UG CBCS Semester-1
Phylum: Arthropoda

Phylum Arthropoda (ar-throp´o-da) (Gr. *arthron,* joint, + *pous, podos,* foot) embraces the largest assemblage of living animals on earth. It includes spiders, scorpions, ticks, mites, crustaceans, millipedes, centipedes, insects, and some smaller groups. In addition, there is a rich fossil record extending back to the mid-Cambrian period.

Arthropods are eucoelomate protostomes with well-developed organ systems, and their cuticular exoskeleton containing chitin is a prominent characteristic. Like annelids, they are conspicuously segmented; their primitive body pattern is a linear series of similar somites, each with a pair of jointed appendages. However, unlike annelids, arthropods have embellished the segmentation theme: variation occurs in the pattern of somites and appendages in the phylum. Often somites are combined or fused into functional groups, called **tagmata,** for specialized purposes. Appendages, too, are frequently differentiated and specialized for walking, swimming, flying, or eating.

Few arthropods exceed 60 cm in length, and most are far below this size. The largest is a Japanese crab (*Macrocheira kaempferi*), which has approximately a 3.7 m span; the smallest is a parasitic mite, which is less than 0.1 mm long.

Arthropods are usually active, energetic animals. However, we judge them, whether by their great diversity or their wide ecological distribution or their vast numbers of species, the answer is the same: they are the most abundant and diverse of all animals.

Although arthropods compete with us for food supplies and spread serious diseases, they are essential in pollination of many food plants, and they also serve as food, yield drugs and dyes, and create such products as silk, honey, and beeswax.

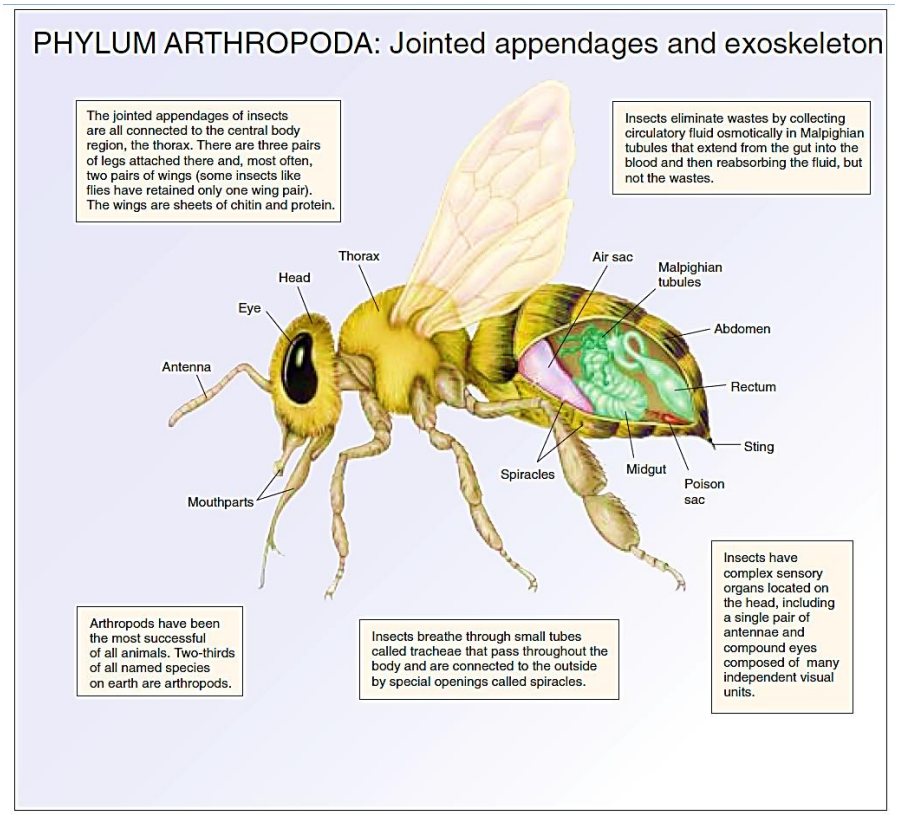


FIGURE 46.3
The evolution of jointed appendages and an exoskeleton. Insects and other arthropods (phylum Arthropoda) have a coelom, segmented bodies, and jointed appendages. The three body regions of an insect (head, thorax, and abdomen) are each actually composed of a number of segments that fuse during development. All arthropods have a strong exoskeleton made of chitin. One class, the insects, has evolved wings that permit them to fly rapidly through the air.

