamorphosis contains three stages: egg, nymph, and adult. There are two broad classifications of incomplete metamorphosis: paurometaboly and hemimetaboly. Immatures of paurometabolous insects are called nymphs, are terrestrial, and usually resemble the adult insect but lack wings. Grasshoppers and true bugs are examples of paurometabolous insects. Immatures of hemimetabolous insects are usually called naiads, are aquatic, and do not strongly resemble the adult insect. Dragonflies and damselflies are examples of hemimetabolous insects. Incomplete metamorphosis does not include the pupa stage and nymphs transition directly to adults during the final molt.

COMPLETE METAMORPHOSIS

Complete metamorphosis contains four stages: egg, larva, pupa, and adult. The egg hatches into a larva that eats, grows and molts into multiple instars, and then pupates. Some pupae will 'spin' their own silk cocoons to pupate in. Pupae might also be surrounded with cut leaf pieces or other natural material. Pupae can be found in protected locations such as in the soil, leaf litter, crevices of tree bark, between rocks, and sometimes in the open with excellent camouflage. The pupa transitions into the adult insect that then reproduces and starts the cycle over again. Bees, beetles, moths and butterflies are examples of insects that undergo complete metamorphosis.

INSECT ORDER DESCRIPTIONS

The following summaries of currently accepted insect orders include the scientific order name, the common name, examples of insects in the order, the type of mouth parts, the type of metamorphosis, and other distinguishing characteristics of the order. With new information, the way insects are classified is subject to change over time. The orders are arranged alphabetically.

BLATTODEA

COCKROACHES, TERMITES

- **Chewing mouthparts**
- **Two pairs of wings**
  - **Forewings hardened into leathery tegmina (cockroaches)**
  - **Wings, when present equal in size and shape (termites; only reproductives have wings)**
- **Incomplete metamorphosis**

All cockroaches (4,400 known species) and termites (3,000 known species) are classified in Blattodea. These two insect groups often appear and behave very differently from one another. They were originally separated into two different orders until 2008, when we learned from DNA analysis that termites arose from cockroach lineages. It may seem hard to believe, but termites and cockroaches share many similar behaviors. They both (to varying degrees) engage in social behavior, subsist on decaying organic matter, and primarily live in wet, warm environments. While most termites must work cooperatively to care for their young and defend their nest, cockroaches are usually more independent but often benefit from cooperation with their fellow cockroaches. A few groups of cockroaches are known to exhibit more complicated social interactions, which are similar to primitive termites.

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These termites (top left, top right) and cockroaches (bottom) are both in the order Blattodea

COLEOPTERA

BEETLES

- **Chewing mouthparts**
- **Two pairs of wings**
- **Forewings hardened into elytra**
- **Complete metamorphosis**

Coleoptera translates to 'sheath wing' and includes all beetles, which is the largest insect order of them all containing over known 400,000 species. Beetles are found all over the world and live in almost every habitat imaginable (except for in the sea or polar regions)! They are easy to identify from the hardened forewings, or 'elytra', that shield the hindwings which are protected at rest and used during flight. Beetles can be beneficial predators, like lady beetles or ground beetles that eat insect pests like aphids or caterpillars. However, some beetle species are themselves troubling insect pests, like the Colorado potato beetle or root weevils, that eat up agricultural crops. Charles Darwin was a famous beetle collector and frequently referred to them in his writings on natural selection and evolution.

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Beetles assume a diversity of shapes and size, but common to all beetles are the presence of hardened forewing, or 'etlyra' that protect the hind wings when not in use.

COLLEMBOLA

SPRINGTAILS

- **Chewing mouthparts**
- **Wings absent**
- **No metamorphosis**
- **Collophore (grooming structure) and often a furcula (jumping organ) present**

Springtails are one of the three groups of non-insect hexapods that are closely related to insects. More than 8,200 species have been described worldwide. Springtails are detritivores that feed on decaying plant material, algae and lichen, and rarely on the roots of plant seedlings. They are found in moist environments, such as leaf litter, under the bark of fallen logs, and in mulch, although a few species can tolerate drier conditions and might be found on sidewalks and similar environments. Springtails use a pair of specialized organs on the underside of the body to jump up to 100 times their body length, usually to escape predators.

