

# **Entomology: Random Facts and Economic/Environmental Impacts of Orders**

## **1. Protura- Telsontails, Proturans, Coneheads**

- Proturans are primarily inhabitants of forest leaf litter. They are part of the community of decomposers that help break down and recycle organic nutrients. None of these arthropods are considered pests.
- Proturans were first discovered by Antonio Sylvestri in 1907 near Syracuse, New York. He found them in samples of leaf litter he had collected for a post-doctoral project on soil-dwelling invertebrates.
- Proturans do not have eyes or antennae. The front pair of legs is usually held in front of the body and apparently serve as sensory organs.
- Two of the three North American families of Protura lack a tracheal system. All gas exchange occurs through the integument.
- With only about 500 species worldwide, Protura is the smallest class in the phylum Arthropoda.
- Proturans are usually regarded as the most primitive of all hexapods. They have six legs and three body regions (head, thorax, and abdomen), but they lack most of the other physical features that are common to arthropods. Most species are very small (0.5-2.0 mm) and unpigmented. They are always found in moist habitats -- usually in the humus and leaf mold of temperate deciduous forests. Both adults and immatures feed on organic matter released by decay.
- Proturans do not have eyes or antennae. The front pair of legs are usually held in front of the body and apparently serve as sense organs. Newly hatched proturans have nine abdominal segments. Each time they molt, another segment is added near the end of the abdomen until they are fully grown (and sexually mature) with 12 abdominal segments. Additional molts may occur during adulthood, but the body does not grow any longer.

## **2. Collembola- Springtails**

- Springtails are part of the community of decomposers that break down and recycle organic wastes. A few species feed on living plants and are occasionally regarded as pests: *Bourletiella hortensis* (the garden springtail) may damage seedlings in early spring, *Sminthurus viridis* (the lucerne flea) is a pest of alfalfa in Australia, and *Hypogastrura armata* has been a frequent pest of commercial mushrooms.

- Springtails may be extremely abundant in certain habitats. Population densities exceeding 750 million individuals per hectare (300 million per acre) have been found in some grassland communities.
- Springtails "hop" by snapping their furcula against the substrate. In this manner, they may propel themselves up to 20 cm in the air -- a distance 50-100 times their own body length!
- Unlike most other arthropods, springtails appear to have evolved in cool climates. Their relative abundance in the soil tends to increase as the mean annual temperature decreases.
- The snowflea, *Hypogastrura nivicola*, is a dark blue collembolan that is often found on the surface of melting snow in late winter or early spring. Other cold-loving species are found on the surface of glacial ice in the far North.
- Females of some Sminthuridae cover their eggs with a glaze of freshly eaten soil and fecal material. This mixture evidently protects the eggs from dehydration and fungal attack.
- Like other non-insect hexapods, Collembola continue to molt after they reach sexual maturity. But unlike other taxa, reproductive activity occurs only during alternate instars: each reproductive stage is followed by a molt, a short period of feeding, and another molt.
- Some springtails live in caves or in the burrows of small mammals. A few species, including all members of the family Cyphoderidae, live in the nests of social insects.
- Springtails come in a wide variety of decorator colors, including white, pink, yellow, green, orange, red, blue, and indigo.
- The springtails are among the most abundant of all soil-dwelling arthropods. They live in a variety of habitats where they feed as scavengers on decaying vegetation and soil fungi. Most species are small (less than 6 mm in length) and quite susceptible to desiccation unless they remain in a moist environment. A unique, tube-like structure, the colophore is located ventrally on the first abdominal segment of most species. The exact function of this organ is unknown, but it probably helps maintain water balance by absorbing moisture from the environment.
- Springtails are named for a forked jumping organ (the furcula) found on the fourth abdominal segment. The furcula is retracted against the ventral wall of the abdomen and held there, in cocked position, by a special catch (the tenaculum) on the third abdominal segment. Releasing the tenaculum causes the furcula to snap down against the substrate and flip the organism some

distance through the air. This device, present in all but a few genera, seems to be an effective adaptation for avoiding predation.

- Immature collembola are similar in appearance to adults. They usually molt 4-5 times before reaching sexual maturity, and continue to molt periodically throughout the rest of their life. Unlike most other arthropods, springtails appear to have evolved in a cool climate. Their relative abundance in the soil tends to increase as the mean annual temperature decreases and their development is most rapid under cool, humid conditions.

### 3. **Diplura**- Diplurans

- Diplurans are common inhabitants of forest leaf litter. They are part of the community of decomposers that help break down and recycle organic nutrients. None of the Diplura are considered pests.
- The sexes are separate and fertilization is external. Males produce sperm packets (spermatophores) and glue them to the substrate on the end of little stalks. Females use their genital opening to gather spermatophores and then lay their eggs on little stalks inside a crevice or small cavity in the ground.
- Male Diplura produce large numbers of spermatophores -- up to 200 per week. This large number is probably necessary because sperm only remain viable in the spermatophore for about two days.
- The cerci of some diplurans are designed to break off near the base if they are mishandled. This spontaneous autotomy is probably an adaptation for avoiding predation. A similar adaptation is found in the legs of some walkingsticks and the tails of some lizards.
- Diplura and some walkingsticks (Phasmatodea) are the only terrestrial arthropods known to be able to regenerate lost body parts. Legs, antennae, and cerci can be regenerated over the course of several molts. Some crustaceans (e.g. crabs and lobsters) can regenerate missing legs or claws
- These small, eyeless arthropods are considered to be among the most primitive of all hexapods. They have a pair of long, beaded antennae on the head and a pair of segmented sensory structures (cerci) at the rear. In one common family (Japygidae), these cerci are developed into strong pincers.
- Diplura are tiny, cryptozoic animals that live in moist soil, leaf litter, or humus. They have small, eversible vesicles on the ventral side of most abdominal segments that seem to help regulate the body's water balance, perhaps by absorbing moisture from the environment.
- Most Diplura are predators; their diet probably includes a wide variety of other soil-dwellers, including collembola, mites, symphyla, insect larvae, and even

other diplurans. They may also survive on vegetable debris and fungal mycelia, but most species seem to prefer animal prey.

#### 4. **Thysanura**- silverfish, firebrats, bristletails

- Domestic species such as silverfish and firebrats may cause extensive damage to household goods. They often feed on wallpaper paste, bookbindings, and the starch sizing of some textiles. Cardboard and other paper products may also be damaged.
- Firebrats have been known to live more than 6 years -- through 60 instars. It has been suggested that frequent molting is an adaptation that reduced the risk of infection by parasitic fungi.
- One family of Thysanura (Nicoletiidae) is adapted to live underground in caves, mammal burrows, or in the nests of ants or termites. Some species mimic ants and steal their food.
- For many years, the family Lepidotrichidae was known only from Oligocene fossils. It was thought to have been extinct until 1959 when living specimens were discovered in northwestern California.
- Silverfish are fast-running insects that hide under stones or leaves during the day and emerge after dark to search for food. A few species are resistant to desiccation and well-adapted to survive in domestic environments such as basements and attics. Silverfish are scavengers or browsers; they survive on a wide range of food, but seem to prefer a diet of algae, lichens, or starchy vegetable matter.
- Thysanurans may be rather long-lived -- three years is probably typical and up to seven or eight years may be possible. They continue to molt frequently, even after reaching adulthood.
- Silverfish have an elaborate courtship ritual to insure exchange of sperm. The male spins a silken thread between the substrate and a vertical object. He deposits a sperm packet (spermatophore) beneath this thread and then coaxes a female to walk under the thread. When her cerci contact the silk thread, she picks up the spermatophore with her genital opening. Sperm are released into her reproductive system, and then she ejects the empty spermatophore and eats it.