Ecological Relationships

Arthropods are found in all types of environment from low ocean depths to very high altitudes and from the tropics far into both north and south polar regions. Some species are adapted for life on land or in fresh, brackish, and marine waters; others live in or on plants and other animals. Most species use flight to varying degrees to move among their favored habitats.Some live in places where no other animal could survive.

Although all types—carnivorous, omnivorous, and herbivorous—occur in this vast group, the majority are herbivorous. Most aquatic arthropods depend on algae for their nourishment, and most land forms live chiefly on plants. There are many parasites.In diversity of ecological distribution arthropods have no rivals.

Characteristics

- Bilateral symmetry; metameric body, **tagmata** of head and trunk; head, thorax, and abdomen; or cephalothorax and abdomen
- **Appendages jointed;** primitively, one pair to each somite (metamere), but number often reduced; appendages often modified for specialized functions
- **Exoskeleton of cuticle** containing protein, lipid, chitin, and often calcium carbonate secreted by underlying epidermis and shed (molted) at intervals
- Muscular system complex, with exoskeleton for attachment; striated muscles for rapid action; smooth muscles for visceral organs; **no cilia**
- Coelom reduced; most of body cavity consisting of **hemocoel** (sinuses, or spaces, in the tissues) filled with blood
- Complete digestive system; mouthparts modified from appendages and adapted for different methods of feeding
- **Circulatory system open,** with dorsal contractile heart, arteries, and hemocoel
- Respiration by body surface, gills, tracheae (air tubes), or book lungs
- Paired excretory glands called coxal, antennal, or maxillary glands present in some; some with other excretory organs, called Malpighian tubules
- Nervous system similar to annelid plan, with dorsal brain connected by a ring around the gullet to a double nerve chain of ventral ganglia; fusion of ganglia in some species; well-developed sensory organs
- Sexes usually separate, with paired reproductive organs and ducts; usually internal fertilization; oviparous or ovoviviparous; often with metamorphosis; parthenogenesis in a few forms; **growth with ecdysis**

Classification

Class I: Arachnids

Chelicerates are a distinct evolutionary line of arthropods in which the most anterior appendages have been modified into chelicerae, which often function as fangs or pincers. By far the largest of the three classes of chelicerates is the largely terrestrial Arachnida, with some 57,000 named species; it includes spiders, ticks, mites, scorpions, and daddy longlegs. Arachnids have a pair of chelicerae, a pair of pedipalps, and four pairs of walking legs. The chelicerae are the foremost appendages; they consist of a stout basal portion and a movable fang often connected to a poison gland.

The next pair of appendages, **pedipalps**, resemble legs but have one less segment and are not used for locomotion. In male spiders, they are specialized copulatory organs. In scorpions, the pedipalps are large pincers. Most arachnids are carnivorous. The main exception is mites, which are largely herbivorous. Most arachnids can ingest only preliquified food, which they often digest externally by secreting enzymes into their prey. They can then suck up the digested material with their muscular, pumping pharynx. Arachnids are primarily, but not exclusively, terrestrial. Some 4000 known species of mites and one species of spider live in fresh water, and a few mites live in the sea. Arachnids breathe by means of tracheae, book lungs, or both.

Order Opiliones: The Daddy Longlegs

A familiar group of arachnids consists of the daddy longlegs, or harvestmen (order Opiliones). Members of this order are easily recognized by their oval, compact bodies and extremely long, slender legs. They respire by means of a primary pair of tracheae and are unusual among the arachnids in that they engage in direct copulation. The males have a penis, and the females an **ovipositor,** or egg-laying organ which deposits their eggs in cracks and crevices. Most daddy longlegs are predators of insects and other arachnids, but some live on plant juices and many scavenge dead animal matter. The order includes about 5000 species.

FIGURE 46.11
A harvestman, or daddy longlegs.

