ARTHROPODS

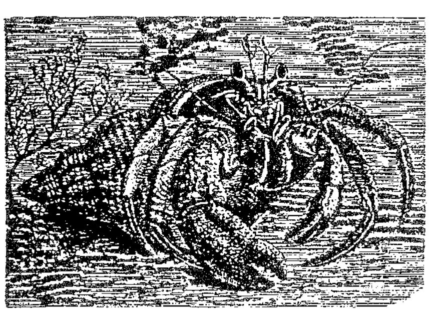
There is no other animal group on Earth that is as diverse in its **species**, as abundant in the number of individuals, and as successful in occupying every conceivable, and sometimes inconceivable, **niche** as the **arthropods**.

The **phylum** Arthropoda includes insects, arachnids (spiders and mites), crustaceans (lobsters, shrimp and crabs), centipedes and millipedes. The phylum's distinguishing characteristics are a hard **exoskeleton**, **bilateral symmetry**, segmented body parts and jointed **appendages**; hence the name arthropod which means "jointed foot." Despite these common characteristics, there is incredible variety among the arthropods, which accounts in part for their tremendous success. Variations in size, color and body shape allow arthropods to take advantage of many different **habitats** and food sources.

ADAPTABILITY

The success of arthropods is due to their incredible adaptability. They are one of only a few groups of animals (including birds, bats and some ancient flying reptiles) that have members which have adapted mechanisms for flight. In doing so, they were able to spread quickly across the Earth's surface. David Attenborough summed up the amazing adaptability of insects in Life on Earth, writing:

"By any standard, the insect body must be reckoned the most successful of all solutions to the problems of living on the surface of the Earth. Insects swarm the deserts as well as the forests; they swim below water and crawl in deep caves in permanent darkness. They fly over the high peaks of the Himalayas and exist in surprising numbers on the permanent ice caps of the poles. One fly makes its home in a pool of crude oil welling up from the ground; another lives in steaming hot volcanic springs. Some deliberately seek high concentrations of brine and others regularly withstand being frozen solid."



No other animal, not even humans, can boast such a wide range of habitats.

Not only have arthropods adapted to Earth's natural environments, but they have also found a place in the human world. We encounter arthropods in our homes, our gardens, our places of play and our places of work. Often we are not even aware of the constant presence of arthropods in our lives. Even though most children have never seen many of the animals about which they learn, such as a wolf or a spotted owl, they have grown up surrounded by arthropods. What better way to teach children about animal adaptations, natural history and conservation than to introduce these topics through a child's own fascination with the familiar.

MORE THAN ANYTHING ELSE....

Approximately three-fourths of all animal species that exist today are insects. It has been estimated that there are approximately 10,000,000,000,000,000,000 (ten quintillion) insects alive in the world today and this population is relatively stable due to natural controls (Newman, 1990, p. 84). There may be as many as 200,000,000 bugs for every human on Earth! E.O. Wilson calculated that the dry weight of all the ants in the rain forest would constitute 10% of the animal biomass. Furthermore, scientists have documented over one million species of insects, and estimate that there may be as many as 30 million. (For comparison there are only about 4,000 mammal species.) No matter how you calculate it—by species, mass, or sheer volume—insects and their phylum, the arthropods, are the most abundant and successful group of animals on Earth.

Woodland Park Zoo is honoring this often misunderstood group of animals in the Temperate Forest exhibit "Bug" World —Adventures With Arthropods. This exhibit contains a number of arthropods from around the world and highlights how they have adapted to different environments and life styles. Here, children can compare familiar arthropods such as honeybees and sowbugs, with less familiar Australian walkingsticks, Madagascar hissing cockroaches and Mexican red-kneed tarantulas. Children can also explore how animals develop adaptations for living in extremely different environments.

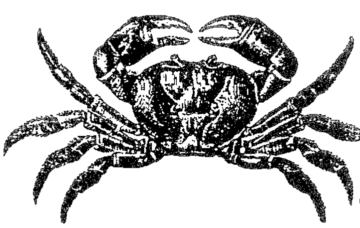
ARTHROPODS - THE MAJOR CLASSES

Here is an example of the taxonomic classification of an arthropod:

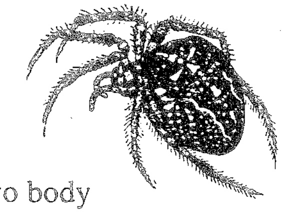
Honey Bee	
Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Order:	Hymenoptera
Family:	Apidea
Genus:	*Apis*
Species:	*mellifera*

There are five major classes of arthropods:

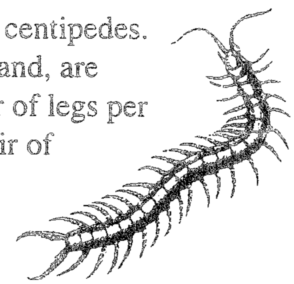
Crustacea: Lobsters, crayfish, barnacles, crabs and sowbugs are all crustaceans. Crustaceans are arthropods that breathe with gills. They have two body regions, two pairs of antennae, several pairs of appendages that serve as mouthparts, and five to 10 pairs of legs. The species in this class are predominately marine, and are often referred to as "insects of the sea"; however, some live in fresh water or on land. Because salt water is buoyant and supports their weight, these arthropods, unlike most others, are able to grow to large sizes. One lobster was recorded to be 44 lb. (19 kg) or 24 inches (60 cm).



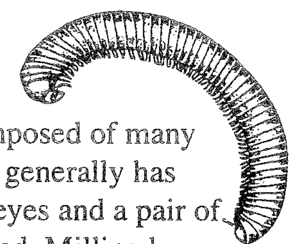
Arachnida: This group contains spiders, harvestmen, ticks, mites and scorpions. These primarily terrestrial, or land dwelling, animals have two body regions (the cephalothorax and abdomen), eight legs and simple eyes. They lack antennae, instead relying on many hairs covering their bodies as their sensory structure.



Chilopoda: Chilopoda are the centipedes. Animals in this group live on land, are long and slender, have one pair of legs per body segment and have one pair of antennae. The body of the centipede is divided into multiple segments. These animals are carnivorous, feeding primarily upon insects. Centipedes inject a paralyzing poison into their prey. This poison can be harmful to humans.



Diplopoda: These are the millipedes. All millipedes are terrestrial. Most have long, cylindrical bodies that are composed of many segments. Each body segment generally has two pairs of jointed legs. The eyes and a pair of antennae are located on the head. Millipedes are selective scavengers, generally feeding on decaying plant matter but generally not animal matter. Even though they have more legs than centipedes do, millipedes move more slowly.



Insecta: Insect is the common name given to all arthropods in the class Insecta. Insects are the largest class of animals. They are characterized by three distinct body regions (head, thorax and abdomen), three pairs of legs and one pair of jointed antennae. Insects range in size from less than 0.01 inches (0.025 cm), in the case of some parasites, to animals such as the Borneo walkingsticks or atlas moths which are almost 12 inches (30 cm) in length or wing span. With the exception of mollusks, insects are the most highly developed invertebrates. Some species, such as bees, have highly developed social structures. There are even insects, for example leaf-cutting ants, that farm their food.