#### 5. **Ephemeroptera**- Mayflies

- Many northern lakes and rivers (in both the United States and Europe) support unbelievably large populations of mayflies. The naiads are "ecological indicators" of good water quality and are an important source of food for fish and other aquatic wildlife. Anglers often use mayflies as bait, or tie "flies" that are made to resemble the imagos (spinners) or subimagos (dun).

- In some mayfly species, summer emergence of winged stages is a sudden and dramatic event that occurs almost simultaneously throughout the entire population. These mass emergences are often regarded as a major nuisance. The insects are attracted to city lights and blown inland by the wind. Their dead bodies pile up in drifts on porches and windowsills; they plaster car windshields and slicken highways. Europeans are often more sanguine than Americans about mass emergences -- in some communities the dead insects are diligently gathered up, dried, and sold as bird food, fish bait, or fertilizer. Although mass emergences still occur, the populations are not as large as in the past. Urban development and water pollution in major lakes and streams has dramatically reduced mayfly populations over the past 50 years.
- The subimagos of mayflies are the only insects that molt when they have wings.
- Mayflies are a favorite bait of fishermen, and many popular fishing "flies" are tied to resemble mayflies. Anglers have names for the stages -- dun is the subimago and spinner is the imago.
- Mayflies have paired genital openings. During copulation, the two penes of the male are inserted simultaneously into the two openings of the female. Sperm is transferred quickly (there is no spermatophore) and eggs are fertilized immediately.
- A few species of mayflies reproduce parthenogenically -- no males have ever been found.
- Although most mayflies are herbivores, a few are predaceous -- e.g. Siphonuridae and Oligoneuriidae.
- Adult mayflies do not feed. Their digestive system is filled with air, making them light enough to float.
- In the Congo, there is one species of mayfly that excavates tunnels in fresh-water sponges.
- Some mayfly species require up to four years to complete development. In that time they may molt more than 20 times
- The immature stages of mayflies are aquatic. They generally live in unpolluted habitats with fresh, flowing water. Some species are active swimmers, others are flattened and cling to the underside of stones, a few are burrowers who dig U-shaped tunnels in the sand or mud. Most species are herbivorous. Their diet consists primarily of algae and other aquatic plant life scavenged from surrounding habitat. Some species mature quickly, in as little as four weeks, while others develop more slowly (one to four years per generation).
- Once a mayfly completes development as a naiad, it leaves the aquatic environment, often rising to the water surface in a bubble of air. It quickly molts

to a winged form (the subimago) and flies to a nearby leaf or stem. The subimago is a brief transitional stage that molts again into a sexually mature adult (imago). The imago usually has transparent wings and a smooth, shiny exoskeleton in contrast to the cloudy wings and dull, pubescent body of the subimago. Mayflies are the only living insects that molt again after they have wings.

- Most adults are delicate insects with a very short lifespan. They do not feed (mouthparts are vestigial), and some species emerge, reproduce, and die in a single day. Males generally fly in swarms that undulate in the air 5-15 meters above the ground. Females fly into the swarm and are quickly grabbed by a male. Copulation takes place in flight, and the female usually lays her clutch of eggs within minutes or hours. Males die shortly after mating; females usually die soon after oviposition.

#### 6. **Odonata**- Dragonflies and Damselflies

- Most dragonflies and damselflies are regarded as beneficial insects because they feed on small flying insects such as mosquitoes. They may also catch and eat honey bees -- then they are regarded as pests by the beekeepers.
- In some parts of Europe, dragonflies are considered a threat to the poultry industry because they transmit *Prosthogonimus pellucidus*, a parasitic flatworm. Dragonfly naiads become infected by ingesting cysts of the flatworm. These cysts survive into adulthood of the dragonfly and may spread to birds (particularly poultry) that catch and eat the adult dragonflies. The flatworm cysts dissolve in the bird's intestine and infection spreads into the cloaca and reproductive organs. The Dutch have a maxim: "Hide the hens, the dragonflies are coming."
- The compound eyes of some dragonflies may have up to 28,000 facets.
- Some naiads can shoot out their labium and catch prey in only 25 milliseconds.
- Scientists have documented large-scale migrations of dragonflies. One swarm was observed 1,400 km off the coast of Australia.
- Some immature damselflies establish feeding territories, areas that are defended against invasion by other conspecifics. Territorial species develop more rapidly and produce larger adults than other non-territorial species.
- Many adult male dragonflies establish and defend territories along the perimeter of a lake or stream. Females will mate only with males that hold a territory, so population density is somewhat regulated by territory size.
- Male Odonata have claspers at the end of their abdomen, but no external genitalia. Before finding a mate, a male attaches a spermatophore to his second

abdominal segment. He then grabs a female around the neck with his claspers and she retrieves the spermatophore with the genital opening of her abdomen.

- Most dragonfly naiads can move forward by "jet propulsion". Rapid contraction of the rectal muscles forces water out the rear end and shoots the insect forward.
- Male damselflies (and perhaps some dragonflies) have a special flagellum associated with the copulatory organ that can reach into a female's body and remove sperm deposited by another male in a previous mating.
- Dragonflies are known by many interesting common names, including "snake doctors", "devil's darning needles", and "mosquito hawks".
- Dragonflies and damselflies are predaceous both as immatures and adults. The adults are quick, agile fliers that are generally considered beneficial because they feed on large numbers of small, flying insects like gnats and mosquitos. Legs are used either as a basket for catching prey or as grapples for clinging to emergent vegetation. Eggs are laid singly in fresh water; females often hover over open water and dip their abdomen as they oviposit.
- Eggs hatch into aquatic immatures (naiads) that feed opportunistically on other forms of aquatic life including mayfly naiads, small crustaceans, annelids, and mollusks. Some of the large dragonfly naiads will even attack small fish and tadpoles. All immature Odonata have a specialized labium for catching prey. Folded under the head and thorax when not in use, the labium can be extended rapidly toward potential prey. Hooked lobes at the tip of the labium grasp or impale the prey and draw it back to the mouth as the labium retracts.
- Damselfly naiads are usually more slender than dragonfly naiads and have three leaf-like gills at the end of the abdomen. Dragonfly gills are located internally, within the rectum, where bellows-like contractions of the rectal muscles cause oxygenated water to circulate in and out.

#### 7. **Blattodea**- cockroaches, waterbugs

- Cockroaches are among the most cosmopolitan of all insect pests. They are associated with human dwellings throughout the world, hiding in cracks and crevices during the day and emerging at night to forage for food and water. Although they do not sting or bite, they are usually associated with unsanitary conditions and may carry a variety of human pathogens on their bodies. The decomposing remains of dead roaches (and their feces) are an important source of household "dander" that becomes airborne and provokes respiratory allergies in sensitive people. But cockroaches also have proven to be very useful as research tools, particularly for the study of insect physiology and toxicology.

- The American cockroach, *Periplaneta americana*, is an introduced species that probably originated in Africa.
- Some cockroaches in the family Polyphagidae live as commensals in the nests of ants.
- *Gromphadorhina portentosa*, a species from Madagascar, can force air out of its tracheal system to produce an audible hiss. This behavior is used to scare predators. These large, slow-moving cockroaches are sometimes kept as pets.
- Despite their bad reputation, only about a dozen species (out of 4,000 worldwide) are regarded as pests.
- The Surinam cockroach, *Pycnoscelus surinamensis*, is the intermediate host of a nematode, *Oxyspirura mansoni*, that may cause blindness in poultry.
- The cockroaches, often known as "waterbugs", are scavengers or omnivores. They are most abundant in tropical or subtropical climates, but they also inhabit temperate and boreal regions. Some species are commonly found in close association with human dwellings where they are considered pests. Cockroaches have an oval, somewhat flattened body that is well-adapted for running and squeezing into narrow openings. Rather than flying to escape danger, roaches usually scurry into cracks or crevices. Much of the head and thorax is covered and protected dorsally by a large plate of exoskeleton (the pronotum).
- When cockroaches lay eggs, the female's reproductive system secretes a special capsule around her eggs. This structure, known as an oötheca, may be dropped on the ground, glued to a substrate, or retained within the female's body. Production of an oötheca is a special adaptation found only in cockroaches and praying mantids. This similarity suggests a close phylogenetic relationship between these groups and explains why some taxonomists prefer to lump them into a single order (Dictyoptera).

