# Insects

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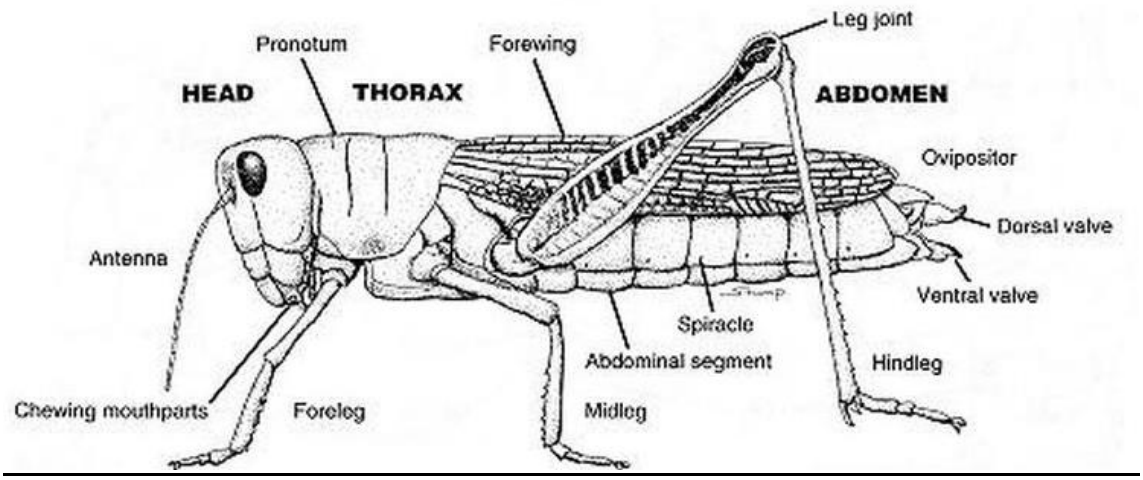
## INTRODUCTION

Insects are a fascinating group of animals that are found all over the world from the poles to the tropics. They live in water, woods, plants, soil, and even inside of other animals. They are extremely adaptive to many different environments and can thrive in the harshest of conditions. Insects are the most diverse group of animals on Earth. There are currently over a million discovered species of insects, and an estimated 6-10 million species total that have yet to be discovered. Many insects play an essential role as pollinators. Bees, for example, do just that and, in the process, make valuable products like beeswax and honey, which are both used in a wide variety of important commercial products. The Giant Silkworm Moth Larvae produces silk that is also an important resource. Other insects help our ecosystems by feeding on dead and decaying materials, and then returning them to the soil. These insects are called decomposers. Most insects feed on plants. Only a small number of insects are considered pests. Normally, these pests are known to do considerable damage to crops. They may also be parasites or carry diseases.