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DERMAPTERA

EARWIGS

- **Chewing mouthparts**
- **Two pairs of wings**
- **Strong pincers (cerci) at end of abdomen**
- **Incomplete metamorphosis**

There are 2,000 known species in the order Dermaptera (earwigs), of which only 25 occur in North America. You may be familiar with the earwig's oily brown coloration, flattened elongated body and abdominal pincers. Earwigs are often found in damp crevices and they are most active at night. Many earwig females are devoted mothers and provide care and protection to their offspring, which is uncommon for most insect species. Earwigs are scavengers and eat diverse foods ranging from decaying organic matter to small insect prey. Recently, earwigs have been found to serve as important predators of aphid pests in apple orchards.

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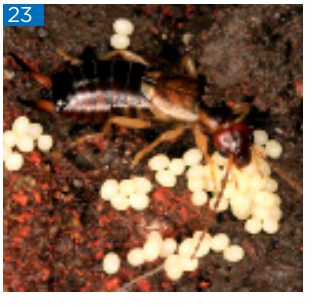

Earwig mothers are often known to care for their offspring (top left) and are easily identifiable from the abdominal pincers at the end of their bodies. The pincers are used for many different purposes, including as a defense against predators, to catch prey, or in mating and courtship behaviors.

DIPLURA

TWO-PRONGED BRISTLETAILS

- **Chewing mouthparts**
- **Wings absent**
- **Two long cerci on the end of the abdomen**
- **No metamorphosis**

Two-pronged bristletails are one of the groups of non-insect hexapods. In North America, they are divided into two groups based on the appearance of the cerci – one group has long, thread-like cerci and the other has the cerci developed into stout pinchers. Two-pronged bristletails live in leaf litter and other moist environments. Some species are detritivores that feed on decaying plant material, others feed on living plant material, while others are predators that feed on small arthropods. Approximately 125 species are known from North America.

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DIPTERA

FLIES

- **Mouthparts highly variable**
  - **Piercing/sucking**
  - **Cutting/lapping**
  - **Sponging**
- **One pair of wings**
  - **Hind wings developed into halters**
- **Complete metamorphosis**

While an estimated 1,000,000 species are in the Diptera order, we have only described about 125,000 of them today. Common to all flies is their two wings and large compound eyes. Flies are, without a doubt, one of the most economically impactful insects in human society today. Many flies including bee flies and hover flies are often underappreciated as critical pollinators of wild and managed ecosystems, and flies often serve as model organisms for scientific research. Mosquitos and houseflies are well-known to transmit diseases such as malaria or cholera (respectively) to millions of people every year.

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Flies display an astonishing diversity of lifestyles and behaviors

EMBIOPTERA

WEBSPINNERS
(not known to occur in Pennsylvania)

- **Chewing mouthparts**
- **Two pairs of wings or wingless**
- **Tarsi of forelegs developed to spin silk**
- **Incomplete metamorphosis**

The webspinners of the order Embiidina are found in tropical and subtropical regions and live socially in silk galleries that are collectively spun from glands on their front legs. Over 400 species are known, all between 0.6 and 0.8 inches in length. The silken galleries provide protection to social colonies from predation and maintain moisture, and are typically built on rocks, trees or leaf litter. Adult males lack mouthparts and only live long enough to breed while adult females are flightless and eat a variety of plant materials. Female flightlessness limits the rate of dispersal of webspinning colonies and they are not generally considered to be of agricultural concern.

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EPHEMEROPTERA

MAYFLIES

- **Chewing mouthparts (vestigial as adults)**
- **Two pairs of wings held vertically at rest**
- **Incomplete metamorphosis**
- **Immatures are aquatic**

The order name Ephemeroptera translates to "ephemeral wing", which refers to the short lifespan mayflies have as adults. Since adult mayflies lack functional mouthparts, these species typically live just a few hours to a few days or weeks. Mayflies spend most of their lifetime underwater as nymphs in aquatic creeks and streams, where they breathe through gills located on the abdomen. The diversity and abundance of mayfly and other aquatic insect species can be and often are sampled in waterways as an indicator of stream health. Adults are easy to identify because of the way they hold their wings upright at rest. They are active in Pennsylvania between April and September, depending upon the species. While we know of over 3,000 mayfly species worldwide, only about 230 species are found in Pennsylvania.