#### 8. **Mantodea**- Mantids

- Generally considered to be highly beneficial insects because they feed on other insects. Since they are cannibalistic and also feed on other beneficial insects, their value as biocontrol agents is probably rather limited.
- Mantids are the only insects that can turn their head from side to side without moving any other part of the body. Many humans mistakenly interpret this behavior as a sign of intelligence.
- A female mantid may eat her mate while he is still linked with her in copulo. This behavior is probably more common in captivity than in the wild.
- Most mantids are cryptically colored to blend with their environment. A pink Malaysian species spends most of its time hunting for prey on pink orchids.



- Although mantids usually feed on insect prey, they have been known to catch and eat small frogs, lizards, and even birds
- Mantids have elongate bodies that are specialized for a predatory lifestyle: long front legs with spines for catching and holding prey, a head that can turn from side to side, and cryptic coloration for hiding in foliage or flowers. Mantids are most abundant and most diverse in the tropics; there are only 5 species commonly collected in the United States and 3 of these have been imported from abroad.

#### 9. **Isoptera**- Termites, White Ants

- Termites are an important part of the community of decomposers. They are abundant in tropical and subtropical environments where they help break down and recycle up to one third of the annual production of dead wood. Termites become economic pests when their appetite for wood and wood products extends to human homes, building materials, forests, and other commercial products. In the United States alone, annual losses due to termite infestations are estimated at more than 800 million dollars.
- Termites are usually the most dominant organisms in tropical forest environments. Their populations typically range from 2000 to 4000 individuals per square meter but may occasionally run as high as 10,000 individuals per square meter. Their biomass (up to 22 g/sq. m.) exceeds the combined biomass of all vertebrate species living in the same area.
- Some termites build large and elaborate nests. In Australia, nests of *Nasutitermes triodidae* may be 20-25 feet tall and 10-12 feet in diameter. A single nest may house nearly a million workers. *Armitermes meridionalis* lives in tall, flat-sided mounds that are always built in a North-South orientation.
- Termites cannot digest wood fibers. Their digestive systems contain symbiotic protozoa or bacteria that digest the cellulose in wood. Termites live on the by-products of this digestion, and on the bodies of the symbionts themselves.
- The Macrotermitinae is a subfamily of Termitidae in which the member species cultivate fungus gardens. Workers make a paste of plant fibers and inoculate it with spores of a symbiotic fungus. The termites feed on special structures produced by the fungi.
- In the African termite, *Macrotermes subhyalinus*, the queen's body becomes so swollen with eggs that she is incapable of movement. When fully engorged, she may be 14 cm long, 3.5 cm in diameter, and capable of producing up to 30,000 eggs per day
- The termites are another group of insects that appear to be closely related to cockroaches. This conclusion is based on behavioral and ecological similarities

between termites and wood roaches (members of the family Cryptocercidae). These cockroaches live in fallen timber on the forest floor, feeding on wood fibers which are then digested by symbiotic microorganisms within their digestive systems. They live in small family groups where each female provides care for her young offspring. Termites and wood roaches are thought to be close relatives because they both occupy similar habitats, share the same type of food resources, have the same intestinal symbionts, and provide care for their offspring.

- Termites are the only hemimetabolous insects that exhibit true social behavior. They build large communal nests that house an entire colony. Each nest contains adult reproductives (one queen and one king) plus hundreds or thousands of immatures that serve as workers and soldiers. Like cockroaches and mantids, the termites are most abundant in tropical and subtropical climates.

#### 10. **Grylloblattodea**- Rock Crawlers, Ice Bugs

- Rock crawlers have no economic importance. They live in places that are not inhabited by humans.
- Rock crawlers were first discovered around 1906; the first formal description of the order was published in 1915.
- With only 25 species described worldwide, Grylloblattodea is the second smallest order of insects. Mantophasmatodea is the only order with fewer species.
- Rock crawlers cannot tolerate warm temperatures. Most species are active below freezing and usually die above 10 degrees Celsius.
- Due to the cold temperature at which they live, growth and development is very slow. Rock crawlers may require up to seven years to complete a single generation.
- No grylloblattids have ever been found in the Southern Hemisphere.
- Rock crawlers are a small and obscure group of insects found only at high elevations in the mountains of China, Siberia, Japan, and western United States and Canada. Cave-dwelling species have been found in Korea and Japan. These omnivorous insects scavenge for food on the surface of snowfields, under rocks, or near melting ice. They are active only at cold temperatures and move downward toward permafrost during warm seasons. As their ordinal name implies, rock crawlers have a blend of physical characteristics from both crickets (gryllo-) and cockroaches (blatta-). Some taxonomists include these insects as a suborder or family within Orthoptera. Others believe these insects are the only survivors of a primitive lineage that gave rise to other orthopteroid orders.

## 11. Dermaptera- Earwigs

- Most earwigs have little or no economic importance. A few species, if abundant, may damage the blossoms of ornamental plants by chewing on stamens or petals. The European earwig, *Forficula auricularia*, was introduced to the United States from Europe around 1900 and has been known to cause economic losses in fruit and vegetable crops.
- The common name "earwig" is derived from an old superstition that these insects crawl into people's ears at night and burrow into the brain. There is no truth to this myth.
- Some earwigs have defensive glands on the second or third abdominal segment that release a noxious liquid. Some species can squirt this fluid up to 100 mm (4 inches).
- In many earwigs, it is possible to determine an individual's sex by the shape of its cerci: relatively straight in females, more curved in males. In some species, the males have asymmetrical cerci.
- Female earwigs usually remain in the nest burrow and care for their eggs and young nymphs. If the nymphs do not leave the burrow after one or two molts, they are likely to be eaten by their mother.
- Earwigs are mostly scavengers or herbivores that hide in dark recesses during the day and become active at night. They feed on a wide variety of plant or animal matter. A few species may be predatory. Females lay their eggs in the soil, and may guard them until they hatch. Nymphs are similar in appearance to adults, but lack wings. The front wings are short, thick, and serve as protective covers for the hind wings. Hind wings are large, fan-shaped and pleated. They fold (both length-wise and cross-wise) to fit beneath the front wings when not in use. Some species are secondarily wingless. In most earwigs, the cerci at the end of the abdomen are enlarged and thickened to form pincers (forceps). These pincers are used in grooming, defense, courtship, and even to help fold the hind wings.
- The Dermaptera contains three suborders. Most species belong to the Forficulina. The other two groups, Arixeniina and Hemimerina, live in close association with mammals. The former (five species) live on Asian bats and the latter (eleven species) live on African rodents. All of these insects are adapted for a parasitic or semi-parasitic lifestyle: they are secondarily wingless and the cerci are not well-developed into pincers. Members of the Arixeniina give birth to live nymphs (vivipary).