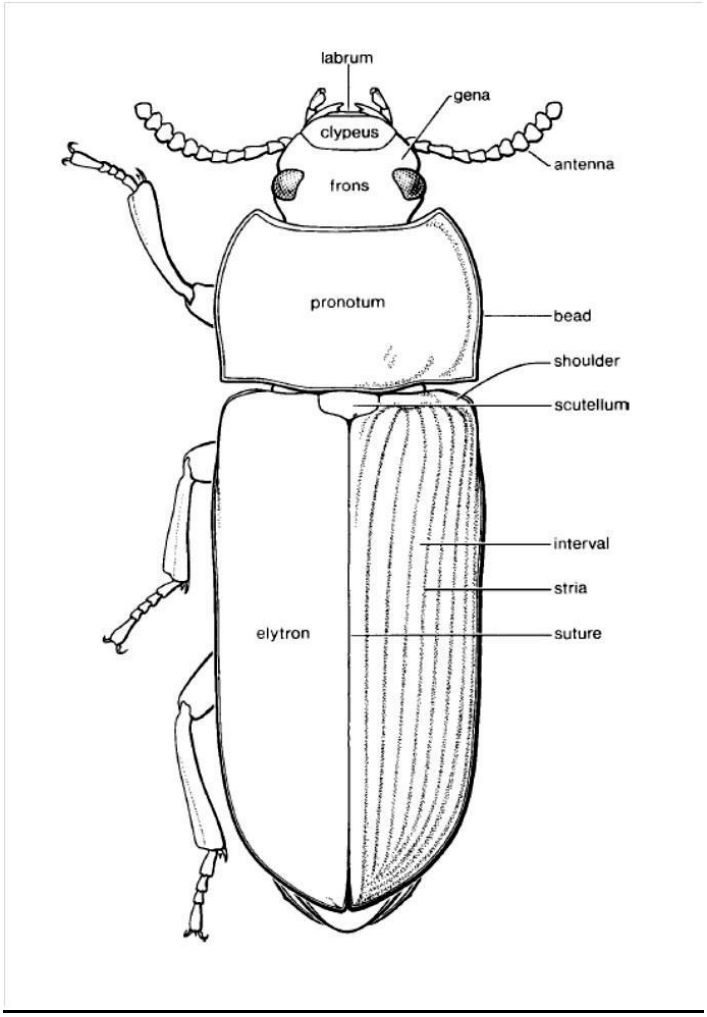
## INSECT ANATOMY

TYPICAL INSECT

Every insect has the same three basic body structures:  a head, a thorax, and an abdomen. An insect's head has two antennae, two compound eyes, and simple eyes or ocelli. The thorax is the middle section and has three pairs of legs (6 legs total) attached to it, along with one or two pairs of wings. These wings can be leathery, which means they are thickened and resilient. They can also be membranous, meaning they are flexible, thin, and finely veined. Most adult insects have two pairs of membranous wings, but flies, for example, have only one pair of flying wings and a pair of club-like halters. In beetles, the forewings are hard and armor-like. They cover the membranous hind wings used for flight. The forewings of true bugs, like the Squash Bug, are leathery and have membrane tips. The abdomen is the third part of the insect and contains the rest of the vital organs.




Insect Anatomy Example #1: Grasshopper

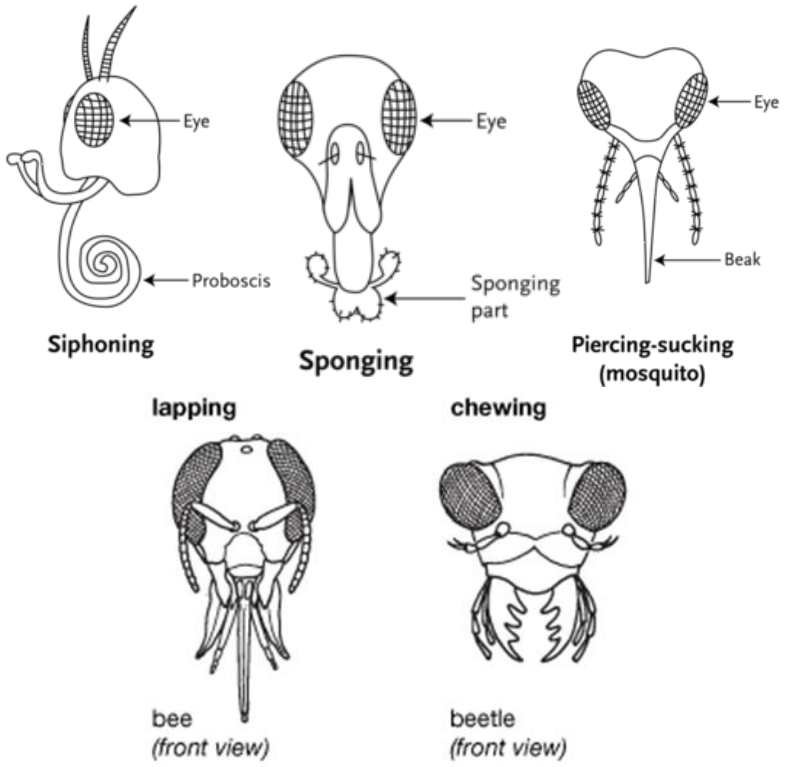



Insect Anatomy Example #2: Beetle

*NOTE: Diagrams are for reference purposes only. Participants will not be required to identify body parts on the exam.*

MOUTHPARTS

Insects as a group feed on a large variety of plant and animal matter. Because of this, they are equipped with mouth parts that are adapted for this mode of life. Five different types of mouthparts are commonly seen in insects. These include biting/chewing, piercing-sucking, siphoning, lapping, and sponging mouthparts.

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https://kids.britannica.com/students/article/insect/275066/285150-toc

## LOCOMOTION

Insects are masters of movement: roaches run, bees swarm, moths fly, mantises strike, beetles swim, caterpillars crawl, dragonflies dart, maggots squirm, water boatmen paddle, mole crickets burrow, mosquito larvae wriggle, fleas jump, whirligigs spin, collembola spring, water striders skate, and army ants march.