Order Scorpiones: The Scorpions

Scorpions are arachnids whose pedipalps are modified into pincers. Scorpions use these pincers to handle and tear apart their food. The venomous stings of scorpions are used mainly to stun their prey and less commonly in self-defense. The stinging apparatus is located in the terminal segment of the abdomen. A scorpion holds its abdomen folded forward over its body when it is moving about. The elongated, jointed abdomens of scorpions are distinctive; in most chelicerates, the abdominal segments are more or less fused together and appear as a single unit. Scorpions are probably the most ancient group of terrestrial arthropods; they are known from the Silurian Period, some 425 million years ago. Adults of this order of arachnids range in size from 1 to 18 centimeters. There are some 1200 species of scorpions, all terrestrial, which occur throughout the world. They are most common in tropical, subtropical, and desert regions. The young are born alive, with 1 to 95 in a given brood.

FIGURE 46.12
The scorpion, *Uroctonus mordax*. This photograph shows the characteristic pincers and segmented abdomen, ending in a stinging apparatus, raised over the animal's back. The white mass is comprised of the scorpion's young.

Order Araneae: The Spiders

There are about 35,000 named species of spiders (order Araneae). These animals play a major role in virtually all terrestrial ecosystems. They are particularly important as predators of insects and other small animals. Spiders hunt their prey or catch it in silk webs of remarkable diversity. The silk is formed from a fluid protein that is forced out of spinnerets on the posterior portion of the spider's abdomen. The webs and habits of spiders are often distinctive.

Some spiders can spin gossamer floats that allow them to drift away in the breeze to a new site. Many kinds of spiders, like the familiar wolf spiders and tarantulas, do not spin webs but instead hunt their prey actively. Others, called trap-door spiders, construct silk-lined burrows with lids, seizing their prey as it passes by. One species of spider, *Argyroneta aquatica,* lives in fresh water, spending most of its time below the surface. Its body is surrounded by a bubble of air, while its legs, which are used both for underwater walking and for swimming, are not. Several other kinds of spiders walk about freely on the surface of water. Spiders have poison glands leading through their chelicerae, which are pointed and used to bite and paralyze prey. Some members of this order, such as the black widow and brown recluse, have bites that are poisonous to humans and other large mammals.

A, A black widow spider, *Latrodectus mactans,* suspended on her web. Note the orange "hourglass" on the ventral side of her abdomen.

Order Acari: Mites and Ticks

The order Acari, the mites and ticks, is the largest in terms of number of species and the most diverse of the arachnids. Although only about 30,000 species of mites and ticks have been named, scientists that study the group estimate that there may be a million or more members of this order in existence.

Most mites are small, less than 1 millimeter long, but adults of different species range from 100 nanometers to 2 centimeters. In most mites, the cephalothorax and abdomen are fused into an unsegmented ovoid body. Respiration occurs either by means of tracheae or directly through the exoskeleton. Many mites pass through several distinct stages during their life cycle. In most, an inactive eightlegged prelarva gives rise to an active six-legged larva, which in turn produces a succession of three eight-legged stages and, finally, the adult males and females.

figure 12.12
Scanning electron micrograph of house dust mite, *Dermatophagoides farinae.*

Mites and ticks are diverse in structure and habitat. They are found in virtually every terrestrial, freshwater, and marine habitat known and feed on fungi, plants, and animals. They act as predators and as internal and external parasites of both invertebrates and vertebrates.

Many mites produce irritating bites and diseases in humans. Mites live in the hair follicles and wax glands of your forehead and nose, but usually cause no symptoms. Ticks are blood-feeding **ectoparasites,** parasites that occur on the surface of their host. They are larger than most other mites and cause discomfort by sucking the blood of humans and other animals. Ticks can carry many diseases, including some caused by viruses, bacteria, and protozoa. The spotted fevers (Rocky Mountain spotted fever is a familiar example) are caused by bacteria carried by ticks. Lyme disease is apparently caused by spirochaetes transmitted by ticks. Red-water fever, or Texas fever, is an important tick-borne protozoan disease of cattle, horses, sheep, and dogs.

Class II: Merostomata (Horseshoe Crabs)

A second class of chelicerates is the horseshoe crabs (class Merostomata). There are three genera of horseshoe crabs. One, *Limulus*, is common along the East Coast of North America. The other two genera live in the Asian tropics. Horseshoe crabs are an ancient group, with fossils virtually identical to *Limulus* dating back 220 million years to the Triassic Period. Other members of the class, the now-extinct eurypterans, are known from 400 million years ago. Horseshoe crabs may have been derived from trilobites, a relationship suggested by the appearance of their larvae. Individuals of *Limulus* grow up to 60 centimeters long. They mature in 9 to 12 years and have a life span of 14 to 19 years.