## 12. Plecoptera- Stone flies

- Stoneflies require clean, well-oxygenated water to survive. They are extremely sensitive to water pollution and are used by ecologists as indicators of water purity. Stoneflies are also an important source of food for game fish (e.g., trout and bass) in cold mountain streams.
- In some species, a male attracts a female by drumming his abdomen against the substrate.
- Stonefly eggs are coated with a sticky slime that adheres to rocks and keeps the eggs from washing away in fast moving water.
- Adults of some Australian stoneflies consume rotten wood as part of their diet. The wood apparently contains a nutrient that is essential in egg production.
- A secondarily wingless species (family Capniidae) passes its entire life cycle in the depths of Lake Tahoe, U.S.A.
- Stoneflies are generally regarded as the earliest group of Neoptera. They probably represent an evolutionary "dead end" that diverged well over 300 million years ago. Immature stoneflies are aquatic nymphs (naiads). They usually live beneath stones in fast-moving, well-aerated water. Oxygen diffuses through the exoskeleton or into tracheal gills located on the thorax, behind the head, or around the anus. Most species feed on algae and other submerged vegetation, but two families (Perlidae and Chloroperlidae) are predators of mayfly nymphs (Ephemeroptera) and other small aquatic insects. Adult stoneflies are generally found on the banks of streams and rivers from which they have emerged. They are not active fliers and usually remain near the ground where they feed on algae or lichens. In many species, the adults are short-lived and do not have functional mouthparts. Stoneflies are most abundant in cool, temperate climates.

### 13. **Orthoptera**- Grasshoppers, Locusts, Crickets, Katydid

- Orthoptera is generally regarded as a dominant group in most terrestrial habitats. These insects feed on all types of plants and often cause serious economic damage. Swarms of grasshoppers (locusts) regularly appear in parts of Africa, Asia, and North America and destroy crops over wide land areas. Mole crickets are major pests in lawns and golf courses in the southern United States. Several species of field crickets are reared commercially as fish bait.
- In many species of Orthoptera, the males use sound signals (chirping or whirring) in order to attract a mate. The sound is produced by stridulation -- rubbing the upper surface of one wing against the lower surface of another wing, or the inner surface of the hind leg against the outer surface of the front wing.

- Each stridulating species produces a unique mating call. In fact, some species may be so similar to each other that they can only be distinguished by their mating calls.
- Many grasshoppers produce ultrasonic mating calls (above the range of human hearing). In some species, the sounds may be as high as 100 kHz. (Human hearing extends to about 20 kHz.)
- Species that produce sound also have auditory (tympanal) organs. In crickets and katydids, these "ears" are on the tibia of the front legs. In grasshoppers, they are on the sides of the first abdominal segment.
- The snowy tree cricket, *Oecanthus fultoni* (family Gryllidae), is often called the temperature cricket. Adding 40 to the number of chirps it makes in 15 seconds will equal the ambient temperature in degrees Fahrenheit.
- The redlegged grasshopper *Melanoplus femurrubrum* is not only a crop pest but also the intermediate host for a tapeworm *Choanotaenia infundibulum* that infests poultry
- Orthoptera probably arose during the middle of the Carboniferous period. Most living members of this order are terrestrial herbivores with modified hind legs that are adapted for jumping. Slender, thickened front wings fold back over the abdomen to protect membranous, fan-shaped hind wings. Many species have the ability to make and detect sounds. Orthoptera is one of the largest and most important groups of plant-feeding insects.

#### 14. **Phasmatodea**- Walkingsticks, Stick Insects, Leaf Insects, Phasmids

- In temperate zones, walkingsticks are seldom abundant enough to cause injury to their host plants. In the tropics, however, some species have been known to defoliate forest trees and cause economic losses to shrubbery and shade trees.
- Phasmid eggs often resemble seeds. The eggs may remain dormant for over a year before hatching.
- In some parts of the tropics, stick insects may be so abundant that eggs falling out of the trees may sound like rain on a tin roof.
- Some walkingsticks are sold as pets. They are easy to rear if kept in a warm environment with fresh foliage from their host plant.
- Glands located on the thorax of many species can produce a foul-smelling liquid that repels predators.
- When attacked by a predator, the legs of some phasmids may separate from the body (autotomy). Some species can even regenerate lost legs at the next molt. These are the only insects able to regenerate body parts.
- Several species produce offspring from unfertilized eggs (parthenogenesis). Males may be uncommon or unknown.

- Some phasmids change color with changes in temperature, humidity, or light intensity. Pigment granules in the epidermis disperse at night or on cool days, darkening the cuticle and absorbing more heat
- The leaf and stick insects are sometimes grouped as a family or suborder of Orthoptera. All species are herbivores. As the name "walkingstick" implies, most phasmids are slender, cylindrical, and cryptically colored to resemble the twigs and branches on which they live. Members of the family Timemidae (=Phyllidae) bear a strong resemblance to leaves: abdomens are broad and flat, legs have large lateral extensions, and coloration is primarily brown, green, or yellow. Most walkingsticks are slow-moving insects, a behavior pattern that is consistent with their cryptic lifestyle. In a few tropical species, the adults have well-developed wings, but most phasmids are brachypterous (reduced wings) or secondarily wingless. Stick insects are most abundant in the tropics where some species may be up to 30 cm (12 inches) in length. Females do not have a well-developed ovipositor so they cannot insert their eggs into host plant tissue like most other Orthoptera. Instead, the eggs are dropped singly onto the ground, sometimes from great heights.

#### 15. **Psocoptera**- Psocids, Barklice, Booklice

- Most of the psocids are woodland insects that rarely come into contact with humans. Species that do inhabit homes and warehouses may occasionally become a nuisance, but they seldom cause economic damage.
- Psocids apparently have excellent powers of dispersal. They are usually among the first insects to colonize new islands and invade disturbed habitats.
- Pearman's organ, a sound-producing structure in the hind coxae of some male barklice, produces a clicking sound that attracts females. The male then performs a courtship dance in an effort to initiate copulation.
- *Trogium pulsatorium*, a common resident in human dwellings, may also live in the nests of bees and wasps.
- Members of the family Psoquillidae often live as scavengers in the nests of birds. These barklice may be the ancestors of parasitic lice (order Phthiraptera).
- The order Psocoptera (also known as Corrodentia) contains the booklice and barklice. These insects are often regarded as the most primitive hemipteroids alive today because their mouthparts show the least modification from the primitive mandibulate condition. In fact, only the lacinia (a subdivision of the maxilla) has become a separate, rod-like structure that is pushed against the substrate as a brace while the mandibles scrape off surrounding food particles. The pharynx and hypopharynx are also modified for grinding food in a mortar-and-pestle arrangement.

- Barklice generally live in moist terrestrial environments (in leaf litter, beneath stones, on vegetation, or under the bark of trees) where they forage on algae, lichens, fungi, and various plant products. They may grow to 10 mm in length and are frequently winged during the adult stage. Some species are gregarious. They often live in small colonies beneath a gossamer blanket spun with silk from their labial glands. Booklice are more common in human dwellings and warehouses. They are wingless and much smaller than barklice (less than 2 mm). Most species feed on stored grains, book bindings, wallpaper paste, fabric sizing, and other starchy products.
- Although most Psocoptera are free-living, a few genera live in the nests of birds. They survive by feeding on residues of feathers or skin cells, but never on the birds themselves. Most entomologists suspect that true lice (ectoparasites of birds and mammals) evolved directly from these commensal barklice. Even today, it is possible to find a gradual progression of species with increasing dependence on vertebrate hosts. A close phylogenetic relationship between barklice and parasitic lice is also supported by similarities in the structure of mouthparts (particularly the hypopharynx).

#### 16. **Mallophaga**- Chewing Lice

- These lice are external parasites that feed mainly on birds although some species also feed on mammals. They infest both domestic and wild animals and birds and cause considerable irritation to their host

#### 17. **Anoplura**- Sucking Lice

- The Anoplura are all blood-feeding ectoparasites of mammals. They can cause localised skin irritations and are vectors of several blood-borne diseases. Children appear particularly susceptible to attracting lice, possibly due to their fine hair.