ANATOMY

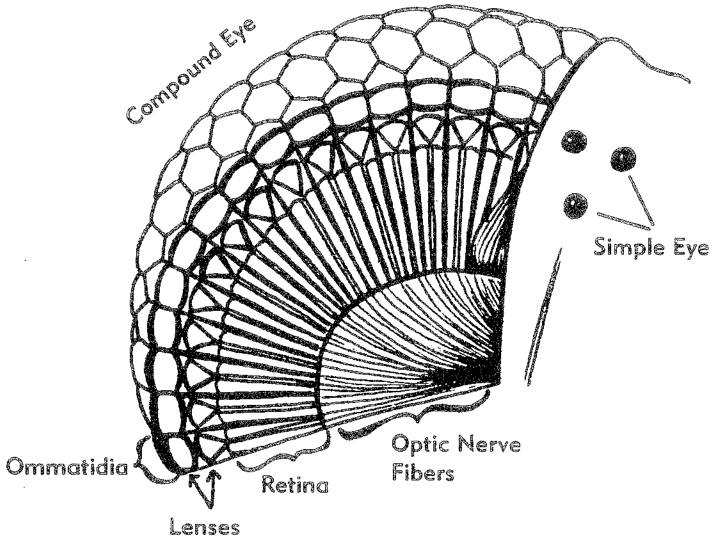
An insect's body comprises three segments: a head, a thorax and an abdomen. Not all arthropods follow this division. Crustaceans and arachnids have the head and thorax combined together to form a cephalothorax (sef-uh-low-THOR-ax). Centipedes and millipedes have a head and multi-segmented bodies. In all arthropods, however, each of the body segments has a particular function.

THE HEAD

The eyes, **antennae** and mouthparts are located on the head.

Eyes

Arthropods have two different types of eyes: simple and compound. Insects may have either simple or compound eyes or both. Millipedes and centipedes usually have two simple eyes. Spiders often have four pairs of simple eyes that are larger in hunting spiders than in web-spinning spiders. Most crustaceans have a pair of compound eyes but they may have unpaired simple eyes or both.



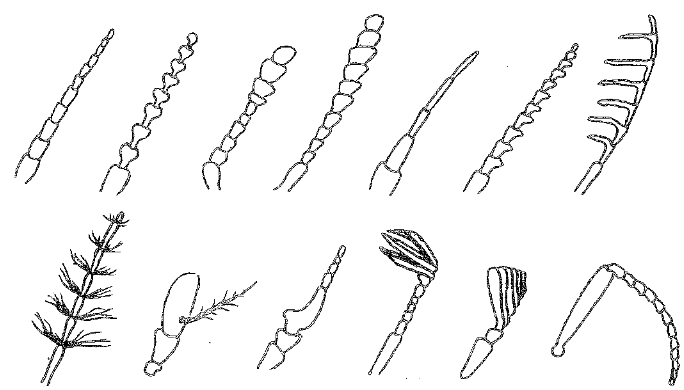
Compound eyes are large eyes that consist of a few to several thousand individual eye units called **ommatidia** (ah-mah-TI-dee-ah). The surface of each ommatidium is a lens. This lens forces light rays to bend and focus on special retinular cells behind the eye. The information received is transferred by optic nerve fibers to the brain. Each lens forms one little picture, and all the lenses together form a mosaic composite of the world.

The mosaic picture formed by a compound eye may lack detail. How much detail is available is dependent on the number of lenses in the animal's eye. The more lenses in a compound eye the better the image is defined; therefore, the better the insect can see. Dragonflies have excellent eyesight; they have over 25,000 separate lenses in each eye. House flies, on the other hand, have approximately 4,000 lenses and, therefore, their eyesight is not as good as that of the dragonfly. Compound eyes enable an arthropod to recognize color and patterns.

Simple eyes are small in comparison to compound eyes and are located on the upper side of the arthropod's head. If the animal has both simple and compound eyes, the simple eyes are generally located between the compound eyes. Simple eyes are sensitive to light, dark and movement. The vision of arthropods utilizing only simple eyes is limited to the detection of shadows and motion.

Antennae

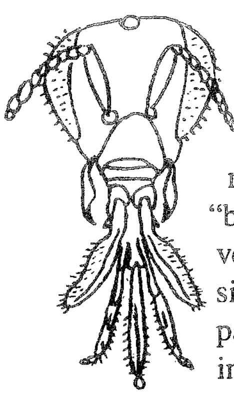
Antennae are present in all arthropods except the arachnids. Antennae come in many shapes and sizes, and can be used to detect odors and sounds. They can also be used to touch and taste objects.



Mouthparts

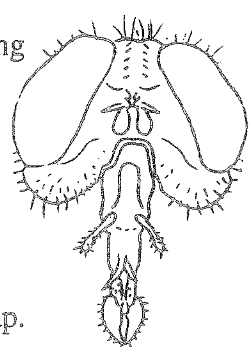
Arthropods' mouthparts can be used for defense, grasping a mate, digging burrows, building nests and transporting eggs, young and food. The mouthparts are usually a set of five structures that surround the mouth opening. Some of the most obvious structures are the mandibles. The mandibles are the jaws of the arthropod and may be either stout and strong with grinding surfaces, or thin and elongated for slicing.

Not all arthropod mouthparts are the same; they have been adapted for many different functions. Among the insects there are animals that chew, lap or suck their food. Each order has its own modification of one of these types, or a combination of them. The following are just a few examples of some of the variations among insect mouthparts.


Piercing Mouthpart

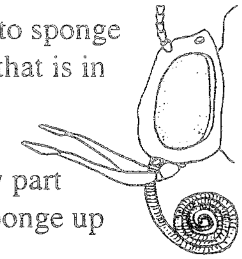
Mosquitoes and aphids are examples of insects with mouthparts designed for piercing and sucking. Think of a mosquito and what occurs when it "bites" you. The mosquito has a very sharp "needle" located inside a siphoning tube. This needle-like part of the mosquito's mouth is inserted through the surface of your skin, or that of another animal. Then the siphoning tube sucks the blood the mosquito requires for survival. When the mosquito's needle is stuck into the skin of its prey, the mosquito drips saliva into the cut which dulls the pain and adds an anticoagulant.

Some insects, such as ants, preying mantids and grasshoppers, have mandibles designed for chewing. The mandibles of these animals can move from side to side in order to crush or tear food.


Chewing Mouthpart

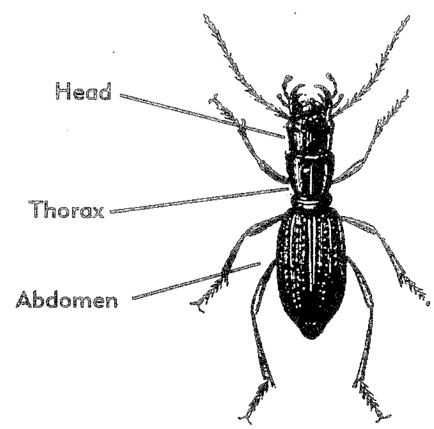
Honey bees can both chew and lap. They use their tongue to lap up the nectar of flowering plants and use their jaws to chew wax.

Flies utilize a sponging proboscis to sponge up liquid food. When eating food that is in a solid form, for example, bread, the fly deposits digestive enzymes on the bread. The enzymes liquefy part of the bread, enabling the fly to sponge up the liquid.