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These terrestrial mayfly adults look very different from their aquatic, immature forms

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HEMIPTERA

TRUE BUGS, LEAFHOPPERS, APHIDS

- **Piercing mouthparts**
- **Two pairs of wings**
  - **Forewings modified into hemelytra**
- **Incomplete metamorphosis**

Insects in this order are commonly referred to as true bugs. The order name Hemiptera translates to 'half-wing', which refers to the way the forewings are modified into hemelytra that are partially hardened and partially membranous. More than 50,000 to 80,000 species occur worldwide and they display an astonishing diversity of appearances and lifestyles. Common to all true bugs is the presence of piercing/sucking mouthparts, which can pierce substrates like plant stems or insect or vertebrate prey to get to the nutritious fluids inside. True bugs share a deep and wide-ranging association with human history. Some true bugs, such as the scale insects, are cultivated for the production of cochineal dye and shellac, and others serve as effective biological control agents as predators of agricultural pests. Unfortunately, other true bugs can impact human health or are major crop pests. For example, kissing bugs in Central America can transmit Chagas disease, which affects millions of people in that region every year. Bed bugs are another well-known pest that, while they don't transmit disease, are annoying and pestiferous nonetheless. Aphids, planthoppers and mealybugs are common agricultural and nursery pests that often require pesticide applications to control.


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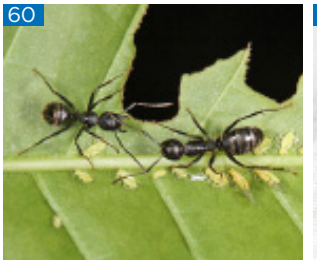
HYMENOPTERA

BEES, WASPS, SAWFLIES, ANTS

- **Chewing mouthparts**
  - **May be modified into chewing/ lapping mouthparts**
- **Two pairs of membranous wings**
- **Complete metamorphosis**

Bees, wasps, ants and sawflies are nested within the order Hymenoptera, which is Latin for 'membrane wing', or 'married wing', depending on who you ask. Both interpretations are accurate, as all winged insects in Hymenoptera have two pairs of membranous wings, in which a series of hooks connect, or 'marry', the hind wings to the fore wings for flight. Hymenoptera is a large order (over 153,000 species) which plays all sorts of interesting ecological roles in the environment and ranging from predators to parasitoids to pollinators. Honey bees are the most familiar species within the order, as they provide essential pollination services to fruit, nut and seed crops around the world. However, most Hymenopterans do not live socially like honey bees do: a lot of variety in cooperative living is represented in this insect group, ranging from completely solitary insects to fully eusocial colonies.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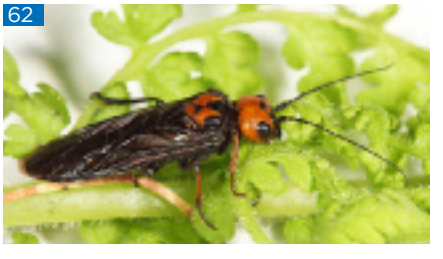
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Hymenopterans are extremely diverse and express a diversity of beautiful forms

LEPIDOPTERA

MOTHS AND BUTTERFLIES

- **Siphoning mouthparts**
- **Two pairs of wings**
- **Complete metamorphosiss**

About 180,000 species of moths and butterflies are in the order Lepidoptera. 'Lepidoptera' is from Ancient Greek and means scale wing, which refers to the flattened hairs, or scales, that underly the beautiful, colorful and patterned wings they are known for. Butterflies and moths are often recognized as important pollinators because the adults sip nectar from flowers. However, these pollination services are generally not as efficient as those provided by bees, wasps and flies, as they are less effective at moving pollen between flowers. Many moth and butterfly species share a tight evolutionary association with specific host plants, which means their very existence is highly dependent on having the right flowering plants available to them for growth and reproduction. In Pennsylvania, the frosted elfin, the regal fritillary and the monarch butterfly have all become 'critically imperiled' due to a lack of available native host plants (yellow and wild indigo, violets, and milkweed, respectively) where they occur.