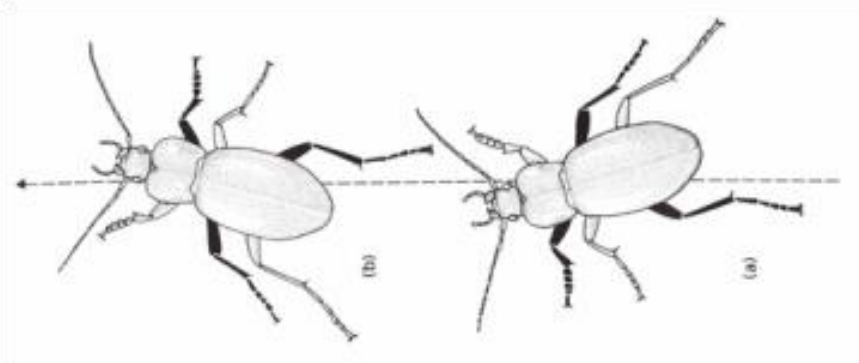
When it comes to walking, an exoskeleton can be awkward baggage as it is bulky and cumbersome for a small insect. To compensate, most insects have three pairs of legs positioned laterally in a wide stance. The body's center of mass is low and well within the perimeter of support for optimal stability. Each leg serves both as a strut to support the body's weight and as a lever to facilitate movement. At very slow walking

speeds, an insect moves only one leg at a time while keeping the other five in contact with the ground. At intermediate speeds, two legs may be lifted simultaneously, but in order to maintain balance, at least one leg of each body segment always remains stationary. This results in a wave-like pattern of leg movements known as the metachronal gait.

When running, an insect moves three legs simultaneously. This is called the tripod gait, so-named because the insect always has three legs in contact with the ground (front and hind legs on one side of the body and middle leg on the opposite side).

The coordination of leg movements is regulated by networks of neurons that can produce rhythmic output without needing any external timing signals. These networks are called central pattern generators (CPGs). Insects have at least one CPG per leg. Individual networks are linked together via interneurons, and output from each CPG is modified as needed by sensory feedback from the legs.

Only animals with a rigid body frame can use the tripod gait for movement. Soft-bodied insects, like caterpillars, have a hydrostatic skeleton. They move with peristaltic contractions of the body, pulling the hind prolegs forward to grab the substrate and then pushing the front of the body forward segment by segment. This distinctive pattern of locomotion has earned them nicknames like “inchworms,” “spanworms,” and “measuring worms.”



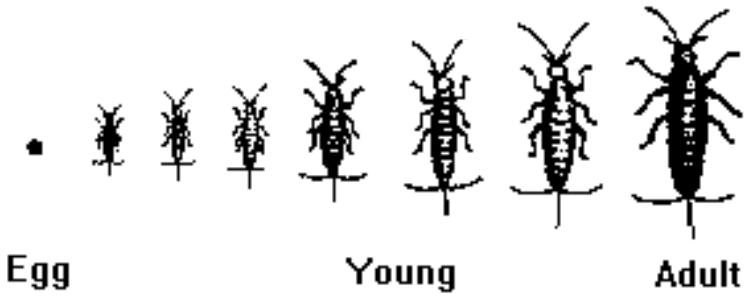
In flying insects, their method of locomotion is focused in the wings rather than the legs. In all flying insects, the base of each wing is embedded in an elastic membrane that surrounds two or three axillary sclerites. Together, these elements form a complex hinge joint that gives the wing freedom to move up and down through an arc of more than 120 degrees. The hinge is a "bistable oscillator,” it stops moving only when the wing is completely up or completely down. During flight, the wing "snaps" from one position to the other. The power for the wing's upstroke is generated by the contraction of dorsal-ventral muscles (also called tergosternal muscles). These are called "indirect flight muscles" because they have no direct contact with the wings. They stretch from the notum to the sternum. When they contract, they pull the notum downward relative to the fulcrum point and force the wing tips up. Elasticity of the thoracic sclerites and the

hinge mechanism allows as much as 85% of the energy involved in the upstroke to be stored as potential energy and released during the down stroke.

Some insects use swimming and skating for their locomotion. Many aquatic beetles (Coleoptera) and bugs (Hemiptera) use their middle and/or hind legs as oars for swimming or diving. These legs are usually flattened or equipped with a fringe of long, stiff hairs to improve their performance and efficiency in the water. The legless larvae and pupae of mosquitoes, midges, and other flies (Diptera) manage to swim by twisting, contouring, or undulating their bodies. Dragonfly naiads (Odonata) have a jet propulsion system, meaning they can propel themselves forward by contracting abdominal muscles and forcing a jet of water out of the rectal chamber that houses their respiratory gills. A few aquatic insects, such as water striders, have a whorl of hydrophobic hairs on the tips of their feet. These hairs prevent the insect's legs from breaking the surface tension of the water, allowing them to skate on the surface.