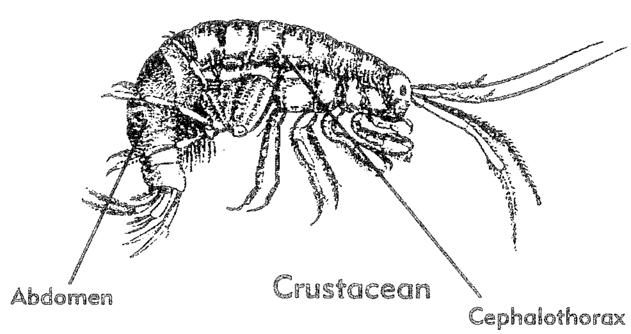

Sponging Mouthpart

THE THORAX AND THE CEPHALOTHORAX

The thorax is the middle segment of the insect, located between the head and the abdomen. The thorax is where the insect's tools of locomotion, such as the legs or wings, can be found. Crustaceans and arachnids have two body segments, the abdomen and the cephalothorax, which is the head and thorax fused together. The legs of crustaceans and arachnids are found on the cephalothorax.



Insect

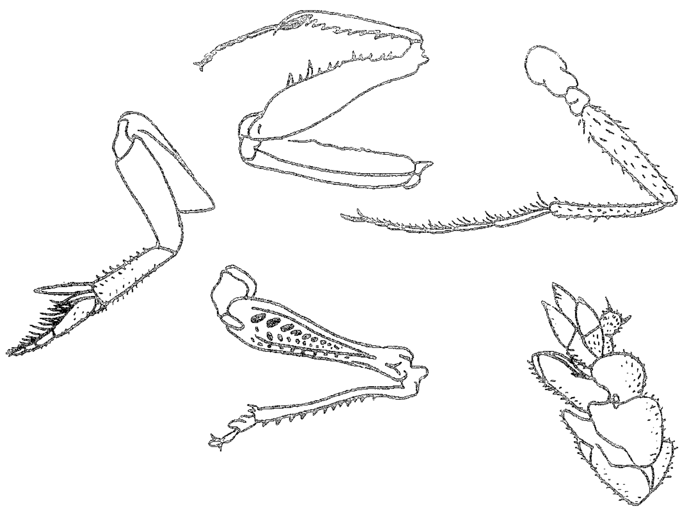


Crustacean

Centipedes and millipedes have multi-segmented bodies and lack a true thorax or a cephalothorax. The legs are located along nearly the entire length of the centipede's or millipede's body.

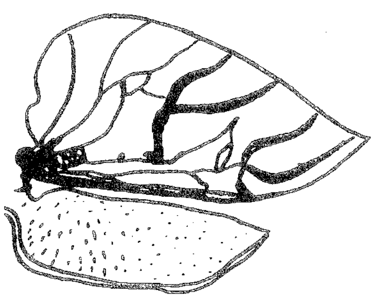
Legs

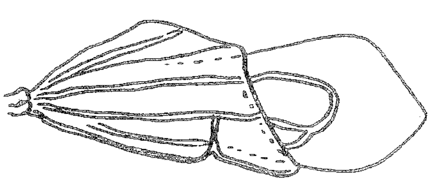
All arthropods have jointed appendages. The legs of arthropods come in many forms and perform many functions: running, jumping, grasping, killing prey, swimming, courtship, making sounds, tasting or cleaning. Some insects, such as moths, even have their "ears" located on their legs. Other insects, such as crickets, use their legs to produce sounds for communication. Sensitive hairs along the legs, like those on tarantulas, may assist some arthropods in sensing the world around them.



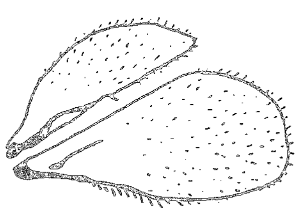
Wings

Wings are characteristic only of some species of insects; other insects and all other arthropods lack wings. Adult insects may possess one or two pairs of wings. In some insects, such as beetles and grasshoppers, the first pair of wings is hard and serves to protect the second pair.



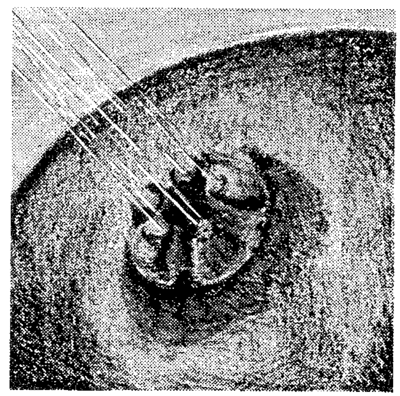


Insects' wings vary in size, shape, color, thickness and **venation**, or vein pattern. Vein patterns are used widely in identification of species.



THE ABDOMEN

The abdomen is the softer, more flexible end of the insect. Most arthropods lack appendages on the abdomen, except near the tip where there may be some external genitalia. Adult females of some groups of insects have an **ovipositor** located at the tip of the abdomen. The ovipositor is a specialized organ for depositing eggs. In some species, the ovipositor has been modified. In honeybees, the ovipositor is modified into a sting connected with poison glands. Grasshoppers have curved ovipositors for digging into soil or plant tissue. Sawflies have blade-like ovipositors for cutting into leaves or stems of plants. Inchneumon flies have needle-like ovipositors for piercing deep into tree bark.



The abdomens of most arachnids are also very soft and flexible. **Spinnerets** are located at the tip of the abdomen of most spiders. The spinnerets are used in spinning silk which is used for many purposes such as making webs, catching prey or lining burrows.

Arthropods' abdomens house the majority of the reproductive, circulatory, respiratory, excretory and digestive organs.

THE EXOSKELETON

Arthropods do not have an internal skeleton; instead, they have a hard, outer **cuticle** called an **exoskeleton**. This exoskeleton, due to its rigidity, provides the arthropod with built-in protection against predation. It was the evolution of a hard exoskeleton that gave arthropods a competitive advantage in the oceans 600 million years ago. Their armor was a unique form of defense: one early arthropod class, the trilobites, dominated the oceans for almost 350 million years, a period of time known as the Age of Trilobites. Another early arthropod, the eurypterid (which looked like a nine-foot-long sea scorpion) climbed to the top of the ancient food chain. When plants first took root on land 400 million years ago, arthropods were soon to follow, and they quickly evolved to fill almost every new ecosystem on Earth.

In addition to providing arthropods with a continuous form of defense, the exoskeleton also prevents them from becoming dehydrated. Special means for breathing through the exoskeleton, such as pores **(spiracles)** that open into tubes **(tracheae)**, are necessary to deliver air to the body's tissues. Gills are used by some aquatic arthropods for breathing.

There are some drawbacks to having an exoskeleton. For example, in order for growth to occur, the exoskeleton must be shed. During the period of time immediately following the shed, the animal is very soft and vulnerable to predation.