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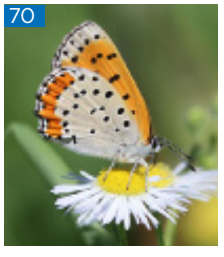

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MANTODEA

MANTIDS

- **Chewing mouthparts**
- **Two pairs of wings**
  - **Forewings modified into leathery tegmina**
- **Front legs adapted to capturing prey (raptorial)**
- **Incomplete metamorphosis**

Mantodea includes all praying mantises, of which 2,400 species are known globally. These charismatic, carnivorous insects are easy to spot because of their triangular shaped head, long "neck", and grasping, raptorial forelegs. Mantids hunt for their prey as ambush predators or through slow and steady stalking. They are exceptional hunters and have been known to catch not just other insects (both beneficial and pestiferous), but also small vertebrates such as lizards, fish, frogs or birds. Mantids are easiest to spot in the late summer and early fall during their mating season. There are just five mantid species known to occur in Pennsylvania, and just one of those, the Carolina mantis, is native to the United States.

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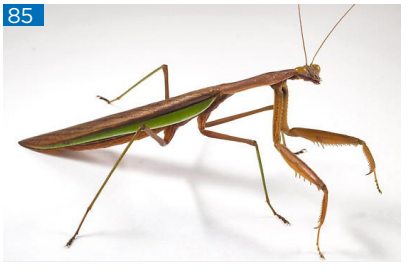

MECOPTERA

SCORPIONFLIES

- **Chewing mouthparts**
- **Two pairs of wings**
- **Complete metamorphosis**
- **Head often elongated**

Mecoptera, or scorpionflies, are perhaps less universally known than other more popular or speciose orders. Scorpionflies are so-named because males of many species have enlarged genitals that look somewhat like a scorpion's stinger. Most of the 600 known species have ranges restricted to tropical regions. Pennsylvania is home to just 11 species. Different species are active at different times of year, including in the middle of winter for one family called snow scorpionflies. Scorpionflies thrive in damp, moist environments and are mostly scavengers of decaying plant matter or dead, soft-bodied insects.

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MEGALOPTERA

DOBSONFLIES, ALDERFLIES

- **Chewing mouthparts**
  - **Males often have large mouthparts**
- **Two pairs of wings**
- **Complete metamorphosis**

Dobsonflies, alderflies and fishflies are in the order Megaloptera and are characterized by the adult's very large wings relative to their body size. The larvae are aquatic predators that grow slowly, taking between one and five years to reach maturity. While there are 300 known species in this order, we do not understand very much of their biology due to their short adult lives, nocturnal habits, and limited human encounters in the wild.

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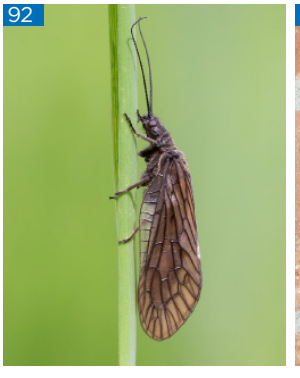

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Male dobsonflies (93) are easily recognizable from the large mandibles they use to attract female mates. Immature dobsonflies (94) are often called 'hellgrammites' and use their strong mandibles to catch and eat prey.

MICROCORYPHIA

JUMPING BRISTLETAILS

- **Chewing mouthparts**
- **Wingless**
- **No metamorphosis**

The Microcoryphia are wingless insects that are commonly called jumping bristletails. They are the most evolutionarily primitive insects that exist today and have a cosmopolitan distribution. There are over 500 species of jumping bristletails, which are so-named because of their three-pronged tails and because they can perform some impressive and acrobatic jumps to get around. These insects are small, usually brownish-yellow in color and found in damp, dark environments like in leaf litter or in other decomposing materials. Individual jumping bristletails can live for up for four years and it can take a full two years for them to reach sexual maturity.

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NEUROPTERA

LACEWINGS, ANTLIONS

- **Chewing mouthparts**
- **Two pairs of wings**
  - **Wings have net-like venation**
- **Complete metamorphosis**

Neuroptera includes 600 species of lacewings and antlions. They have large, membranous wings which with heavy venation. Nearly all insects in this order are terrestrial, live in vegetation and feed on soft-bodied prey such as aphids, scale insects and mites. Species that are not predatory visit flowers and eat pollen and nectar. The cocoons of pupating Neuropterans are frequently composed of organic debris that aid in camouflage at this vulnerable stage.

