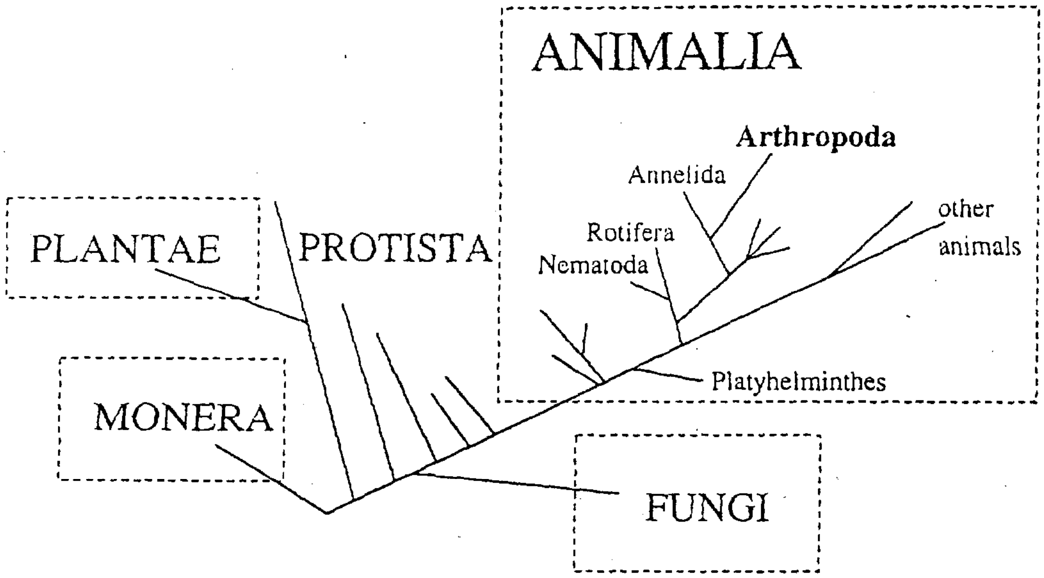
EXTANT ARHROPODS: CRUSTACEANS, CHELICERATES, & INSECTS

Figure 1. A possible phylogeny of the Animal Kingdom.



Arthropods are by far the most diverse group of organisms on the planet. This monophyletic group is believed to have evolved from an ancestor resembling polychaete annelids. Recall that arthropods are separated from the annelids by the presence of a chitonous exoskeleton and jointed appendages. These two simple characters give rise to a huge diversity of forms that allowed arthropods to adapt to a wide variety of lifestyles. The goal of this lab is to explore the diversity and success of arthropods. The arthropods are also among the most specialized of the invertebrates, with a number of novel features. Like annelids, the arthropods show a segmented body plan. However, the segments are usually arranged into groups that make up distinct body sections called tagmata (for example, the head, thorax, and abdomen). Often the divisions between segments are not visible on the outside except for the fact that each appendage (antenna, leg, etc.) is associated with one body segment. Sometimes the tagmata fuse together to form distinct regions (for example, head + thorax = cephalothorax). The jointed appendages of arthropods are unique along the invertebrates and give the arthropods their name ("jointed legs"). The joints allow more precise movements, as well as the specialization of appendages (and appendage parts) for specific functions. Appendages are moved through the use of muscles that insert on the inside of the hard cuticular exoskeleton, or carapace. Oddly, the arthropods completely lack cilia and flagella (except for sperm), which means that adults must generate water currents, and larvae must swim and feed, using the muscular jointed appendages rather than cilia. Arthropods are coelomate, though the coelom is much reduced.