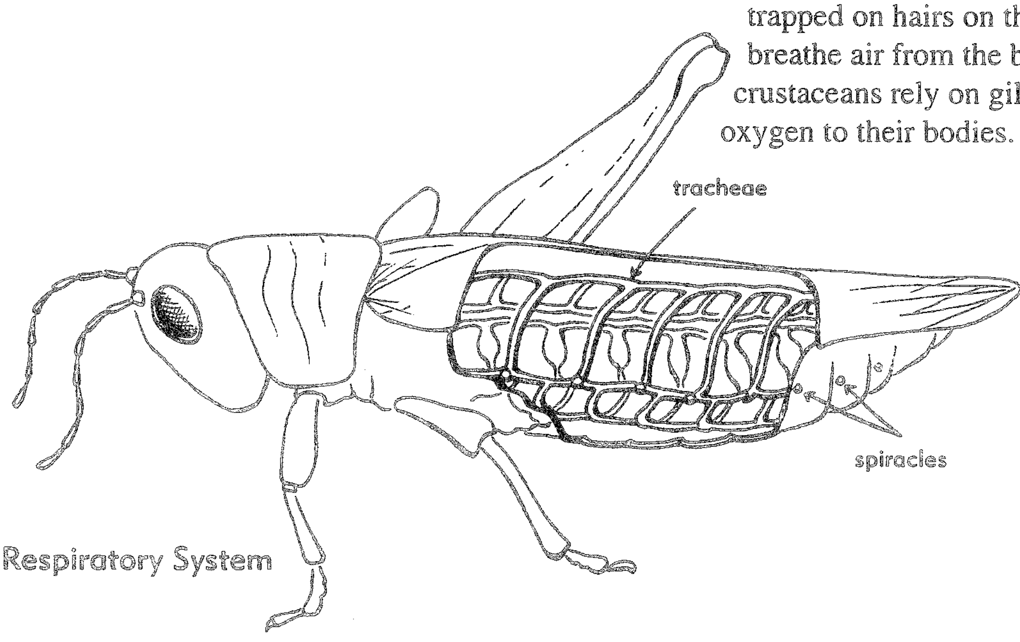
PHYSIOLOGY

Circulatory System

Arthropods have simple circulatory systems. Rather than having a complex network of veins and arteries enclosing the circulatory system, insects and most other arthropods have **open circulatory systems.** This means that they have a simple heart that pumps blood through the open body cavity. The blood, called **hemolymph** (HEE-mo-limf), is a clear fluid that is usually colorless or slightly green or yellow. The blood cells transport food and waste. There is no oxygen transporting function as performed by the red **corpuscles** of higher animals. The heart of an insect is a long tube with a series of chambers divided by valves. Circulation is achieved by pulsation of the heart which circulates the hemolymph around most of the organs and tissues.

Respiratory System

Most arthropods have no lungs, although many spiders have book lungs. Book lungs are air-filled sacs located in the abdomen of the spider. Air from outside the spider's body travels through slit-like openings into the air sacs. The air sacs have page-like folds, thus the name book lungs. In most insects, millipedes and centipedes, air is taken in by external pores, called spiracles. The spiracles are located on each side of the abdomen and thorax. The air is conducted to all organs by means of many branching tubes called tracheae. However, closed tracheal systems with permanently closed spiracles occur in some aquatic and parasitic insects. Some aquatic insects have tracheal gills or they carry air bubbles trapped on hairs on their body and breathe air from the bubbles. Aquatic crustaceans rely on gills to supply oxygen to their bodies.



Respiratory System

Nervous System

The nervous system of most arthropods consists of parallel nerve cords running the length of the animal's body. The nerve cord has nerve knots, called **ganglia**, at various intervals. The fused ganglia located in the head function as the brain and coordinate the whole insect, serving the eyes, antennae and mouthparts. The ganglia located throughout the body vary in size according to the activity level of the body region. Nerves branch out from the ganglia to all parts of the body.

Digestive System

Arthropods feed upon almost all types of organic substances found in nature. The digestive system of most arthropods is complete and consists of a tube that extends the full length of the body and has two openings. The tube is made up of a mouth, **pharynx, esophagus, crop, midgut, hindgut** and **anus**. Glands near the mouth secrete juices that aid in digestion. Fat bodies in some insects serve as food storage reservoirs, enabling these insects to go for long periods without eating.

Excretory System

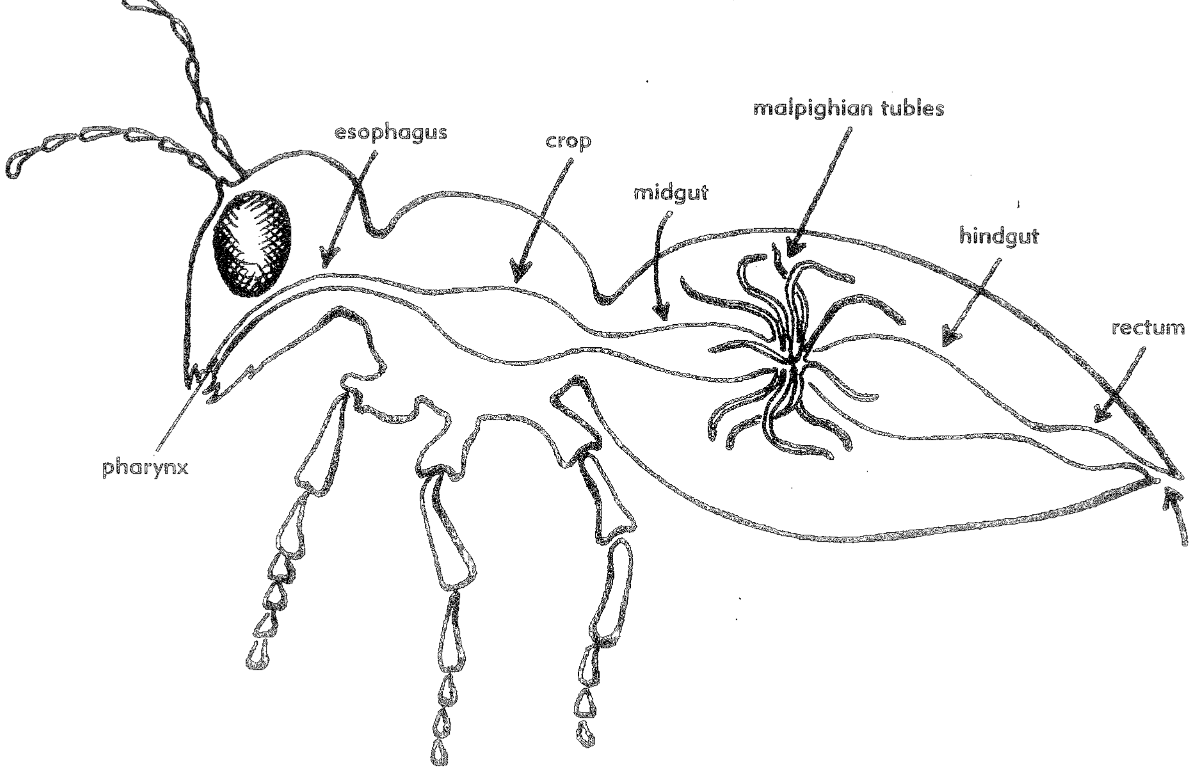
The excretory system of most arthropods consists of a set of **malpighian** (mal-PI-gee-an) **tubules**. Waste products are taken up from the blood by these tubules and passed by way of the hindgut and anus. Glands in the rectum remove water and salts from waste material. The word for insect waste material is **frass**.

Musculatory System

The muscles of arthropods are very strong and efficient. Many arthropods can lift as much as 20 times their own body weight; some can lift significantly more.

"Their [insects] athletic prowess dwarfs the efforts of the world's Olympic champions. The commonest of fleas can jump 150 times its own length (the equivalent of a man jumping six city blocks from a standing start), go months without feeding, and after a year of being frozen solid, be revived. An ant can lift 50 times its own weight and carry it in its jaws proportionately farther than an average man can walk empty handed, while to match a bee's strength, a man would have to pull a load equal to a 30-ton trailer truck" (Newman, 1990, p. 40).

Digestive and Excretory Systems



Much of the credit for the incredible strength of insects and other arthropods can be attributed to the efficient supply of oxygen by the tracheal system and the leverage created by large areas of muscle attachment. An insect's muscles are capable of very rapid contraction.