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NOTOPTERA

ICE CRAWLERS, ROCK CRAWLERS, HEEL-WALKERS (do not occur in Pennsylvania)

- **Chewing mouthparts**
- **Wingless**
- **Incomplete metamorphosis**

Notoptera is a small order of wingless insects and includes the ice crawlers (suborder Grylloblattodea) and rock crawlers or gladiators (suborder Mantophasmatodea). There are fewer than 60 living species included in the order, although they were more diverse in the past and are known from a number of extinct fossil groups. Ice crawlers in North America are associated with glaciers and ice caves of western mountain ranges and cannot survive the heat from being held in a human hand. They are often nocturnal and eat insects that are blown onto glaciers or into caves and killed or immobilized due to the cold. Due to their limited distribution, these rare insects are infrequently encountered and not much of their biology is known. Rock crawlers were known only from amber fossils until living specimens were discovered in Namibia in 2002. Since then, 21 extant species have been described, all of which are only found in Africa.

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ODONATA

DRAGONFLIES, DAMSELFLIES

- **Chewing mouthparts**
- **Two pairs of wings**
  - **Wings cannot be folded over the abdomen**
- **Incomplete metamorphosis**
- **Immatures are aquatic, with extendable labrum**

There are about 5,900 species of damselflies and dragonflies that have been described in the order Odonata. Most of their life is lived underwater as nymphs and they are most active as flying adults in Pennsylvania during June and July. Both nymphal and adult stages are predators of smaller insects. In adulthood, nearly everything that Odanates do is performed on the wing, including hunting, eating and mating. This order is particularly sensitive to changes in water quality and climate, making damselflies and dragonflies valuable ecological indicators of freshwater systems.

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ORTHOPTERA

GRASSHOPPERS, CRICKETS, KATYDIDS

- **Chewing mouthparts**
- **Two pairs of wings**
  - **May be wingless**
- **Hind legs typically enlarged for jumping**
- **Incomplete metamorphosis**

Grasshoppers, locusts, katydids and crickets are all in the order Orthoptera, representing over 20,000 species globally. They are easiest to recognize from the sounds that they make by rubbing their wings or legs against each other, which is important for courtship, and are active throughout the spring, summer and fall in Pennsylvania. Locusts pose unique and difficult agricultural challenges, as demonstrated by their decimation of West African crops in 2020 and 2021. While primarily herbivorous, most species are not of significant agricultural concern.

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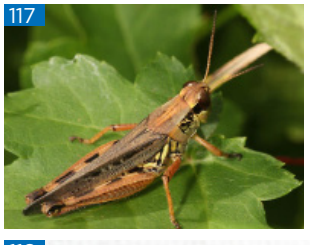

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PHASMATODEA

WALKING STICKS

- **Chewing mouthparts**
- **Winged or wingless**
  - **If winged, forewings developed into leathery tegmina**
- **Long, skinny body**
- **Incomplete metamorphosis**

The walking sticks and leaf insects, classified in the order Phasmatodea, are found on every continent but Antarctica. They are highly camouflaged to resemble twigs or leaves, and primarily feed on leaves. There are over 3,000 known species, although only two occur in Pennsylvania. When walking sticks are approached by potential predators, rather than remaining still, they often can expel defensive compounds, engage in a showy display, or make loud, disruptive noises by rubbing their wings together to scare the predators away. Walking sticks are susceptible to habitat fragmentation, pesticide use and collection for the pet trade in certain parts of the world. Some of the largest insects known today are walking sticks, which can reach over 20 inches in length in tropical regions.

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PLECOPTERA

STONEFLIES

- **Chewing mouthparts**
- **Two pairs of wings held flat along back at rest**
- **Incomplete metamorphosis**
- **Immatures are aquatic**

Plecoptera includes over 3,500 species of stoneflies. The nymphs are aquatic and require between one and four years to reach maturity, which is usually short-lived. Stoneflies are highly sensitive to polluted and poorly oxygenated water, so are often used as water quality indicators like mayflies (Ephemeroptera) and caddisflies (Trichoptera). Stonefly nymphs are popularly referenced by fly fisherman in the making of lures for flyfishing. The adults are recognizable from paired cerci projecting from the tip of the abdomen and their beautifully veinated wings that lay flat against the body (unlike mayflies).