## GROWTH AND DEVELOPMENT

An insect's skeleton is external and is able to stretch at the folds between the chitinous plates. This allows the insect to grow for a while then shed its tight, old skeleton for a new larger one that is capable of stretching further. All insects cast their skeletons, or molts, a number of times during their growth from egg to adult. In most primitive insects, the general body form does not change appreciably during the process. This is direct development with no metamorphosis. In these cases, the insect will leave its egg in an advanced stage of body development and only differs from the adult in size and sexual maturity.

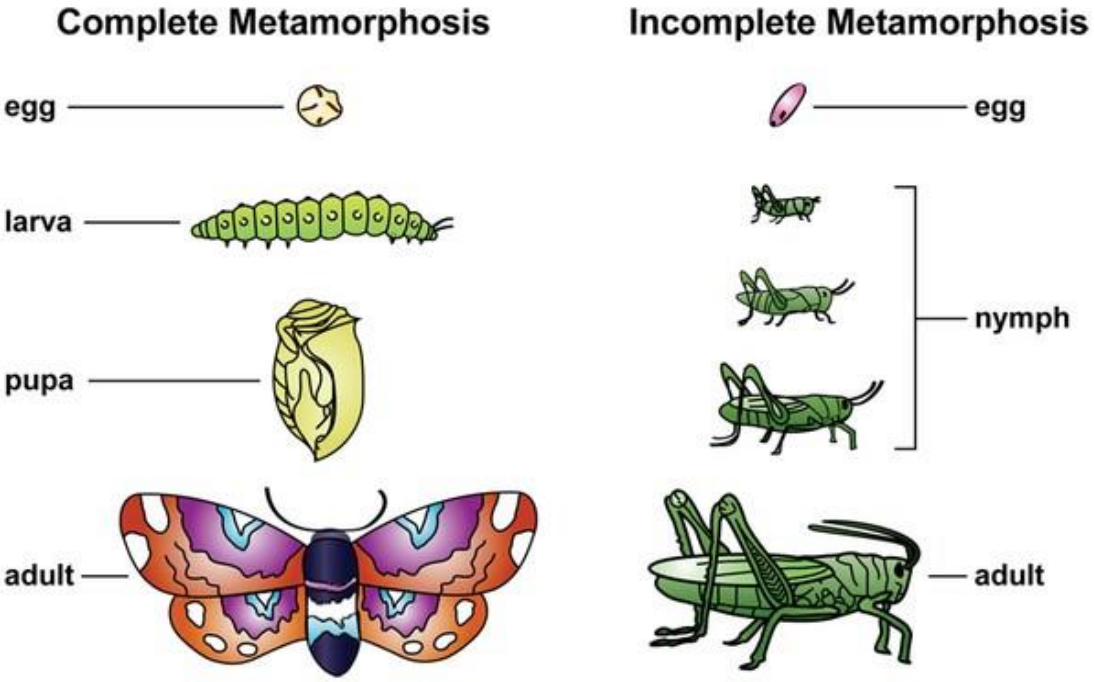



Direct Development without Metamorphosis

Immature insects like this are referred to as "young," for a lack of a more descriptive term, and their development is said to be more direct with no metamorphosis. A more advanced type of development, simple or gradual, is exhibited by insects like the grasshopper whose young, called a "nymph." Nymphs are like adult grasshoppers in a lot of ways. The nymph has both compound and simple eyes, eats the same food as the adult, and behaves in many of the same ways. The main

difference is in the wings, as the wings of the nymph are short, pouch-like extensions from the thorax wall. Its sexual organs are also not fully developed. The change from mature nymph to winged adult is a considerable transformation but is still considered to be an incomplete metamorphosis.

Complete metamorphosis occurs in beetles, butterflies, and other “higher” insects. In this type of change, the young, called “larva,” observe no characteristics like the adults. They have no trace of wings and no compound eyes like the adult form does. In this complex type of development, a transition stage (pupal period) exists between the larval and adult stages. The pupa is usually in a cell in soil, plant tissue, the silken cocoon that was fashioned by the larva, or inside the un-shed skin of the larva.




Complete vs. Incomplete Metamorphosis
Examples: Butterfly (Complete); Grasshopper (Incomplete)

## BEHAVIOR

Insects hold some of the most remarkable behavior patterns of any species in nature. Even from a young age, they show incredible instinct, and this instinct carries throughout the entire species. For example, some insects make elegant and complicated cocoons without having a large brain or any education from a parent figure.