DEVELOPMENT

Molting

The hard exoskeleton of an arthropod does not continue to grow with the animal and must be shed if the arthropod is going to reach adulthood. **Molting** is the process involved in loosening the old cuticle and producing a new, larger replacement. The molting process can take several days to weeks as the animal prepares to shed its skin. The actual shedding of the old cuticle usually takes a few hours. Because the exoskeleton is hard, a molted skin generally retains the shape of the arthropod and can often be mistaken for the animal itself.

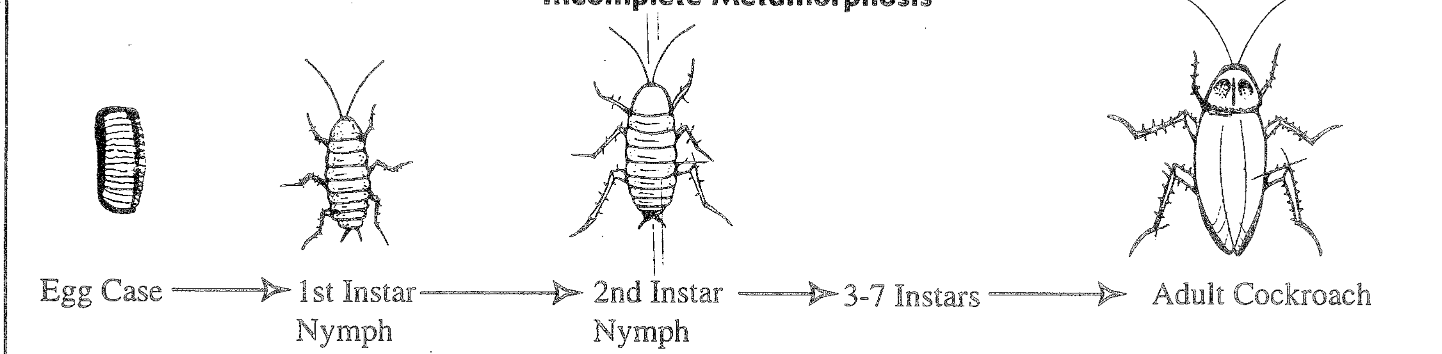
During molting an arthropod is vulnerable to attack, damage and **desiccation**. The number of molts that occur during development averages from four to eight but can be more or less, depending on the species. Most adult insects do not molt. Between molts, the insect is called an instar.

Metamorphosis

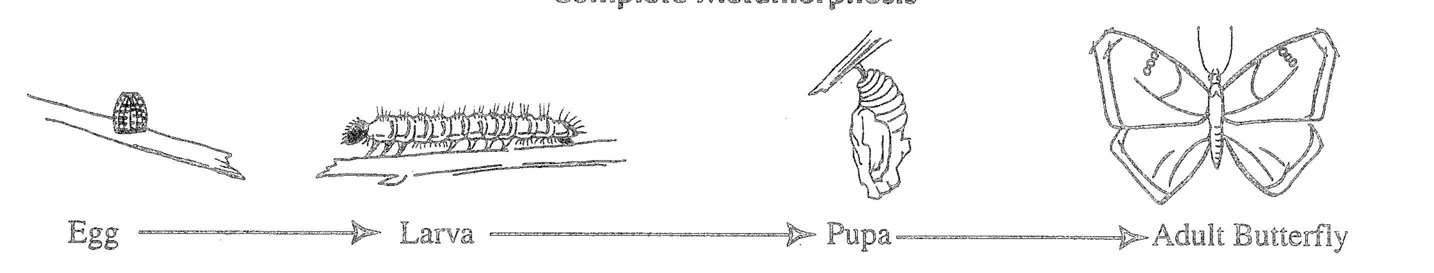
Although insects molt to increase in body size, they develop through a process called **metamorphosis**. Metamorphosis is a changing of form. There are two basic classifications of metamorphosis: **incomplete** and **complete**. In species which undergo incomplete metamorphosis, the immature animal resembles the adults. Incomplete metamorphosis results in a size increase and the development of wings and genitalia. Immature insects that go through incomplete metamorphosis are called **nymphs**. Nymphs have compound eyes and mouthparts like adults and their wings develop externally as pads. Immature insects in this group generally feed on the same food as adults do.

Immature insects that undergo complete metamorphosis develop through distinct body forms before reaching their adult stage. Immatures of this group do not resemble the adults and have an additional developmental stage called the **pupa**. Butterflies are an example of insects that go through complete metamorphosis. The butterfly begins its life in a larval form as a caterpillar, it then goes through a pupal stage and it finally emerges as a butterfly. The **larvae** of insects that undergo complete metamorphosis have simple eyes, chewing mouthparts and very short antennae. The larvae generally eat different foods than the adults of the

Incomplete Metamorphosis



Complete Metamorphosis



species, helping to reduce competition and ensure adequate food sources for the insects at both stages. Wings develop beneath the larval skin and are not visible until the pupal stage. The mature larva molts into a stage called the pupa. The pupa does not eat and is usually unable to move. Pupae of many moths, some wasps and various other insects are covered by a silken **cocoon**. Most of the structural changes necessary for the transition from a larva to an adult occur during the pupal stage.

After several days or weeks, the adult insect emerges by pushing and crawling out of the pupal skin. The wings are crumpled and the body is soft. Within minutes to hours, depending on the species, the adult's body dries, hardens and becomes more **pigmented**. The wings expand from air and liquid pressure and form a rigid framework.

There are several advantages to metamorphosis. Each life stage is specialized, which increases efficiency and success. Competition for food and habitat resources within a species and within a population is reduced because the larvae and the adults often have different food habits and occupy different **niches**. Metamorphosis also increases the insect's ability to withstand climatic extremes. Most insects can overwinter in an egg or pupal stage.

Reproduction

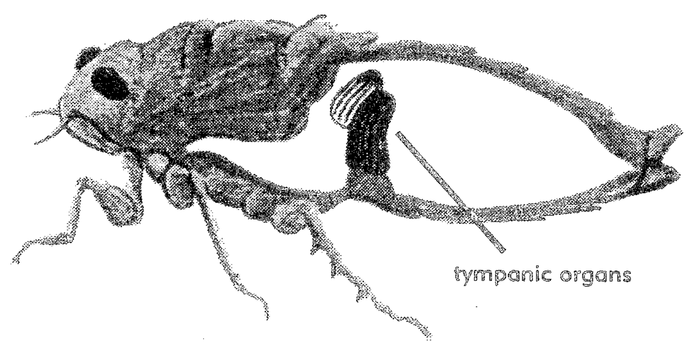
Like vertebrates, the female arthropod has ovaries and the male has testes. In both the male and the female, the reproductive organs are located in the abdomen. The male's testes produce sperm, which in primitive orders are encased in **spermatophores** (sper-MA-to-forz). The sperm are transferred in the spermatophores to the female during copulation or placed on a **substrate** and picked up by the female. The female has a sac-like structure, called the **spermatheca** (sper-mah-THEE-kah), where the sperm is stored after copulation and until fertilization.

Most arthropods produce eggs. Eggs may be laid singly or in batches via the ovipositor of the female. Eggs vary in size, shape and color depending on the species. In some species, the eggs are enclosed in an egg case. Females also have glands which secrete an adhesive material used to fasten the eggs to objects or to produce a protective covering for the egg mass. The embryo may develop from either a fertilized or unfertilized egg. In some cases, such as honeybees, an unfertilized egg develops into a male. **Parthenogenesis**, or asexual reproduction, also occurs in some species such as walkingsticks. Asexual reproduction means that the embryo develops from the unfertilized egg of the insect.