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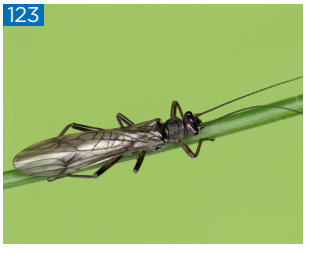

PROTURA

CONEHEADS

- **Chewing mouthparts**
- **Wings absent**
- **No metamorphosis**

Protura are one of three groups of non-insect Hexapods that are closely related to insects. Like two-pronged bristletails and springtails, coneheads are found in moist leaf litter. However, unlike the other two groups, they are extremely small (<2 mm) and unlikely to be seen without a microscope. While they are tiny and inconspicuous, more than 750 species have been described worldwide and 80 species are known to occur in North America. Unlike insects, springtails, and two-pronged bristletails, coneheads lack antennae. Instead, their first pair of legs are modified into sensory organs that are held above and in front of the body while the second and third pairs of legs are used for walking.

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PSOCODEA

PARASITIC LICE, BOOK LICE, BARK LICE

- **Piercing or chewing mouthparts**
- **Wingless or two pairs of wings**
- **Incomplete metamorphosis**
- **Parasitic groups associated with bird or mammal hosts**

Book lice, bark lice and true lice are all housed within the order Psocodea, which includes over 11,000 species in total. Humans are most familiar with the true lice, which are common blood feeding parasites capable of vectoring diseases such as typhus. Book lice and bark lice are less frequently encountered and are small scavenging insects the primarily feed on fungi, algae, lichen and other organic detritus. Book lice get their name for their novel association with old books, from which they survive on the paste used in the bindings. Bark lice live on the bark of tree trunks and are easy to spot from the characteristic webbing they produce (which is not harmful to the trees). There is much variation in the appearance of different lice species; some are wingless, some lack ovipositors and they exhibit a range of body shapes.

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RAPHIDIOPTERA

SNAKEFLIES
(do not occur in Pennsylvania)

- **Chewing mouthparts**
- **Two sets of wings**
- **Complete metamorphosis**

Snakeflies are predatory insects that possess a notably elongated thorax. While there are just 260 living species, many extinct species are known from fossils and they were apparently much more diverse in the past. Snakeflies are mostly found in temperate regions and in North America limited to areas west of the Rocky Mountains. Snakeflies live beneath the bark of trees, in small crevices in rocks or among leaf litter, and can require up to three years for larvae to reach maturity.

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SIPHONAPTERA

FLEAS

- **Chewing mouthparts**
- **Wingless**
- **Complete metamorphosis**

There are over 2,500 species of fleas, all of which are small, dark-colored, flightless insects that feed on the blood of various bird and mammal hosts. Fleas are small with a narrow or flattened body plan that make it easy for them to navigate the feathers or hairs of their hosts. They are well known for their jumping abilities, which comes from specially adapted hind legs that store energy for propulsion. Fleas cannot live for more than a few days as larvae or adults without a host.

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STREPSIPTERA

TWISTED-WING PARASITES

- **Piercing mouthparts**
- **Males have one pair of wings with the other pair reduced to small appendages**
- **Complete metamorphosis**

Strepsipterans are also known as the twisted-wing parasites. While 530 species are known worldwide, only about 110 occur within the United States. Strepsipterans survive as internal parasites that reside inside various bee, wasps, grasshopper and true bug species. They exhibit a specialized developmental habit known as hypermetamorphism whereby the larvae take on two distinct physical forms before reaching sexual maturity: a dispersing, crawler form to find the host and then a physical form lacking any distinctive features once inside the host. Upon pupation, adult male and female body plans vary substantially. Male strepsipterans have one pair of wings (the forewings are reduced), large eyes and legs while female lack these parts and lives her life largely immobile inside the host with just her copulatory organs exposed to the environment to mate. Male strepsipterans lack functional mouthparts and live only long enough to mate, so are rarely seen or collected. Eggs hatch in the host as crawlers and the cycle begins again.