Moths are another incredible example of instinctive behavior. Many different scientific studies and hypothesis surround the mystery of why moths are so attracted to

light. Some scientists believe moths zoom toward unnatural light sources because the lights throw off their internal navigation systems. Moths evolved at a time when all the light on Earth came solely from the distant sun, moon, and stars. They use an instinct behavior called transverse orientation, meaning they navigate by flying at a constant angle relative to a distant light source, such as the moon. Scientists have found that moths are less attracted to artificial lights during the week of the full moon than they are during the week of the new moon.

Observations of behaviors like this and behaviors from other insects have puzzled scientists for years. The exact reasons for some insect instinctual behaviors remains a mystery still today.

## CONSERVATION

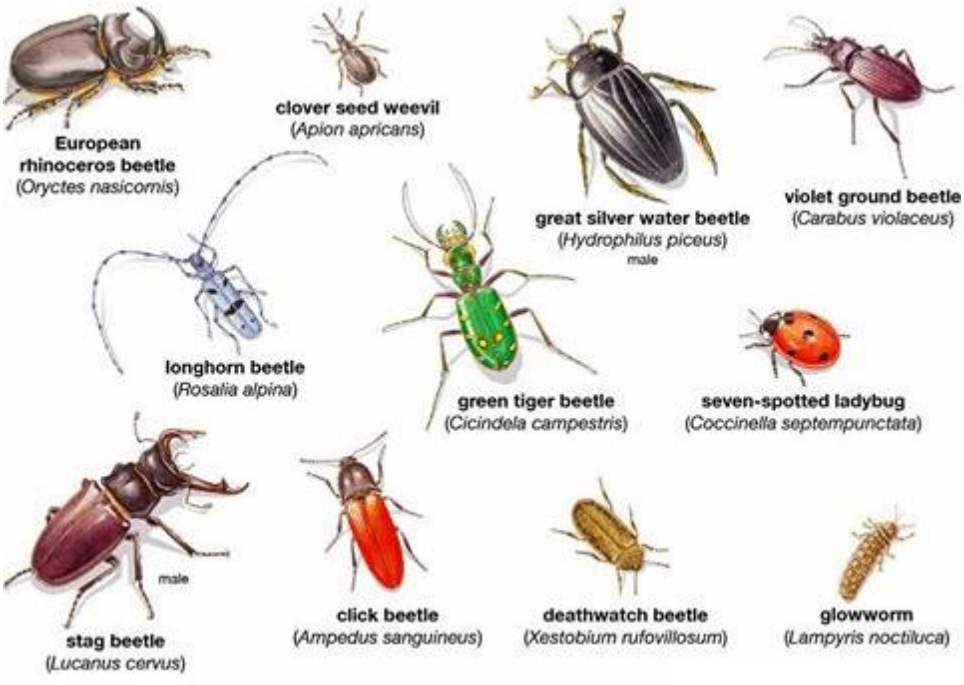
Insect populations around the world are in major decline due to things like climate change, development, and human disruption/destruction of natural habitat. In 1976, the Endangered Species Act recognized invertebrates. Since then, five insects have been placed on the Endangered Species list in Illinois alone.

## INSECT ORDERS

There are between 29 and 32 different known and accepted orders of insects in all different parts of the world. For the purpose of this competition, we will focus on the eight orders that are most commonly found in Illinois.

COLEOPTERA (Beetles)

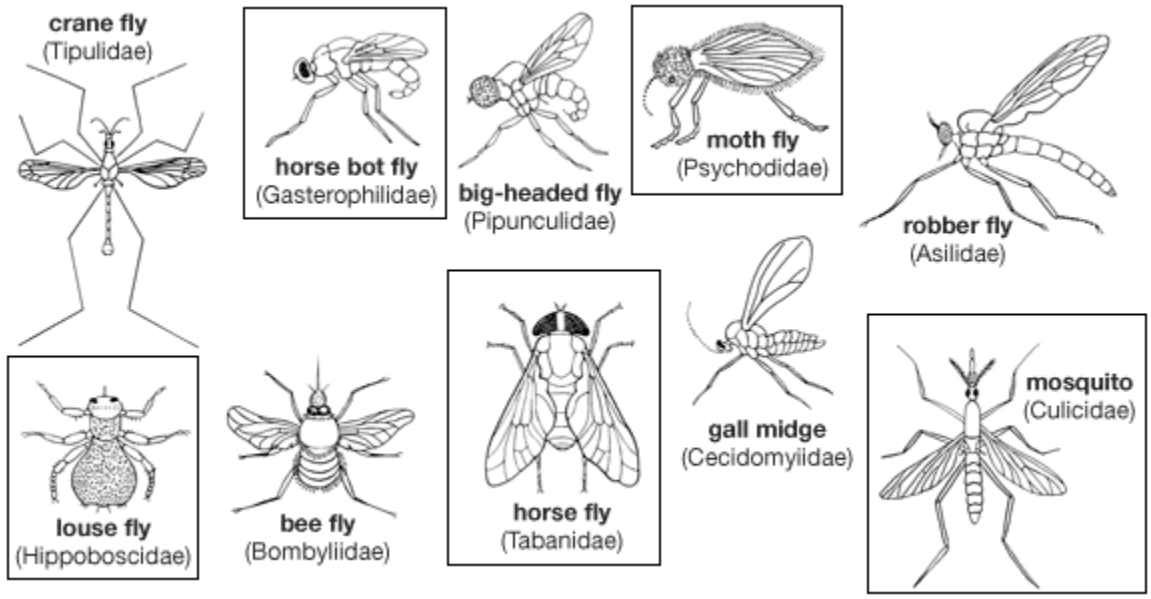
This is the largest order of insects, containing over 40% of all known insects, with over 350,000 different species recognized worldwide. Characteristics of this order include forewings that are thick, either leathery or brittle, and meet in a straight line on the back. The hindwings are membranous. They are equipped with chewing mouthparts and have a wide variety of feeding habits including acting as predators, scavengers, herbivores, and parasites. This order goes through a complete metamorphosis development.