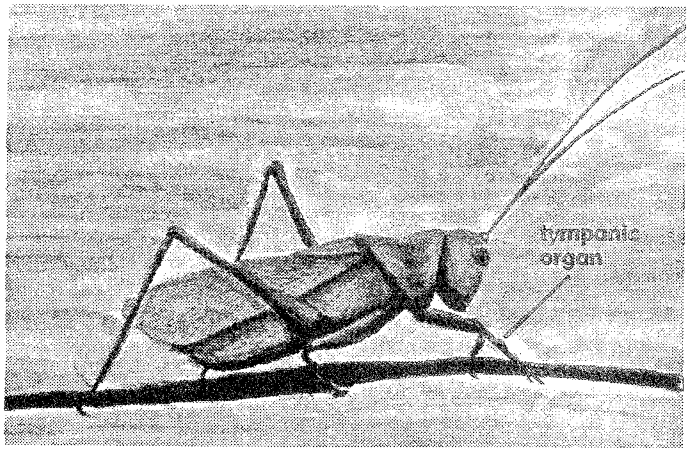
Senses

Sound

Insects are the only arthropods that produce sounds to attract and locate mates; to aggregate their species to a mating site, food source or social grouping; to defend or warn; to distinguish members of the same species; or to define territory. Sound is usually produced by rubbing two parts of the body together, one part having a file, the other part having a ridge. This method of producing sound is called **stridulation**. The body parts being rubbed together may be two wings, a wing and a leg or any other two parts of the body. For example, grasshoppers produce sound by rubbing a leg against one wing. Crickets rub both wings together to form sounds. Insects can also produce sounds by tapping or vibrating some part of their body or by forcing air through their spiracles. Cicadas vibrate a special drum-like area in their abdomen to make a popping sound. They can do this 500 times per second.



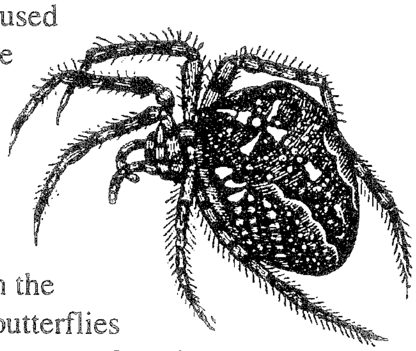
Insects detect sounds by sensory hairs or by **tympanic organs** (sensory cells attached to membranes). Some tympanic organs are found on the abdomen while others are found on the leg.



Hairs Used for Sensing

Arthropods are sensitive to touch and vibrations. The touch receptors are called hair **sensilla** (sen-SI-la) or **setae** (SEE-tee) and are connected to nerve cells. These hairs are abundant on the antennae but also occur practically everywhere on the animal's body.

Insect hairs are also used for taste. Insects have chemoreceptors that can be considered taste receptors. In a majority of insects these receptors are in the mouth; however, in butterflies and flies, these receptors are found on the feet.

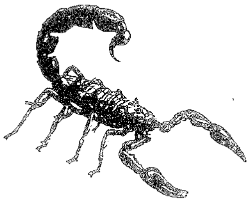


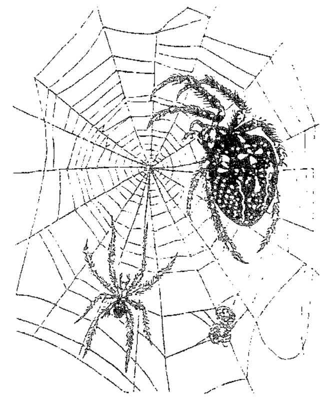
Vision and Smell

The olfactory organs in the arthropods are primarily the antennae. Smell is used to recognize similar species or the opposite sex. Smell is also used in the search for food, to find a place to lay eggs, or to find the way back to the nest.

Visual ability varies a great deal within the arthropod world, from excellent in butterflies to poor in termites. But in general, vision is a very important sense in insects. They use their eyes to find food, mates and homes, to detect predators and to find places to lay eggs (called oviposition sites). The optic lobes of insects are the most highly developed areas of the brain. Winged insects' eyes are superior to ours at detecting motion. The number of neurons devoted to visual points in a fly far exceeds the number of human visual connections. The spectrum of colors seen by insects is wider than our own, and ranges from ultraviolet to near infrared.

FASCINATING FACTS





Arthropods are adapted to live in some strange places:

- The larvae of some brine flies live in pools of crude oil in California.
- Wingless flies inhabit frozen Antarctica. They are the largest animal solely terrestrial living in Antarctica.
- There are beetles in the Namib Desert in Africa that can only get water by drinking dewdrops that form on their bodies.
- Some insects (fungus gnats, roaches and wasps) have even been in space! They orbited the Earth in Biosatellite II.

It is estimated that 10% of the animal biomass of the world is made up of ants and another 10% is made up of termites.

In one acre of African savanna the biomass of all the termites will outweigh the biomass of all the mammalian herbivores.

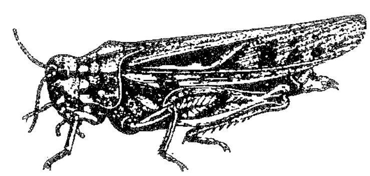
A termite queen may live as long as 50 years. Some colonies of termites may build mounds up to six meters (18 feet) high.

For every one person in the world there are 200 million insects.

Caterpillars have as many as 4,000 separate muscles, whereas humans have only 792 distinct muscles.

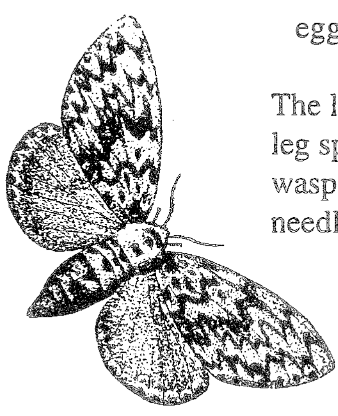
Spiders make their own very strong "glue." They use it to attach threads together or to other surfaces.

Insects are needed to cross-pollinate 75% of our commercially grown crops.

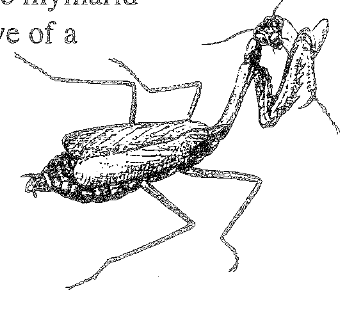


Life cycles of different insects exhibit extreme variations in time:

- The "17-year locust" (cicada) matures over a period of 13 to 17 years.
- The common housefly reaches maturity in 10 days.
- Some parasitic wasps reach adulthood only seven days after the eggs have been laid.



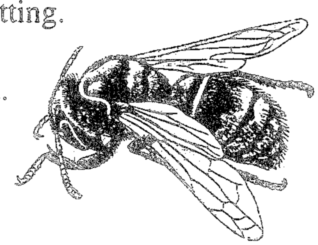
The largest arthropod in the world, the Japanese spider crab, has a leg span of three meters (9 feet). The smallest insects are mymarid wasps. They are so small that they can fit through the eye of a needle.