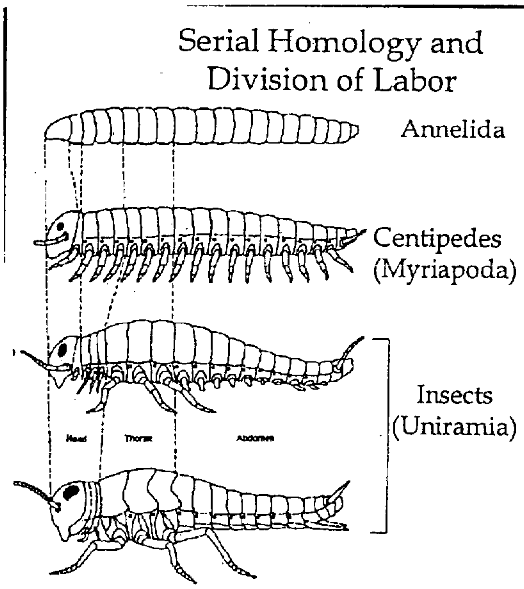
DEFININING FEATURES

One of the key characteristics of arthropods is the presence of a chitonous skeleton. The skeleton serves many purposes, the first of which is to provide support and protection for the animals. The exoskeleton is just that: a skeleton outside of the body that holds the tissues and muscles in place. It also is a full set of armor to protect the soft tissues inside. The articulated skeleton is also important for movement of the organism, particularly on land. Each segment is protected by a rigid section of chitonous tissue that moves with relation to the other segments. The skeleton also provides sites for muscle attachment, allowing very intricate and sophisticated movement.

The exoskeleton also serves as a preadaptation for life on land. As a hard supportive layer, it allows organisms to grow large and still be able to move against gravity. It also prevents water loss due to evaporation. As you look at the different types of arthropods, note the armor on the outside, what color, and how hard it is.

- You've learned that most gains come with a cost. If you have a hardened skeleton, how do you grow to a larger size?

- What problems could an organism face while molting?



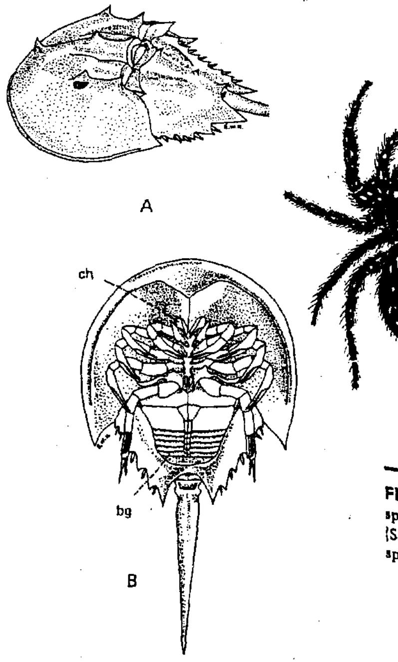
As in the annelids, arthropods show serial homology. However, arthropods have gone further by developing specialization of parts. This leads to a division of labor for functions such as perception, movement and feeding. As you look at the different orders of arthropods, note the level of differentiation between parts and note what different appendages could be used for.

I. CHELICERATA (horseshoe crabs, spiders, ticks, mites, scorpions)

Chelicerates lack antennae and typically have six pairs of appendages found on the cephalothorax. The first pair are modified into piercing mouthparts called chelicerae. The second pair of appendages function as jaws. The remaining four pairs are leglike appendages. (See examples on next page)

- Behavioral experiment: turn off the lights and shine UV light on the scorpion. Why do you think it reflects?

Chelicerata



Igure 6–2. A horseshoe crab, *Limulus* sp. (subclass iphosùra). A, dorsolateral view; B, ventral view. *bg*, ook gills; *ch*, chelicera.

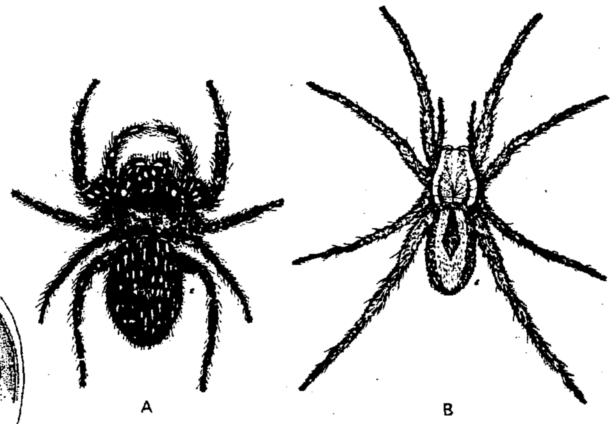


Figure 6–13. A, a jumping spider, *Phidippus audax* (Hentz) (Salticidae); B, a wolf or ground spider, *Lycòsa* sp. (Lycòsidae).