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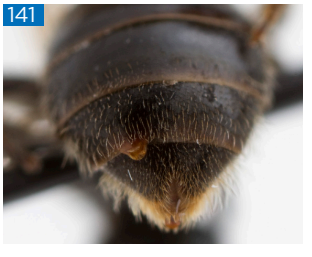

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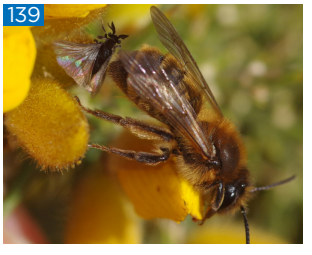

THYSANOPTERA

THRIPS

- **Punching/sucking mouthparts**
- **Two pairs of wings**
  - **Wings fringed**
- **Incomplete metamorphosis with a pupa-like resting stage**

Thrips are small (usually 1mm or less), slender insects with fringed wings that feed on plants or are predatory on other small insects. Their mouthparts are unlike those of any other insect group – the left mandible is used to "punch" a hole into the food and then long, proboscis-like mouthparts are used to suck the out the contents of the plant or animal. Cycad-associated thrips are believed to have been the first pollinivores and predated the evolution of bee and butterflies. Thrips are most well-known as a major agricultural pest of crops, as their feeding on plant tissues can damage crops and they can vector over 20 known viruses that can permanently damage entire orchards. They are quick to develop chemical resistance to pesticide applications and represent some of the fastest-spreading invasive species in the world.

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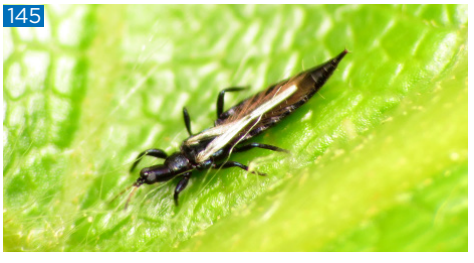

TRICHOPTERA

CADDISFLIES

- **Piercing mouthparts**
- **Two pairs of wings held like a pup-tent over body**
  - **Wings covered in hair**
- **Complete metamorphosis**
- **Immatures are aquatic**

The order Trichoptera, which are commonly called caddisflies, contains approximately 14,500 species worldwide. Adult caddisflies are usually nocturnal and resemble moths, which they are closely related to. The wings of caddisfly adults are covered in hairs, which have the same origin as the flattened scales of moths and butterflies. Caddisfly larvae are aquatic and are best known for their tendency to craft protective cases around themselves from nearby sand, gravel, shells, leaves, sticks, and other material. The structure and preferred materials for case construction vary by species and can aid in identifying caddisflies, often to the level of genus even without physical examination of the larva inside. Trichoptera larvae are frequently associated with creeks, streams and rivers and are usually intolerant of pollution, so the presence or absence of caddisflies can help determine whether a body of water is polluted or not. Larvae are important prey for fish and other larger, aquatic insects.

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ZORAPTERA

ZORAPTERANS

- **Chewing mouthparts**
- **Two pairs of wings or wingless**
- **Incomplete metamorphosis**

Insects in the order Zoraptera are also known as the angel insects. Of the 55 living and extinct members of this order, only two are known to occur in the U.S. They are small, soft bodied insects that generally live socially in rotting wood, under the bark of fallen trees, and are often associated with termite colonies. Zorapteran colonies include one dominant male who mates with the females in the colony. As detritivores, these insects are excellent custodians of the environment as they eat up and help break down decaying organic matter.

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ZYGENTOMA

SILVERFISH, FIREBRATS

- **Chewing mouthparts**
- **Wingless**
- **No metamorphosis**

Zygentoma includes 550 described species. Many species are commonly referred to as silverfish because of the silvery scales that cover their bodies. They are nocturnal, small, wingless insects that are cosmopolitan and frequently found in dusty basements, attics, sinks, kitchens or bookcases. They are detritivores that can consume a diverse array of materials. In nature, this makes them important decomposers.