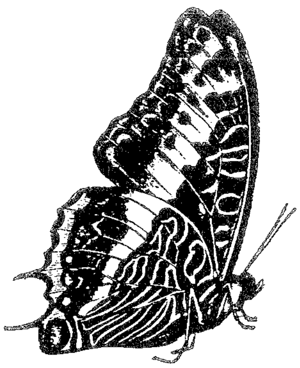


Bombardier beetles defend themselves by squirting a hot (100° C, 212° F), irritating chemical from their abdomen.

Many caterpillars use **camouflage** to avoid being eaten. Great swallowtail caterpillars, when they curl up in a spiral, look just like bird droppings!

A female mosquito can sip her own weight in blood at one sitting. But in just the first two days of its life, a Polyphemus moth larva will consume 86,000 times its own birth weight in food.





Insects have been important as medicinal treatments:
- Pouring a mixture of powdered earwigs mixed with hare's urine into your ears every night before going to sleep was considered to be a cure for deafness.
- In China, 10 centipedes ground with herbs may be prescribed to treat kidney problems.
- "Apitherapy" is popular in China. Bee stings are commonly used to treat arthritis.
- Black ants have been used to help suture wounds in many parts of the world. The ants are made to bite into the flesh on either side of the wound. Then their bodies are broken off, leaving the heads with the clamped mandibles as stitches.

Conservation

Throughout history arthropods have gotten a bad rap. Many people think of insects killing crops, spreading disease and being a nuisance. However, only 1% of all known insect species have a negative effect on humans. It is also important to remember that all arthropods, including the 1% that negatively affect humans, are important components in the global ecosystem. They provide food for numerous other animals (and even some carnivorous plants). Some arthropods even eat bugs we consider pests. Researchers are exploring ways to use insects to fight off other bugs instead of relying on dangerous pesticides. Tiny crustaceans, called krill, are the main source of food for the largest animal on Earth, the blue whale. Still other crustaceans and insects provide a major protein source for human societies. Insects are also important pollinators. In fact, it is believed that insects and flowering plants co-evolved, making the process of pollination extremely efficient. For example, plants that are pollinated by bees and butterflies bloom during the day when these animals are active. The difference in what flowers are pollinated by bees or butterflies is in part due to the colors that can be seen by the animals. Plants with yellow and blue flowers attract bees, whereas deep-throated orange or red flowered plants are pollinated by butterflies. Flowers that are pollinated by moths bloom at night and are pale or white so that they can be seen well in the dark. Some flowers are pollinated by flies and smell like rotting meat to attract the flies. Many arthropods also play a vital role in decomposing dead and decaying matter returning important nutrients to the soil.

Unfortunately, like so many of Earth's animal species, arthropods are not immune to the effects of human development. Although arthropods have adapted to many different habitats and, as a whole, are highly successful, many species are also at risk due primarily to habitat loss. In some cases this is due to the extreme specialization of a species. Certain species of insects may live in only one species of tree or may eat the leaves of only a few plants.

Many of the more than 1 million arthropod species are endangered. For example, the California freshwater shrimp, Tooth Cave spider, American burying beetle and mission blue butterfly are on the Endangered Species List. Habitat destruction is the primary cause of arthropod endangerment, since many species are adapted to very specific (and often small) regions. Paradoxically, the extinction of so many species is not a result of the elimination of targeted species through the use of pesticides or other means. Insects are able to develop resistance to our most powerful pesticides within a relatively few generations.

"Within the next 25 years we may witness the extinction of more than one-half of the world's insect species, about three million, even before they have been made known to science. The vast majority represent essential keys to future pest management programs, crop pollination, soil production, and in brief, healthy ecosystems" (Newman, 1990, p. 84).

HELPING AT THE ZOO!

One of the major goals of "Bug" World—Adventures With Arthropods at Woodland Park Zoo is to demystify bugs and to show children and adults alike that arthropods are an important part of our global community. Because arthropods make up the largest single group of animals on Earth, we must remember that we need insects, arachnids, crustaceans, millipedes and centipedes to survive, and their survival may also depend in part on us. If we conserve only what we know and love, then we must learn to appreciate the significance and beauty of arthropods in order to preserve these important animals.

Woodland Park Zoo does not currently participate in breeding programs for its arthropods. However, with the opening of our new exhibit "Bug" World—Adventures With Arthropods, we are now able to participate in captive management programs. Even without a breeding program, it is important for Woodland Park Zoo to have non-breeding arthropods. We are able to act as a support facility for other zoos and we can be a holding facility until breeding is needed in the future. By observing the animals we currently have at the zoo, we are able to gather important research information which will benefit future programs involving critically endangered species.

HOW YOU CAN HELP!

The effort to save animals and their habitat requires cooperation and support at the international, national, regional and individual levels. You can help in this cause. Join and become active in Woodland Park Zoo and other conservation organizations of your choice. To conserve habitat for arthropods, reduce your use of pesticides and herbicides and work to preserve vegetation in your neighborhood and in other regions.

Learn to use natural cleansers around your house and find nontoxic means for getting rid of pests in your garden or around your home! Toxins can easily get into the ground water and affect many more animals than you can ever imagine.

Learn as much as you can about arthropods and their fascinating habits. Through observing arthropods in their natural environment you can learn many fascinating things. Remember, if in your studies, you ever pick up an animal, put it back where you found it so it may continue to do its job helping us!

FOR MORE INFORMATION

Contact the Woodland Park Zoological Society at (206) 789-6000 to find out how you can support conservation efforts at the zoo. Learn other ways you can help conserve wildlife and the habitats they require for survival by calling the zoo's Education Center at (206) 684-4800.

Even More....

You can also contact the following organizations to find out more fascinating information about arthropods.

Entomological Society of America
9301 Annapolis Road
Lanham, MD 20706

The Sonoran Arthropod Studies Institute
PO Box 5624
Tucson, AZ 85703
(520) 883-3945
www.azstarnet.com/~sasi

Young Entomologist Society
Michigan State University Dept. of Entomology
East Lansing, MI 48824

The Insects Home Page
www.ex.ac.uk/~gjlramel/six.html

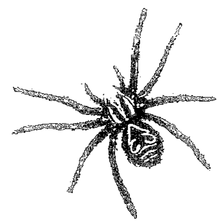
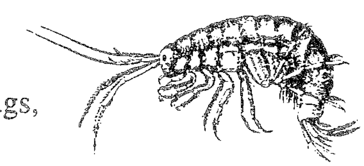
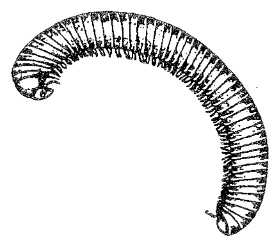
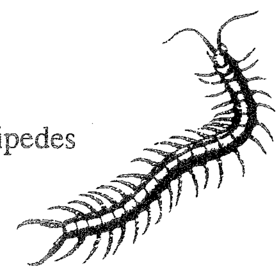
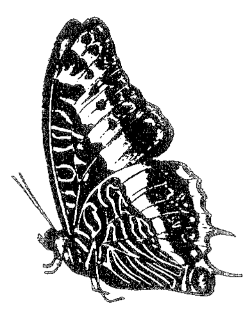
American Tarantula Society
www.concentric.net/~DmaMarrtin/ats

Iowa State University Tasty Insect Recipes
www.ent.iastate.edu

Phylum Arthropoda

Characteristics:
Jointed legs
Hardened exoskeleton
Bilateral symmetry
Distinct body segments

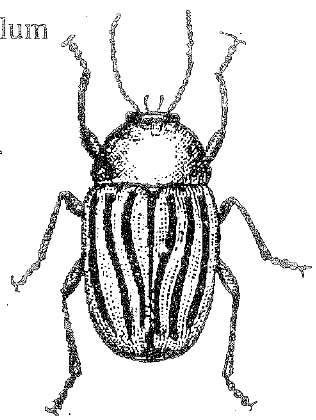
There are five major classes of arthropods (numbers of species in each class vary widely between sources).