#### 18. **Hemiptera**- True Bugs

- Plant feeding bugs are important pests of many crop plants. They may cause localized injury to plant tissues, they may weaken plants by removing sap, and they may also transmit plant pathogens. Predatory species of Heteroptera are generally regarded as beneficial insects, but those that feed on blood may transmit human diseases. Chagas disease, for example, is transmitted to humans by conenose bugs (genus *Triatoma*, family Reduviidae). Although bed bugs (family Cimicidae) can inflict annoying bites, there is little evidence that they regularly transmit any human or animal pathogen.
- Two families of Heteroptera are ectoparasites. The Cimicidae (bed bugs) live on birds and mammals (including humans). The Polyctenidae (bat bugs) live on bats.

- Water striders in the genus Halobates (family Gerridae) are the only insects that are truly marine. They live on the surface of the Pacific Ocean.
- Unlike other insects, male bedbugs do not place their sperm directly in the female's reproductive tract. Instead, they puncture her abdomen and inject the sperm into her body cavity. The sperm swim to the ovaries where they fertilize the eggs. This unusual type of reproductive behavior is appropriately known as "traumatic insemination".
- Some members of the family Lergidae resemble ants. They live as social parasites in ant nests, mimicking the ants' behavior to get food
- Members of the suborder Heteroptera are known as "true bugs". They have very distinctive front wings, called hemelytra, in which the basal half is leathery and the apical half is membranous. At rest, these wings cross over one another to lie flat along the insect's back. These insects also have elongate, piercing-sucking mouthparts which arise from the ventral (hypognathous) or anterior (prognathous) part of the head capsule. The mandibles and maxillae are long and thread-like, interlocking with one another to form a flexible feeding tube (proboscis) that is no more than 0.1 mm in diameter yet contains both a food channel and a salivary channel. These stylets are enclosed within a protective sheath (the labium) that shortens or retracts during feeding.
- The Heteroptera include a diverse assemblage of insects that have become adapted to a broad range of habitats -- terrestrial, aquatic and semi-aquatic. Terrestrial species are often associated with plants. They feed in vascular tissues or on the nutrients stored within seeds. Other species live as scavengers in the soil or underground in caves or ant nests. Still others are predators on a variety of small arthropods. A few species even feed on the blood of vertebrates. Bed bugs, and other members of the family Cimicidae, live exclusively as ectoparasites on birds and mammals (including humans). Aquatic Heteroptera can be found on the surface of both fresh and salt water, near shorelines, or beneath the water surface in nearly all freshwater habitats. With only a few exceptions, these insects are predators of other aquatic organisms.

19. **Homoptera**- Leafhoppers, Planthoppers, Treehoppers, Cicadas, Aphids, Psyllids, Whiteflies, Scale Insects

- Homoptera are among the most abundant herbivores found in terrestrial habitats. Many species are pests of cultivated plants. Aphids and leafhoppers are important carriers of plant diseases.
- A scale insect, *Laccifer lacca*, is the source of natural shellac. The insect lives on various fig trees in the tropics.



- *Dactylopius coccus*, the cochineal insect, is the source of a bright red dye formerly used in the textile industry. It is a scale insect that lives on prickly pear cacti.
- Aphids in the subfamily Pemphiginae are gall-makers. The galls are usually open at one end so the insects can come and go freely.
- The ground pearls (family Margarodidae) are a group of scale insects that live on plant roots. In some tropical species, the females form large wax cysts, often bronze or gold in color, that people collect and use as beads.
- Honeydew, an excretory product that is rich in sugars and amino acids, is produced by many species of Homoptera. Other animals use honeydew as a source of food.
- Honeydew from a mealybug, *Trabutina mannipara*, is regarded as the probable source of Biblical manna
- All members of the suborder Homoptera have piercing/sucking mouthparts and feed by withdrawing sap from vascular plants. The proboscis is shorter than that found in true bugs (suborder Heteroptera), and it emerges near the ventral posterior margin of the head capsule (opisthognathous). Although some Homoptera are secondarily wingless, the majority have membranous or uniformly textured wings that fold tent-like over the body at rest.
- It is difficult to generalize about the biology of these insects. Cicadas are the largest members of the suborder. As nymphs, they live underground and feed on the roots of trees and shrubs. Some species complete development in as little as four years, but others have a 13- or 17-year life cycle. In contrast, the aphids are tiny, soft-bodied insects with multiple generations per year. Many species have complex life cycles involving more than one host plant. Winged and wingless forms of the same species may develop at different times of the year. Asexual reproduction (parthenogenesis) is common and males are unknown in some species. The scale insects are even more specialized. During much of their life cycle, they remain immobile, living beneath an impervious cover of wax or cuticle that they secrete over themselves. Legs and antennae often disappear after the first molt. Only newly hatched nymphs and adult males bear any resemblance to other insects. Females grow to sexual maturity, mate, produce offspring, and die without ever leaving their protective cover.
- In most of the Homoptera, a portion of the digestive system is modified into a filter chamber. This structure allows the insects to ingest and process large volumes of plant sap. Excess water, sugars, and certain amino acids bypass most of the midgut and are shunted directly into the hindgut for excretion as honeydew. Only a small volume of filtered plant sap passes through the midgut

for digestion and absorption. Many species of ants are attracted by the honeydew and provide care and protection for the homopterans in exchange for the honeydew they excrete.

#### 20. **Thysanoptera**- Thrips

- Many thrips are destructive pests of plants, especially grain crops, fruits and vegetables, and ornamentals. Feeding activities result in plant deformities, scarring, loss of yield, and in some cases, transmission of plant pathogens. Predatory thrips are beneficial species that may control mites and other small insects.
- The word "thrips" is both singular and plural. There is no such thing as a "thrip".
- Thrips are the only insects that have asymmetrical mouthparts. Of the three feeding stylets, two are derived from the maxillae and one is derived from the left mandible. The right mandible disappears during embryogenesis.
- Thrips are able to walk on glassy smooth surfaces because they have an eversible adhesive pad located on the tip of each foot, between the claws.
- Thrips are generally small insects (under 3 mm). Most species feed on plant tissues (often in flower heads), but some are predators of mites and various small insects (including other thrips). Many species are parthenogenetic. Adults may be winged or wingless. When present, the wings are slender and rod-like with a dense fringe of long hairs.
- Although Thysanoptera are hemimetabolous, many species undergo an extended metamorphosis in which the final immature stage is quiescent, non-feeding, and sometimes even enclosed in a silken cocoon. This developmental stage, usually called a "pupa", has aroused a great deal of speculation by some entomologists who claim that thrips represent an "intermediate" stage between hemi- and holometabolous development. A close examination of the thysanopteran "pupa", however, reveals that it does not undergo any internal transformation. Without additional evidence to support a phylogenetic link to the Holometabola, it would appear that this "pupal stage" may be nothing more than a curious coincidence of convergent evolution.

#### 21. **Megaloptera**- Dobsonflies, Alderflies

- Larvae of Megaloptera are important predators in aquatic ecosystems. They also serve as food for fish and other aquatic vertebrates.
- The Megaloptera are always aquatic as immatures. They live under stones or submerged vegetation and feed on a variety of small aquatic organisms. Large species, often called hellgrammites, may require several years of growth to reach maturity. Adults usually remain near water, although they are attracted to lights at night. In most species, the adults live only a few days and rarely feed.

- As adults, all neuropterans have two pairs of membranous wings with an extensive pattern of veins and crossveins. At rest, the wings are folded flat over the abdomen or held tent-like over the body. Most species are rather weak fliers.