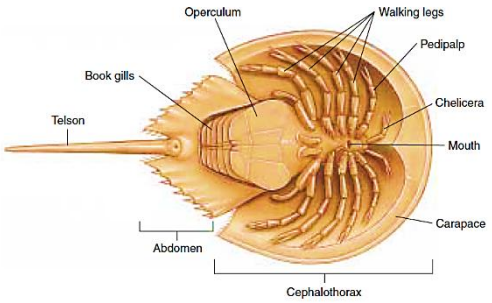


FIGURE 46.16
Diagram of a horseshoe crab, *Limulus*, from below. This diagram illustrates the principal features of this archaic animal.

Limulus individuals live in deep water, but they migrate to shallow coastal waters every spring, emerging from the sea to mate on moonlit nights when the tide is high. Horseshoe crabs feed at night, primarily on mollusks and annelids. They swim on their backs by moving their abdominal plates. They can also walk on their four pairs of legs, protected along with chelicerae and pedipalps by their shell.

Class III: Pycnogonida (The Sea Spiders)

The third class of chelicerates is the sea spiders (class Pycnogonida). Sea spiders are common in coastal waters, with more than 1000 species in the class. These animals are not often observed because many are small, only about 1 to 3 centimeters long, and rather inconspicuous. They are found in oceans throughout the world but are most abundant in the far north and far south. Adult sea spiders are mostly external parasites or predators of other animals like sea anemones. Sea spiders have a sucking proboscis in a mouth located at its end. Their abdomen is much reduced, and their body appears to consist almost entirely of the cephalothorax, with no well-defined head. Sea spiders usually have four, or less commonly five or six, pairs of legs. Male sea spiders carry the eggs on their legs until they hatch, thus providing a measure of parental care. Sea spiders completely lack excretory and respiratory systems. They appear to carry out these functions by direct diffusion, with waste products flowing outward through the cells and oxygen flowing inward through them. Sea spiders are not closely related to either of the other two classes of chelicerates.

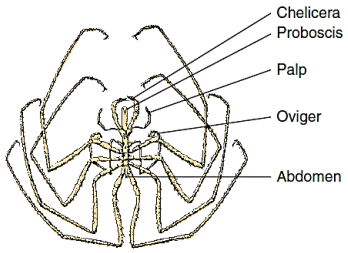


figure 12.3
Pycnogonid, *Nymphon* sp. In this genus all anterior appendages (chelicerae, palps, and ovigers) are present in both sexes, although ovigers are often not present in females of other genera.

Class IV: Crustacea

The crustaceans are a large group of primarily aquatic organisms, consisting of some 35,000 species of crabs, shrimps, lobsters, crayfish, barnacles, water fleas, pillbugs, and related groups. Most crustaceans have two pairs of antennae, three types of chewing appendages, and various numbers of pairs of legs. All crustacean appendages, with the possible exception of the first pair of antennae, are basically biramous. In some crustaceans, appendages appear to have only a single branch; in those cases, one of the branches has been lost during the course of evolutionary specialization. The **nauplius** larva stage through which all crustaceans pass

provides evidence that all members of this diverse group are descended from a common ancestor. The nauplius hatches with three pairs of appendages and metamorphoses through several stages before reaching maturity. In many groups, this nauplius stage is passed in the egg, and development of the hatchling to the adult form is direct.

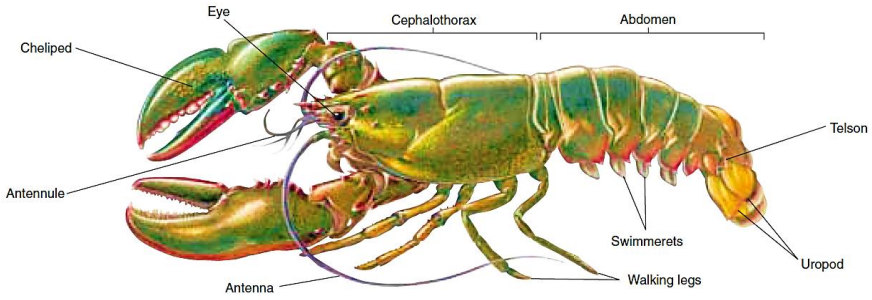


FIGURE 46.19
Decapod crustacean. A lobster, *Homarus americanus.* The principal features are labeled.