http://www.imgrum.org/user/biologyconcepts/1909909957/1060961797005998560_1909909957

DIPTERA (Housefly, Mosquito, Crane Fly, Horse Fly, True Flies)

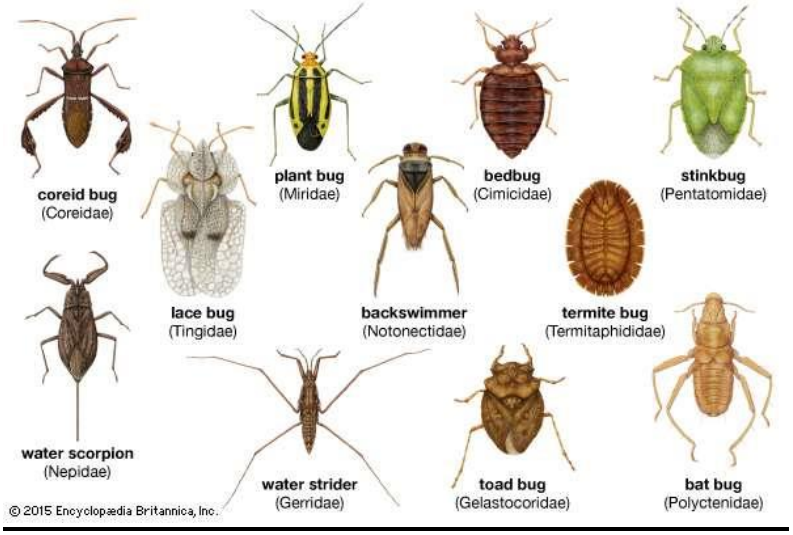
These insects are recognized by their one pair of wings. Their second pair is reduced to small knobbed structures called halters that are used for balancing. They are equipped with sucking mouthparts that are sometimes modified to sponging mouthparts. Some members of this order, like mosquitos, are blood-sucking insects. Other members are also very harmful to humans and animals because they carry diseases like malaria, sleeping sickness, and dysentery. Approximately 120,000 species are currently identified worldwide, all of which develop through complete metamorphosis.




https://www.britannica.com/animal/dipteran

HEMIPTERA (Stink Bug, Backswimmer, Giant Water Bug, Bed Bug, True Bugs)

This order, often referred to as the true bugs, is a diverse group of insects numbering about 90,000 known species worldwide. These insects have two pairs of forewings that differ in structure. The front half of each wing is thicker and more leathery while the rear half is thin and membranous. They are equipped with sucking mouthparts and vary widely in diet, habitat, etc. Some of these insects are also equipped with scent glands that help to ward off predators. These insects develop through an incomplete metamorphosis.




https://www.britannica.com/animal/heteropteran

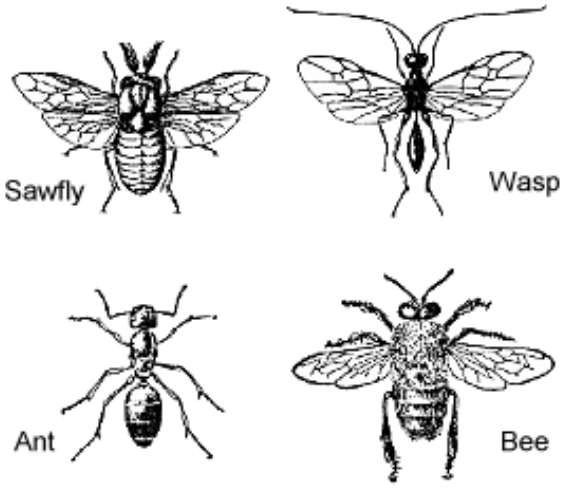
HYMENOPTERA (Wasps, Ants, Bees)