## 22. **Neuroptera**- Lacewings, Antlions, Snakeflies

- Lacewing larvae are beneficial as predators of agricultural pests (aphids, whiteflies and scale insects). Some species are reared and sold commercially as biocontrol agents.
- A lacewing's egg sits atop a slender stalk secreted by the female's reproductive system. For many years, biologists thought these eggs were the fruiting bodies of a fungus they called *Ascophora ovalis*. The true nature of these eggs was first discovered in 1737 by Rene Reaumur, a French physicist, biologist and inventor.
- Some lacewing larvae camouflage themselves by attaching the dead bodies of their prey to spines on their back. Other species use bits of bark, moss, etc.
- Adult lacewings in the subfamily Chrysopinae can detect the sound of bats with auditory organs in the large veins of their front wings.
- Larvae of spongillaflies, family Sisyridae, are predators of freshwater sponges.
- As larvae, lacewings and antlions do not have a complete digestive system: the midgut ends in a dead end. Waste materials accumulate in the midgut throughout larval development and are finally expelled only after a connection is made with the anus near the end of the pupal stage. The accumulated fecal material is called a meconium.
- Antlion larvae are sometimes known as doodlebugs. The name is apparently derived from the squiggly trails these insects make when they move around in the sand.
- When they pupate, larvae of lacewings and antlions dig a small cavity in the soil and spin a loose silken cocoon around themselves. Many holometabolous insects exhibit similar behavior, but neuropterans are unusual because their silk is produced by Malpighian tubules (excretory organs) and spun from the anus. In contrast, most other endopterygote insects produce silk in modified salivary or labial glands and spin it with their mouthparts. Only one other order, the Coleoptera, makes silk in the same manner as Neuroptera.
- Except for larval spongillaflies (family Sisyridae) which feed on fresh-water sponges, all members of the suborders Planipennia and Raphidoidea are terrestrial. Antlion larvae live in the soil and construct pitfall traps to snare prey. Lacewing larvae are usually found in vegetation where they typically feed on aphids, mites, and scale insects. Snakefly larvae live in leaf litter or under bark and catch aphids or other soft-bodied prey. In most cases, the adults of these

insects are also predators -- the non-predatory species usually feed on nectar, pollen, or honeydew.

- The larvae of antlions and lacewings have specialized mouthparts with large, sickle-shaped mandibles and maxillae that interlock to form pincers. Once impaled on these pincers, a prey's body contents are sucked out through hollow food channels running between the adjacent surfaces of the mandibles and maxillae.
- As adults, all neuropterans have two pairs of membranous wings with an extensive pattern of veins and crossveins. At rest, the wings are folded flat over the abdomen or held tent-like over the body. Most species are rather weak fliers.

### 23. **Coleoptera**- Beetles, Weevils

- Many beetles are regarded as major pests of agricultural plants and stored products. They attack all parts of living plants as well as processed fibers, grains, and wood products. Scavengers and wood boring beetles are useful as decomposers and recyclers of organic nutrients. Predatory species, such as lady beetles, are important biological control agents of aphids and scale insects.
- Coleoptera is the largest order in the animal kingdom. It includes 40% of all insects and nearly 30% of all animal species.
- The smallest beetle is the fringed ant beetle, *Nanosella fungi* (family Ptiliidae). At 0.25 mm in length it is some 16 million times smaller in volume than the largest beetle, *Goliathus giganteus* (family Scarabaeidae), which may have a body length up to 10 cm.
- Two families of Coleoptera are bioluminescent (able to produce light). Fireflies (family Lampyridae) and glowworms (family Phengodidae) have light-producing organs in the abdomen. In some species, the females are wingless and larviform.
- Ancient Egyptians believed that a scarab beetle rolled the sun across the sky each day. The scarab icon became associated with Ra, the sun god, and scarab beetles, *Scarabaeus sacer*, were worshiped as a symbol of immortality.
- Over 1000 beetle species are known to live as predators, parasites or commensals in the nests of ants. They gain entrance to the nest by mimicking the odor and behavior of the ants.
- Bombardier beetles, *Brachinus* spp. (family Carabidae), have the ability to discharge a defensive spray of hot quinones. Two chemical reactants are stored in adjacent compartments of an abdominal gland and combine explosively when the insect is disturbed.

- Males of many stag beetles (family Lucanidae) and scarab beetles (family Scarabaeidae) have enlarged mandibles or protruding horns which are used in courtship and in ritualized fights with other males.
- The Spanish fly, *Lytta vesicatoria* (family Meloidae), is a source of cantharadin. This chemical, once thought to be an aphrodesiac, is now used as a mating stimulant when breeding cattle and in the treatment of certain urogenital diseases.
- Coleoptera (beetles and weevils) is the largest order in the class Insecta. As adults, most beetles have a hard, dense exoskeleton that covers and protects most of their body surface. The front wings, known as elytra, are just as hard as the rest of the exoskeleton. They fold down over the abdomen and serve as protective covers for the large, membranous hind wings. At rest, both elytra meet along the middle of the back, forming a straight line that is probably the most distinctive characteristics of the order. During flight, the elytra are held out to the sides of the body where they provide a certain amount of aerodynamic stability.
- Both larvae and adults have strong mandibulate mouthparts. As a group, they feed on a wide variety of diets, inhabit all terrestrial and fresh-water environments, and exhibit a number of different life styles. Many species are herbivores -- variously adapted to feed on the roots, stems, leaves, or reproductive structures of their host plants. Some species live on fungi, others burrow into plant tissues, still others excavate tunnels in wood or under bark. Many beetles are predators. They live in the soil or on vegetation and attack a wide variety of invertebrate hosts. Some beetles are scavengers, feeding primarily on carrion, fecal material, decaying wood, or other dead organic matter. There are even a few parasitic beetles -- some are internal parasites of other insects, some invade the nests of ants or termites, and some are external parasites of mammals.

#### 24. **Strepsiptera**- Twisted-Wing Parasites, Stylopids, Strepsipterans

- Strepsipterans are not abundant enough to have a significant impact on other insect populations.
- Female Strepsiptera are unusually fecund. Each one may produce 2500-7000 offspring
- An insect infested with a strepsipteran parasite is often said to be "stylopized". This often results in destruction of the hosts' reproductive organs (parasitic castration), and in some cases a reversal of secondary sex characteristics (females look like males).

- Strepsipteran legs are unusual. In the first place, only first instar larvae and adult males have legs. And secondly, the trochanters, a leg segment present in all other insects, is missing in all strepsipterans.
- An oral secretion produced by triungulin larvae softens the host's exoskeleton enough to aid entry of the tiny parasite.
- Most Strepsiptera (also known as twisted-wing parasites) live as internal parasites of bees, wasps, grasshoppers, leafhoppers, and other members of the order Hemiptera. Only a few species that parasitize bristletails (Archeognatha) are known to be free-living in the adult stage.
- Strepsiptera share so many characteristics with beetles that some entomologists classify them as a superfamily of Coleoptera. In fact, Strepsiptera and certain parasitic beetles (in the families Meloidae and Rhipiphoridae) are among the very few insects that undergo hypermetamorphosis, an unusual type of holometabolous development in which the larvae change body form as they mature. Upon emerging from their mother's body, the young larvae, called triunguloids, have six legs and crawl around in search of a suitable host. In species that parasitize bees or wasps, a triunguloid usually climbs to the top of a flower and waits for a pollinator. When a host arrives, the larva jumps aboard, burrows into its body, and quickly molts into a second stage that has no distinct head, legs, antennae or other insect-like features. These larvae grow and continue to molt inside the host's body cavity, assimilating nutrients from the blood and non-vital tissues. After pupating in the host, winged males emerge and fly in search of mates. An adult female remains inside her host, managing to attract and mate with a male while only a small portion of her body protrudes from the host's abdomen. Embryos develop within the female's body, and a new generation of triunguloid larvae begin their life cycle by escaping through a brood passage on the underside of her body.
- Adult male Strepsiptera are strange-looking insects. The head is small, with protruding compound eyes that look like tiny raspberries. The antennae are multi-segmented and have up to three branches. Front wings are reduced to small, club-like structures; hind wings are very large and fan-shaped

#### 25. **Mecoptera**- Scorpionflies, Hangingflies

- None of the scorpionflies are considered pests. Most species are not abundant enough to have much of an environmental impact.
- Snow scorpionflies (family Boreidae) are adapted to cold climatic conditions. They often live on the surface of ice or snow, and may die if exposed to the heat from a human hand.