Crustaceans differ from insects but resemble centipedes and millipedes in that they have appendages on their abdomen as well as on their thorax. They are the only arthropods with two pairs of antennae. Their mandibles likely originated from a pair of limbs that took on a chewing function during the course of evolution, a process that apparently occurred independently in the common ancestor of the terrestrial mandibulates. Many crustaceans have compound eyes. In addition, they have delicate tactile hairs that project from the cuticle all over the body. Larger crustaceans have feathery gills near the bases of their legs. In smaller members of this class, gas exchange takes place directly through the thinner areas of the cuticle or the entire body. Most crustaceans have separate sexes. Many different kinds of specialized copulation occur among the crustaceans, and the members of some orders carry their eggs with them, either singly or in egg pouches, until they hatch them, either singly or in egg pouches, until they hatch.

Class V: Chilopoda (Centipedes)

Centipedes are active predators with a preference for moist places such as under logs or stones, where they feed on earthworms, insects, etc. Their bodies are somewhat flattened dorsoventrally, and they may contain from a few to 177 somites. Each somite, except the one behind the head and the last two, bears one pair of appendages. Those of the first body segment are modified to form poison claws, which they use to kill their prey. Most species are harmless to humans.

FIGURE 46.22
A centipede. Centipedes, like this member of the genus *Scolopendra*, are active predators.

Their head bears a pair of eyes, each consisting of a group of ocelli (simple eyes). Respiration is by tracheal tubes with a pair of spiracles in each somite. Sexes are separate, and all species are oviparous. Young are similar to adultS. Common house centipedes *Scutigera,* with 15 pairs of legs, and *Scolopendra*, with 21 pairs of legs, are familiar genera.

Class VI: Diplopoda (Millipedes)

Diplopods, or "double-footed"arthropods, are commonly called millipedes,which literally means "thousand feet". Although they do not have a thousand legs,they do have a great many. Their cylindrical bodies are made up of 25 to 100 segments. The four thoracic segments bear

only one pair of legs each, but abdominal segments each have two pairs, a condition that may have evolved from fusion of somites.Two pairs of spiracles occur on each abdominal somite, each opening into an air chamber that gives rise to tracheal tubes.

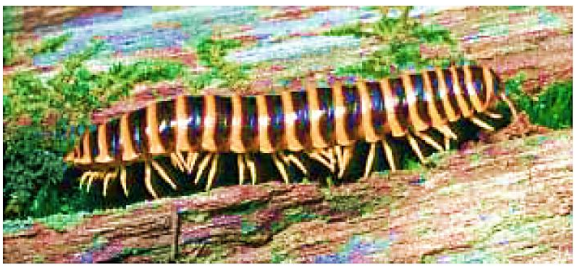


FIGURE 46.23
A millipede. Millipedes, such as this *Sigmoria* individual, are herbivores.

Millipedes are less active than centipedes and are generally herbivorous, living on decayed plant and animal matter and sometimes living plants. They prefer dark moist places under stones and logs.Females lay eggs in a nest and guard them carefully. Larval forms have only one pair of legs per somite.

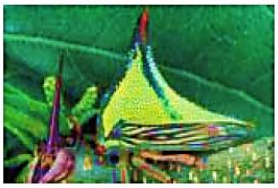
Class VII: Insecta (The Insects)

The insects, class Insecta, are by far the largest group of organisms on earth, whether measured in terms of numbers of species or numbers of individuals. Insects live in every conceivable habitat on land and in fresh water, and a few have even invaded the sea. More than half of all the named animal species are insects, and the actual proportion is doubtless much higher because millions of additional forms await detection, classification, and naming. Approximately 90,000 described species occur in the United States and Canada, and the actual number of species in this area probably approaches 125,000. A hectare of lowland tropical forest is estimated to be inhabited by as many as 41,000 species of insects, and many suburban gardens may have 1500 or more species. It has been estimated that approximately a billion billion (1018) individual insects are alive at any one time.