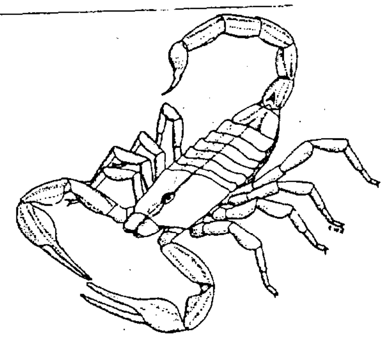


Figure 6–3. A scorpion, 2×.

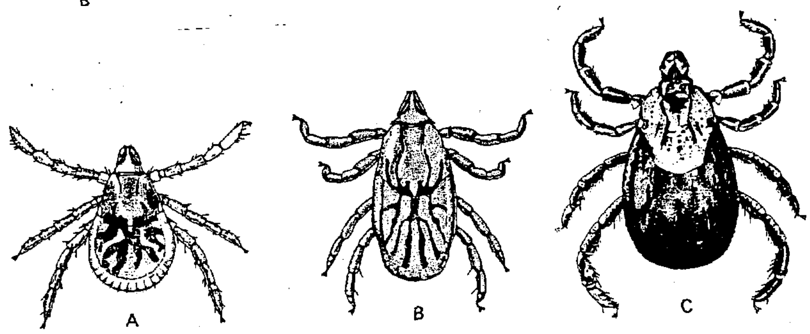
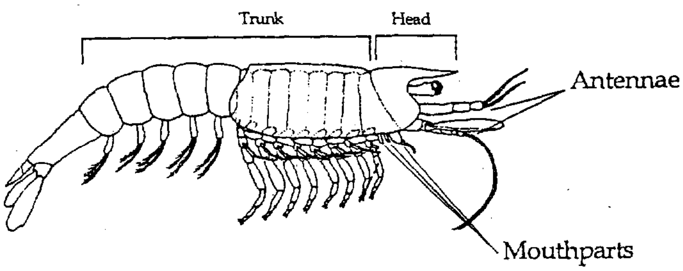


Figure 6–17. The American dog tick, *Dermacéntor variábilis* (Say) (Ixódidae). A, larva; B, nymph; C, adult (unengorged) female. (Courtesy of USDA.)

.Crustacea
(True Crabs, King Crabs, Hermit Crabs, Shrimp)
Head - 5 appendages
- 2 antennae
- 3 feeding

Trunk - All appendages biramous



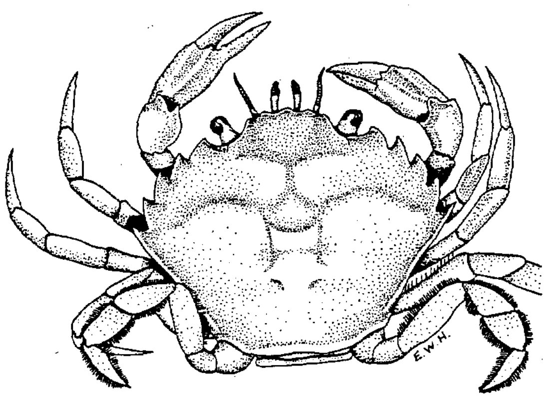
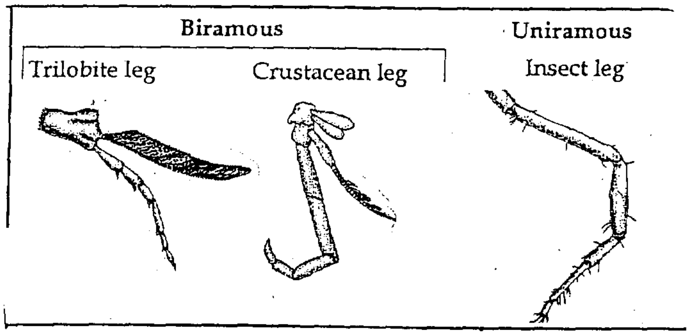


Figure 6–30. A green crab, *Carcinides* sp., 1½×.



II. CRUSTACEA (crabs, lobsters, crayfish, shrimp, barnacles, copepods)

Crustaceans have a large amount of variation in the appendages and body regions. Typically there are two pairs of antennae and five pairs of appendages. The leglike appendages are generally biramous. They usually have two obvious body regions: the cephalothorax and the abdomen. In many crustaceans, the cephalothorax is covered by a shieldlike portion of the body wall called the carapace. (See figures on previous page.)