These insects can be with or without wings. If winged, they will have two pairs of membranous wings that link together with tiny hooks called hamuli. The forewings are always larger than the hind wings. These insects will have mouthparts that are shaped like a tube for taking up nectar. They are very thin-bodied, especially between the thorax and the abdomen, and have well developed compound eyes.

They are known to be one of the most social insects. For instance, the mother, along with individuals of the colonies, may or may not be directly related. This is called cooperative care of young. They also have a reproductive division of labor that evolves from sterile castes which often have certain tenancy or characteristics associated with helping behavior. An overlapping of generations exists, allowing for the older generations of offspring to help related, younger generations. This type of social system is referred to as being eusocial.

For example, all ants are eusocial. Ants have morphologically distinct workers and queens. In some ants, the workers do not even have ovaries. Other workers can lay male eggs. Some wasps and bees are eusocial but many are not.

All insects in this order go through a complete metamorphosis. This order of insects in beneficial to humans because they are pollinators. There are about 103,000 different species recognized worldwide.




https://projects.ncsu.edu/cals/course/ent425/library/compendium/hymenoptera.html

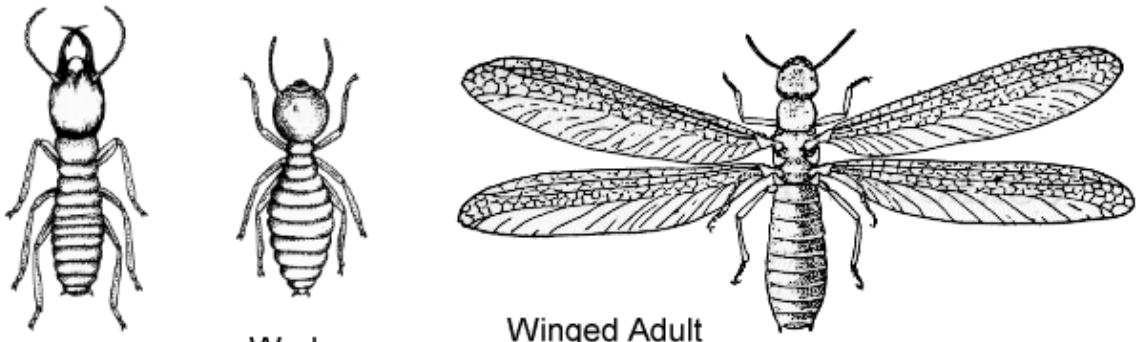
ISOPTERA (Termites)

Termites make up this order, with about 1,900 species found worldwide. Termites have three forms: reproductive males/females, workers, and soldiers. All of them share some common characteristics like their shape being ant-like with wider waits. They also all possess a beaded antennae, have chewing mouthparts and soft bodies. Termites are wing-less most of the time, except for reproductive males and females during breeding season. After breeding season, they will lose their wings.

The soldiers are identified by their larger heads with armed pincher-like mandibles (jaws). Workers have round, bulbous heads and lack these mandibles. Both workers and soldiers typically have pale-colored bodies. The reproductive male and females normally have dark-colored bodies. Workers and soldiers either lack compound eyes or have very small compound eyes, while reproductive males and females have well developed compound eyes.

All termites go through an incomplete metamorphosis. Termites are also very social, living in colonies that have divisions of labor. They often have a king and a queen.

Their diet consist of wood from trees, houses, etc., which results in them being considered pests to humans. The cellulose in wood is often indigestible by most animals. However, termites are able to digest the wood because of the protozoans in their stomach that digest the cellulose.




https://projects.ncsu.edu/cals/course/ent425/library/compendium/isoptera.html

LEPIDOPTERA (Moths, Butterflies, Skippers)