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INSECT CONSERVATION

Insect declines have been occurring globally over the recent decades. Many factors contribute to insect decline, including habitat loss and degradation, pesticide use, and outdoor lighting.

HABITAT

Habitat loss, degradation, and fragmentation are leading factors of insect decline. Habitat loss is straightforward – without places to live, feed, and breed, insects cannot exist. Habitat degradation includes a variety of issues that make otherwise healthy habitat unsuitable to insects. For example, the presence of invasive plant species that outcompete the native plants Pennsylvania's insects evolved with degrade habitat since many insects cannot utilize the invasive plants. Habitat fragmentation is the breaking up of healthy habitat into smaller blocks. Insects often cannot travel far, so large gaps between habitat can stop groups of insects from mating. Once geneflow between patches of habitat slows or stops, isolated populations can become inbred and eventually die out, even in otherwise appropriate habitat.

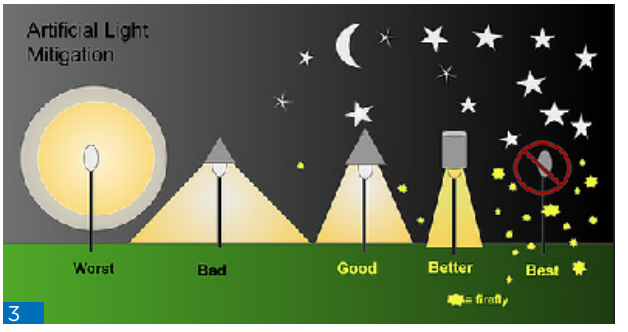
Protecting natural habitats and a planting diversity of native plants are some of the easiest ways to promote habitat for native insects. Since many pupae are found in leaf litter, leaving an area of leaf litter around trees in the autumn can greatly benefit insects.

PESTICIDES

Inappropriate pesticide use is a direct threat to insect survival so minimizing pesticide use can benefit native insects. Utilizing Integrated Pest Management (IPM) to the greatest extent possible may lead to less dependence on pesticides and healthier insect communities. Integrated pest management utilizes thresholds of acceptable damage, the use of natural predators to control pests, practices such as crop rotation, and finally judicial pesticide use if needed. Some considerations when using pesticides include timing of pesticide use, the specific pesticide selected, and the method of application. For homeowners, allow the propagation and blooming of dandelions and clovers in lawns to provide important forage to beneficial insects such as bees.

OUTDOOR LIGHTING

Artificial outdoor lighting can disrupt insect reproductive activity, especially of nocturnal insects but also of day-active insects. Minimizing the amount of outdoor lighting as much as practical and utilizing motion-activated lights can reduce the impact on insects. Using yellow lights also has less impact than white lights that are attractive to many insects.



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GLOSSARY

ABDOMEN: Rear most body segment of an insect

COCOON: The case in which the pupa transforms into an adult

COMPOUND EYE: An eye composed of many small eyes

EXOSKELETON: The hard outer "skin" of the insect

HALTERE: Small knobbed or club-like vestigial hind wing of flies

HOST: The living organism on which another organism depends for survival. Monarch caterpillars rely on milkweed host plants for development

INSTAR: The stages of an insect between molts

INTEGRATED PEST MANAGEMENT: Sustainable decision-making process that utilizes different methods to reduce risks from pests and to native insects. The process utilizes thresholds of acceptable damage, a variety of practices to reduce pest risk, and still allows for judicial pesticide use if needed.

LARVA: The insect stage between the egg and pupa for insects going through complete metamorphosis

METAMORPHOSIS: The change in structure and size of an insect as it develops

NYMPH: The immature stage of an insect between the egg and adult going through incomplete metamorphosis

OCELLUS: Simple eye

OVIPOSITOR: Part of the insect adapted for laying eggs

PARASITE: An organism that lives on or in another organism from which it feeds. Does not usually kill the host

PARASITOID: A larval insect that lives on or in another organism from which it feeds, usually resulting in the death of that organism.

PREDATOR: An animal that kills another animal for food

PUPA: The insect stage between a larva and adult for insects going through complete metamorphosis

SCLEROTIZATION: Hardening of the exoskeleton

THORAX: The middle body segment of an insect. The legs and wings join the thorax

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