Class	Example	
Arachnida—have four pairs of legs, one or two body regions, no wings or antennae. Most live on land but some live in freshwater. 35,000+ species	spiders, scorpions, mites, ticks	
Crustacea—have five or more pairs of legs, two body regions, two pairs of antennae and lack wings. Most are marine, some live in freshwater, a few are terrestrial. 35,000+ species.	crabs, crayfish, barnacles, sowbugs, shrimp, lobsters	
Diplopoda—have round multi-segmented bodies with two pairs of legs on most segments, have one pair of antennae and lack wings. Terrestrial. 8,000+ species.	millipedes	
Chilopoda—have flattened multi-segmented bodies, with one pair of legs on most segments, have one pair of antennae and lack wings. Terrestrial. 5,000+ species.	centipedes	
Insecta—have three pairs of legs, three body regions, one or two pairs of wings (sometimes absent) and one pair of antennae. Mostly terrestrial or freshwater, a few marine. 1 million+ species currently identified.	flies, beetles, walkingsticks, bees, ants, cockroaches, ladybugs, crickets, butterflies	

INVERTEBRATES

When most people think about animals, they tend to think about vertebrates, animals with backbones, such as birds, fish or mammals. However, most of the animals in the world are invertebrates. Invertebrates include the arthropods, about which this packet has been written, but also include 27 other phyla. The following is a description of just a few of the invertebrate phyla.

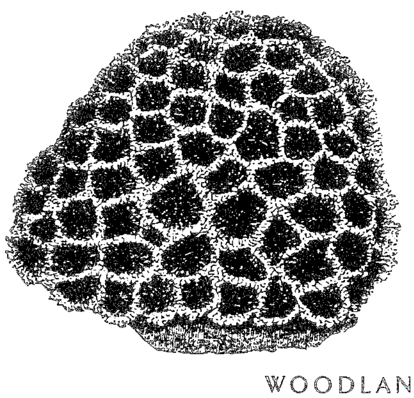
Phylum Arthropoda — Crustaceans, Insects, Millipedes, Centipedes, Arachnids



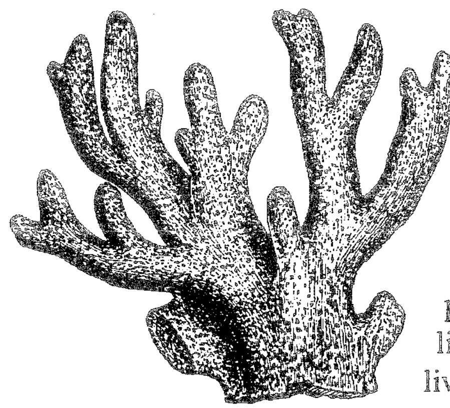
Arthropoda is the largest phylum of animals and has a wide variety of species. The word arthropod means jointed foot. Jointed appendages (legs and antennae) are a major characteristic of the group. Further major characteristics of the arthropods include segmented body parts and an external skeleton which protects the arthropods from drying out and from injury. Most arthropods have an open circulatory system, where blood does not flow in closed vessels.

Phylum Porifera — Sponges

These animals live attached to one spot and do not have a definite shape. They have no true organs or tissues, but they do have specialized cells. Their body is made of two layers of cells with a gel-like substance in between. When they die they leave behind an internal skeleton that may be made of silica (glass), lime or a fibrous protein called spongin. Porifers were the first animals to have multicellular bodies in which different cells have different functions. These animals always live in water.



Phylum Cnidaria — Jellyfish, Coral and Sea Anemones



In general, cnidaria are shaped like a hollow sac composed of two layers of tissue with a jelly-like material in between. Like the porifera, cnidaria live in water. Some live attached to the ocean floor, but others move around. The cells are grouped into simple tissues. Digestion takes place in a simple cavity and whatever isn't digested goes out through the same opening as it came in. Cnidaria have toxic stinging cells that they use to catch their prey. Cnidaria come in two forms, medusa and polyp.

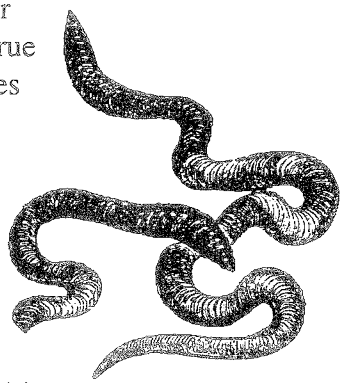
Phylum Platyhelminthes — Flat Worms

These are the simplest animals to have three layers of tissue as well as simple digestive (one opening), reproductive and nervous systems. They have a head, tail and long, flat body; some also have eye spots. Many platyhelminthes, such as tapeworms and flukes, are parasites and live in or on people or other animals.

Phylum Nematoda — Round Worms

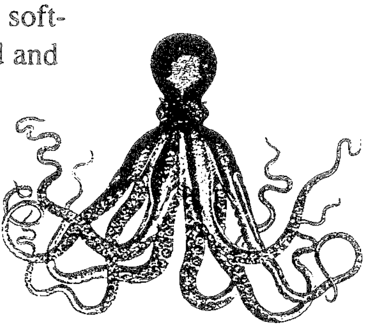
Nematodes have long, tube-like bodies that taper to a point at both ends. Many live in mud or soil but others, such as ascarids and hook worms, are parasites to people and other animals. Nematodes have a digestive tract with two openings; they also have both a nervous and a reproductive system.

Phylum Annelida — Segmented Worms



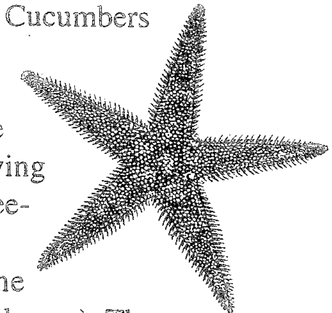
Annelids are segmented worms that live in soil or water. Annelids have a true body cavity that separates the organs from the muscles of the body. They also have specialized organ systems including: a reproductive system, an excretory system and a digestive system with two openings. Most also have a closed circulatory system (blood flows through vessels and is pumped by strong muscles).

Phylum Mollusca — Snails, Clams, Squid, Octopi and their relatives



Mollusks are generally soft-bodied, non-segmented and usually enclosed in a hard shell of calcium carbonate. Some mollusks have one shell, some have two and others, such as the squid, have internal "shells." Most mollusks live in water or moist areas. They have a muscular body, sometimes called a head-foot, which comes in many forms depending on the class of mollusk. They have well developed digestive, respiratory, excretory and reproductive systems. The circulatory system is closed and has a two-chambered heart. This is considered the most advanced group of invertebrates.

Phylum Echinodermata — Sea Stars, Sand Dollars, Sea Urchins and Sea Cucumbers



Echinoderms are spiny-skinned invertebrates that live in the sea. Most are slow moving as adults but the larvae are free-swimming and closely resemble the embryos of the chordates (animals with back bones). These animals have a pentaradial, or five "spoke," structure with a mouth in the middle. Echinoderms have no head and no excretory or respiratory systems. They have a system of water filled tubes or tube feet which they use for locomotion and sometimes to catch prey.