(a)

(b)

(c)



(d)

(e)

(f)

FIGURE 46.24
Insect diversity. (*a*) Luna moth, *Actias luna*. Luna moths and their relatives are among the most spectacular insects (order Lepidoptera). (*b*) Soldier fly, *Precticus trivittatus* (order Diptera). (*c*) Boll weevil, *Anthonomus grandis*. Weevils are one of the largest groups of beetles (order Coleoptera). (*d*) A thorn-shaped leafhopper, *Umbonica crassicornis* (order Hemiptera). (*e*) Copulating grasshoppers (order Orthoptera). (*f*) Termite, *Macrotermes bellicosus* (order Isoptera). The large, sausage-shaped individual is a queen, specialized for laying eggs; most of the smaller individuals around the queen are nonreproductive workers, but the larger individual at the lower left is a reproductive male.

It is difficult to appreciate fully the significance of this extensive group and its role in the biological pattern of animal life. The study of insects **(entomology)** occupies the time and resources of thousands of skilled men and women all over the world. The struggle between humans and insect pests seems to be endless, yet paradoxically, insects are so interwoven into the economy of nature in so many roles that we would have a difficult time without them.

Insects differ from other arthropods in having **three pairs of legs** and usually **two pairs of wings** on the thoracic region of the body, although some have one pair of wings or none. In size insects range from less than 1 mm to 20 cm in length, the majority being less than 2.5 cm long. Insect tagmata are **head, thorax,** and **abdomen.** The cuticle of each body segment is typically composed of four plates **(sclerites),** a dorsal notum **(tergum),** a ventral **sternum,** and a pair of lateral **pleura.** Pleura of abdominal segments are membranous rather than sclerotized. The head usually bears a pair of relatively large compound eyes, a pair of antennae, and usually three ocelli. Mouthparts typically consist of a **labrum,** a pair each of **mandibles** and **maxillae,** a **labium,** and a tongue like **hypopharynx.**

The type of mouthparts an insect possesses determines how it feeds. The thorax is composed of three somites: **prothorax, mesothorax,** and **metathorax,** each bearing a pair of legs. In most insects the mesothorax and metathorax each bear a pair of wings. Wings consist of a double membrane that contains veins of thicker cuticle, which serve to strengthen the wing. Although these veins vary in their patterns among different species, they are constant within a species and serve as one means of classification and identification.

Legs of insects are often modified for special purposes. Terrestrial forms have walking legs with terminal pads and claws as in beetles. These pads may be sticky for walking upside down, as in house flies. Hindlegs of grasshoppers and crickets are adapted for jumping. Mole crickets have the first pair of legs modified for burrowing in the ground. Water bugs and many beetles have paddle-shaped appendages for swimming. For grasping prey, the forelegs of a praying mantis are long and strong.

Table 46.2 Major Orders of Insects

Order	Typical Examples		Key Characteristics	Approximate Number of Named Species
Coleoptera	Beetles		The most diverse animal order; two pairs of wings; front pair of wings is a hard cover that partially protects the transparent rear pair of flying wings; heavily armored exoskeleton; biting and chewing mouthparts; complete metamorphosis	350,000
Diptera	Flies		Some that bite people and other mammals are considered pests; front flying wings are transparent; hind wings are reduced to knobby balancing organs; sucking, piercing, and lapping mouthparts; complete metamorphosis	120,000
Lepidoptera	Butterflies, moths		Often collected for their beauty; two pairs of broad, scaly, flying wings, often brightly colored; hairy body; tubelike, sucking mouthparts; complete metamorphosis	120,000
Hymenoptera	Bees, wasps, ants		Often social, known to many by their sting; two pairs of transparent flying wings; mobile head and well-developed eyes; often possess stingers; chewing and sucking mouthparts; complete metamorphosis	100,000
Hemiptera	True bugs, bedbugs, leafhoppers		Often live on blood; two pairs of wings, or wingless; piercing, sucking mouthparts; simple metamorphosis	60,000
Orthoptera	Grasshoppers, crickets, roaches		Known for their jumping; two pairs of wings or wingless; among the largest insects; biting and chewing mouthparts in adults; simple metamorphosis	20,000
Odonata	Dragonflies		Among the most primitive of the insect order; two pairs of transparent flying wings; large, long, and slender body; chewing mouthparts; simple metamorphosis	5,000
Isoptera	Termites		One of the few types of animals able to eat wood; two pairs of wings, but some stages are wingless; social insects; there are several body types with division of labor; chewing mouthparts; simple metamorphosis	2,000
Siphonaptera	Fleas		Small, known for their irritating bites; wingless; small flattened body with jumping legs; piercing and sucking mouthparts; complete metamorphosis	1,200