- Some female scorpionflies will accept a male suitor only if he brings her a gift of prey. Males occasionally mimic females in order to get a free meal!
- Scorpionflies have been known to rob freshly caught prey from spider webs.
- Hanging scorpionflies are the only predatory insects that catch prey with their hind legs.
- The Mecoptera (scorpionflies) are a curious group of terrestrial insects that usually live in moist sylvan habitats. Both larvae and adults are omnivorous. Mostly, they feed upon decaying vegetation and dead (or dying) insects. Larvae generally remain in the soil; they have chewing mouthparts and resemble caterpillars (Lepidoptera) or white grubs (Coleoptera). Most adults have an elongated head with slender, chewing mouthparts near the tip of a stout beak. Front and hind wings are similar in shape (occasionally reduced in size or absent), and often mottled with patches of color. The common name of this order (scorpionfly) refers to the distinctive appearance of male genitalia in members of the family Panorpidae: the terminal segments are enlarged and held recurved over the abdomen like the tail of a scorpion. Despite its appearance, the scorpionfly's tail is quite harmless.
- Hanging scorpionflies, family Bittacidae, are predators of small flying insects. Their legs, especially the tarsi, are unusually long and slender. At the tip of each leg there is a single opposable claw. The adults hang from vegetation with their front legs and catch small flying insects with their middle and hind legs. These scorpionflies, which bear a striking resemblance to crane flies (Diptera: Tipulidae), may have developed from the same ancestral lineage that also give rise to the caddisflies (order Trichoptera) and the true flies (order Diptera).

## 26. Siphonaptera- Fleas

- In addition to their irritating bites, fleas may also transmit pathogens that cause disease in humans and other animals. Cat and dog fleas, for example, are intermediate hosts for a tapeworm (*Dipylidium caninum*) that infects dogs, cats, and humans. Rabbit fleas spread a myxomatosis virus within rabbit populations, and the oriental rat flea is the primary vector of *Yersinia (=Pasteurella) pestis*, the bacterial pathogen for bubonic plague.
- Cat fleas commonly infest dogs, and dog fleas may infest cats. Both species may bite humans! Cat and dog fleas are similar in appearance, but the dog flea has a rounder head and the first bristle in its genal comb is shorter than the others.
- Travelling flea circuses were a popular form of entertainment in Europe during the 1800's. Mole fleas were used as performers because they are large (up to 5.5 mm in length) and cannot jump as far as most other fleas.

- Since their larvae must mature in the host's nest, fleas only infest animals that have a regular nest site. This explains why most rodents (e.g., rats, mice, etc.) have fleas but most ungulates (e.g., cows, horses, deer, etc.) do not.
- In some species, the reproductive cycle of a female flea is triggered by reproductive hormones in the female host. This ensures that a new generation of fleas will mature before the host's offspring leave the nest.
- As adults, all fleas are blood-sucking external parasites. Most species feed on mammals, although a few (less than 10%) live on birds. Only adult fleas inhabit the host's body and feed on its blood. They are active insects with a hard exoskeleton, strong hind legs adapted for jumping, and a laterally flattened body that can move easily within the host's fur or feathers. Unlike lice, most fleas spend a considerable amount of time away from their host. Adults may live for a year or more and can survive for weeks or months without a blood meal.
- Flea larvae are worm-like (vermiform) in shape with a sparse covering of bristles. They rarely live on the body of their host. Instead, they are usually found in its nest or bedding where they feed as scavengers on organic debris (including adult feces). In general, flea larvae can survive more arid conditions than most fly larvae. After a larval period that includes two molts, fleas pupate within a thin silken cocoon. Under favorable conditions, the life cycle can be completed in less than a month.

**27. Diptera-** True flies, mosquitoes, gnats, midges

- The Diptera probably have a greater economic impact on humans than any other group of insects. Some flies are pests of agricultural plants, others transmit diseases to humans and domestic animals. On the other hand, many flies are beneficial -- particularly those that pollinate flowering plants, assist in the decomposition of organic matter, or serve as biocontrol agents of insect pests.
- Although they have only two wings, flies are among the best aerialists in the insect world - they can hover, fly backwards, turn in place, and even fly upside down to land on a ceiling.
- Flies have the highest wing-beat frequency of any animal. In some tiny midges, it may be as high as 1000 beats per second. Male mosquitoes are attracted by the wing-beat frequency of a virgin female.
- Larvae of some shore flies (family Ephydriidae) live in unusual habitats that would kill other insects. For example, *Ephydra brucei* lives in hot springs and geysers where the water temperature exceeds 112 degrees Fahrenheit; *Helaeomyia petrolei* develop in pools of crude oil; and the brine fly, *Ephydra cinera*, can survive very high concentrations of salt.



- The arista in the antenna of higher flies is an air speed indicator. It allows the insect to sense how fast it is moving.
- As they mature, black fly pupae become inflated with air. Upon emergence, the pupal skin pops open and the adult fly floats to the water surface inside a bubble of air. It never even gets its feet wet!
- The little scuttle fly, *Megaselia scataris* (Phoridae), is truly an omnivore. It has been reared from decaying vegetation, shoe polish, paint emulsions, human cadavers pickled in formalin, and even lung tissue from living people.
- The order Diptera includes all true flies. These insects are distinctive because their hind wings are reduced to small, club-shaped structures called halteres - only the membranous front wings serve as aerodynamic surfaces. The halteres vibrate during flight and work much like a gyroscope to help the insect maintain balance.
- All Dipteran larvae are legless. They live in aquatic (fresh water), semi-aquatic, or moist terrestrial environments. They are commonly found in the soil, in plant or animal tissues, and in carrion or dung -- almost always where there is little danger of desiccation. Some species are herbivores, but most feed on dead organic matter or parasitize other animals, especially vertebrates, molluscs, and other arthropods. In the more primitive families (suborder Nematocera), fly larvae have well-developed head capsules with mandibulate mouthparts. These structures are reduced or absent in the more advanced suborders (Brachycera and Cyclorrhapha) where the larvae, known as maggots, have worm-like bodies and only a pair of mouth hooks for feeding.
- Adult flies live in a wide range of habitats and display enormous variation in appearance and life style. Although most species have haustellate mouthparts and collect food in liquid form, their mouthparts are so diverse that some entomologists suspect the feeding adaptations may have arisen from more than a single evolutionary origin. In many families, the proboscis (rostrum) is adapted for sponging and/or lapping. These flies survive on honeydew, nectar, or the exudates of various plants and animals (dead or alive). In other families, the proboscis is adapted for cutting or piercing the tissues of a host. Some of these flies are predators of other arthropods (e.g., robber flies), but most of them are external parasites (e.g., mosquitoes and deer flies) that feed on the blood of their vertebrate hosts, including humans and most wild and domestic animals.

#### 28. **Trichoptera**- Caddisflies

- Caddisfly larvae may serve as food for fish and other aquatic vertebrates. Fishermen often gather them for use as bait for trout and other game fish.

Although a few species have been recorded as pests in rice paddies, most caddisflies have very little economic importance.