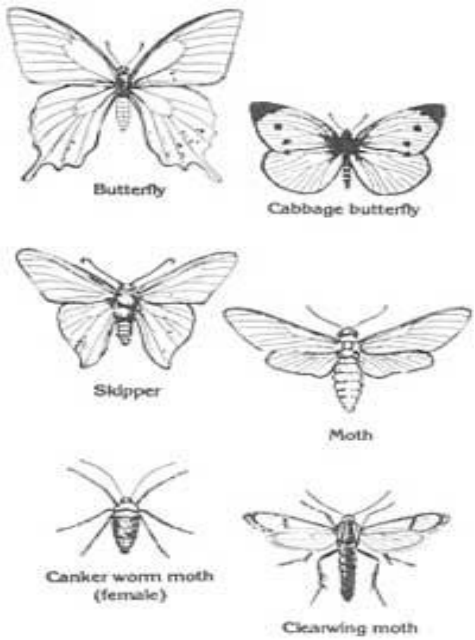
Nearly 150,000 different species of insects in the Lepidoptera order are recognized worldwide, with 3,500 of those being skippers. Moths and butterflies are sometimes mistaken for each other as they do have many similarities. Nonetheless, moths and butterflies do indeed have some distinct differences.

Both moths and butterflies have two pairs of large, broad wings that are covered with tiny colored scales. The forewings are usually larger and shaped differently than the hind wings. They both have soft, cylindrical bodies and coiled mouthparts. Moths and butterflies go through complete metamorphosis.

Butterflies have slender bodies and clubbed antennae that are swelled at the tips. This swelling can be slight or very obvious. A butterfly's forewings overlap with its hindwings, but they are not linked like a moth's wings.

Moths have stout bodies and forewings and hindwings that are linked together. A small spine, or bristle, on the hind wing latches onto a small hook called a retinaculum on the forewing. Moths' antennae are not clubbed but do come in a variety of shapes, including thread-like, broad, and feather-like.

Skippers are also occasionally mistaken for butterflies. They are known for their quick, darting flight habits. Most have the antenna tip modified into a narrow hook-like projection.




http://entomology.ifas.ufl.edu/bug_club/bug_ID/order-lepidoptera.shtml

ODONATA (Damselflies and Dragonflies)

Nearly 4,900 species of damselflies and dragonflies are found worldwide. All of these, once adults, have two pairs of equal size, membranous wings, large compound eyes, and chewing mouthparts.

At rest, the damselfly and dragonfly can be distinguished by their wing positions. The damselfly holds its wings close over the body in a straight up position, while the dragonfly holds its wings open and horizontal during rest.

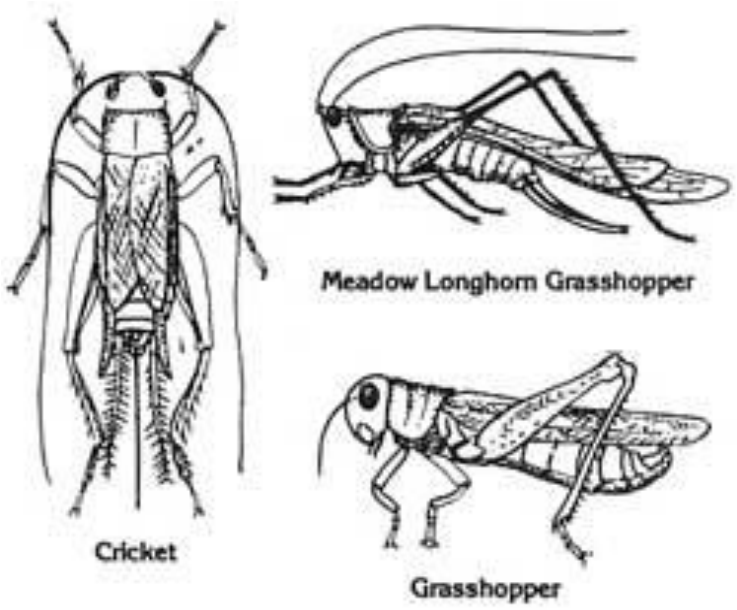
Damselflies and dragonflies have extremely similar characteristics other than their wing position at rest. Their heads are highly maneuverable and equipped with large compound eyes that often cover most of the head. They have very short antennae and have chewing mouthparts. Their bodies have tilted thorax segments which allow the legs to be bunched up near the head while the wings are set further back on the body. Damselflies and dragonflies go through an incomplete metamorphosis.


Left: Dragonfly Right: Damselfly

http://www.bbc.co.uk/nature/23142299

ORTHOPTERA (Grasshoppers, Crickets, Cockroaches, Mantises, and Walking Sticks)

The insect order Orthoptera encompasses more than 20,000 different species of insects worldwide. A wide variety of insects are classified in this order, but they all possess the same type of morphology. All Orthoptera have long hind legs, long, thin antennas, and two pairs of wings. The front wings, called tegmina, are long and narrow, with a leathery texture. The hind pair of wings is hidden beneath the forewings when the insect is at rest. All insects in this order go through incomplete metamorphosis.

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