- Many species of Trichoptera are very similar in appearance, both as larvae and as adults. It is often easier to identify a species by the structure of its case than by the features of its body.
- While still in their pupal case, caddisfly adults have sharp mandibles used for cutting through the pupal case. Once they emerge, their mandibles degenerate and become nonfunctional. From this time on they do not feed (or ingest food only in liquid form).
- The order Trichoptera (caddisflies) is another likely descendant of the Mecopteran lineage. Adults are mostly nocturnal, weak-flying insects that are often attracted to lights. During the day, they hide in cool, moist environments such as the vegetation along river banks. The body and wings are clothed with long silky hairs (setae) -- a distinctive characteristic of the order. In flight, the hind wings are coupled to the front wings by specially curved hairs. At rest the wings are held tent-like over the abdomen. Many caddisflies have reduced or vestigial mouthparts. Few species have actually been observed feeding, and most adults are relatively short-lived.
- All caddisfly larvae live in aquatic environments; they may be herbivores, scavengers, or predators. In most cases, the predatory species are free-living or spin silken structures in the water (webs or tunnels) to entrap prey. The scavengers and herbivores live within protective "cases" which they build from their own silk and stones, twigs, leaf fragments, or other natural materials. Case design and construction is distinctive for each family or genus of caddisfly. The case is usually portable, dragged around like a snail shell as the insect moves, and held in place by a pair of hooked prolegs at the tip of the abdomen. Most species have thread-like abdominal gills and get oxygen from water that circulates inside the case. All larval growth and development (including pupation) occurs within the case.

#### 29. **Lepidoptera**- Butterflies, Moths

- Although many Lepidoptera are valued for their beauty, and a few are useful in commerce (e.g., the silkworm, *Bombyx mori*), the larvae of these insects are probably more destructive to agricultural crops and forest trees than any other group of insects.
- Some butterflies (family Lycaenidae) are considered "endangered species". The Xerces blue (*Glaucopsyche xerces*) was last collected in 1943 from sand dunes near San Francisco, CA. This butterfly's name has been adopted by the Xerces Society, an organization dedicated to the preservation of endangered species.

- In flight, front and hind wings are linked together by a bristle (frenulum) or a membranous flap (jugum) so both wings move up and down in synchrony.
- According to folklore, larvae of the banded woollybear, *Pyrrharctia isabella*, can forecast the severity of winter weather. A wide brown band means the winter will be harsh, a narrow brown band means the winter will be mild.
- Adults of most Noctuidae and Arctiidae have "ears" in the thorax that help them detect and evade echo-locating bats. Some species of Arctiidae even produce high-pitched ticks that confuse the bats.
- Lepidoptera (moths and butterflies) is the second largest order in the class Insecta. Nearly all lepidopteran larvae are called caterpillars. They have a well-developed head with chewing mouthparts. In addition to three pairs of legs on the thorax, they have two to eight pairs of fleshy abdominal prolegs that are structurally different from the thoracic legs. Most lepidopteran larvae are herbivores; some species eat foliage, some burrow into stems or roots, and some are leaf-miners.
- Adults are distinctive for their large wings (relative to body size) which are covered with minute overlapping scales. Most entomologists believe that these scales are structurally related to the hair (setae) covering adult caddisflies. Lepidopteran wing scales often produce distinctive color patterns that play an important role in courtship and intraspecific recognition.
- Although moths probably diverged from caddisflies in the early Triassic period, about 230 million years ago, adults in a few primitive families (e.g., Micropterygidae) still retain evidence of chewing mouthparts. In all other lepidopteran families, the mouthparts are vestigial or form a tubular proboscis that lies coiled like a watch spring beneath the head. This proboscis is derived from portions of the maxillae. It uncoils by hydrostatic pressure and acts as a siphon tube for sipping liquid nutrients, such as nectar, from flowers and other substrates.
- From a taxonomic standpoint, the distinction between moths and butterflies is largely artificial -- some moths are more similar to butterflies than to other moths. As a rule, butterflies are diurnal, brightly colored, and have knobs or hooks at the tip of the antennae. At rest, the wings are held vertically over the body. In contrast, most (but not all) moths are nocturnal. They are typically drab in appearance, and have thread-like, spindle-like, or comb-like antennae. At rest, their wings are held horizontally against the substrate, folded flat over the back, or curled around the body.

### 30. **Hymenoptera**- Ants, Wasps, Bees, Sawflies, Horntails

- Although some species are regarded as pests (e.g., sawflies, gall wasps, and some ants), most members of the Hymenoptera are extremely beneficial -- either as natural enemies of insect pests (parasitic wasps) or as pollinators of flowering plants (bees and wasps).
- In the Hymenoptera, females develop from fertilized eggs and males develop from unfertilized eggs. Since females control whether or not an egg is fertilized, they can regulate the sex ratio of their offspring.
- The fairyflies (family Mymaridae) are probably the world's smallest insects. They parasitize the eggs of other insects.
- Some species of cuckoo wasps (family Chrysididae) invade the nests of wasps or bees, kill the larvae they find, and deposit their own eggs on the stored provisions. This behavior is known as kleptoparasitism.
- Slave-maker ants raid the nests of other species to steal their pupae. When the stolen ants emerge as adults, they become workers in the slave-maker's colony.
- Aculeate Hymenoptera (certain wasps, bees, and ants) are the only insects that can sting.
- Larvae of bees, ants, and wasps do not form a complete digestive system until near the end of the pupal stage. Wastes accumulated by larvae are excreted just before the insect emerges as an adult.
- The females of some parasitic hymenoptera produce extremely large numbers of eggs. One Eucharitidae female was observed to lay 10,000 eggs in one hour.
- Some parasitic wasps swim beneath the water to lay their eggs on aquatic prey. *Caraphractus cinctus* (family Mymaridae) is an egg parasite of water beetles (genus *Dytiscus*).
- Fig wasps (family Torymidae, subfamily Agaoninae) are the only insects that can pollinate fig trees. The wasp larvae, which develop in flower galls, become coated with fig pollen when they emerge as adults. They unwittingly cross-pollinate each flower they visit when laying eggs. The Smyrna fig is a commercial variety that does not produce any pollen. Its survival depends entirely upon *Blastophagus psene*, a wasp that develops in wild Caprifigs but cross-pollinates the Smyrna fig in a fortuitous case of mistaken identity.
- As a rule, members of the order Hymenoptera can be regarded as ecological specialists. Most species are rather narrowly adapted to specific habitats and/or specific hosts. Their remarkable success as a taxon probably has more to do with their immense range of behavioral adaptation rather than any physical or biochemical characteristic. The Hymenoptera is the only order besides the Isoptera (termites) to have evolved complex social systems with division of labor.

- Herbivory is common among the primitive Hymenoptera (suborder Symphyta), in the gall wasps (Cynipidae), and in some of the ants and bees. Most other Hymenoptera are predatory or parasitic. The large hunting wasps are agile predators that catch and paralyze insects (or spiders) as food for their offspring. The greatest diversity, though, is found among the many families of parasitoid wasps whose larvae feed internally on the living tissues of other arthropods (or their eggs). These insects eventually kill their host, but not before completing their own larval development within its body. Despite their small size and characteristically narrow host range, these wasps are highly abundant and exert a tremendous impact on the population dynamics of many other insect species.
- Most of the Hymenoptera have relatively unspecialized mandibulate mouthparts. An exception is found in the bees (superfamily Apoidea) where the maxillae and labium are modified into a proboscis that works like a tongue to collect nectar from flowers. In these insects, the mandibles are used to gather or manipulate pollen and wax.
- Except for worker ants, most adult Hymenoptera have two pairs of wings. Front and hind wings are linked together by hooks (hamuli) along the leading edge of the hind wings that catch in a fold near the back of the front wings. In flight, both wings operate in unison to form a single aerodynamic surface.