- Although Crustaceans have five pairs of appendages as an adult, they have six pairs during development. Can you guess why this may be important?

- Hermit crab shell preference: Tickle a hermit crab out of its shell by inserting a piece of fishing line into the hole drilled into the shell. Place the crab in a small finger bowl containing sea water and either shells from different species or shells of different sizes. Are some shells too small? Too big? Are some species favored over others? Does the crab ever pick ones shell and then try to switch? Are shells with symbionts (e.g. hydroids) avoided or favored?

- Switching shells and shell competition: Place naked hermit crabs (see above about how to remove crabs from their shells) in shells that are obviously too big or too small for them. Place the crabs together in a small finger bowl with sea water. Watch what happens. After about 5-10 minutes place a third crab with a shell that fits just right in the bowl. What happens?

- Interspecific competition: Try either of the previous two experiments using two different species of hermit crabs that are about the same size.

- Fiddler crab vision: Fiddler crabs have simple visionary rules for "good" and "bad". Try holding different objects in different places in front of the crab and watch its reactions to determine what these rules are.

- Spider crabs clothes: Place 2-3 different kinds of material (approved by your TA) in with the spider crab. What does it choose to wear on its back? Will it change if you change its visual environment?

- Planktonic movement: Place several planktonic crustaceans in a large finger bowl. Cover most of the bowl with black plastic for 10 minutes. Is there any sign of phototaxy? Is there anything else that influences planktonic movement? Do all species act the same?

III. HEXAPODA (proturans, collembolans, diplurans, insecta)

Hexapods are generally known as insects, although some scientists exclude the orders Protura, Collembola, and Diplura from the class Insecta. The hexapod body is divided into three distinct regions: the head, thorax, and abdomen. Insects have one pair of antennae, mandibles, maxillae, and a labium on the head (parts used in sensing and feeding). Most insects have three pairs of legs, one on each thoracic segment. There are generally no appendages on the abdomen of an adult although some insects have parts used for reproduction.

- Examine the various mouthparts on the dissected and intact grasshopper, *Romalea microptera*. Note the serrated edges of the mandibles used for cutting. Why is there a large edge for muscle attachment on the mandibles? Also note the sensory palps on the maxillae and labium.

- Use the dichotomous key to identify different orders of insects. Which insects appear to be more ancestral than others? Why have hexapods become the most successful group of animals in terms of the number of species?

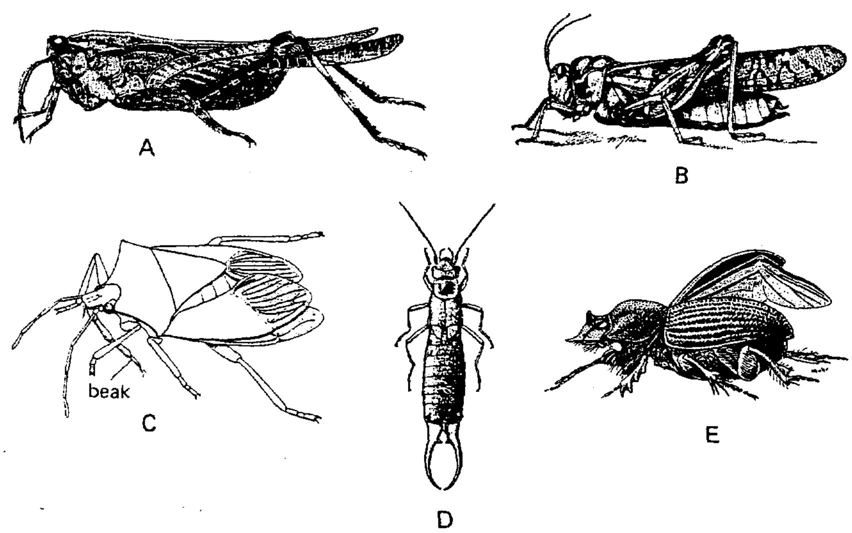


Figure 7–2. Insects with front wings thickened and hind wings membranous. A, a pygmy grasshopper (Orthóptera); B, a band-winged grasshopper (Orthóptera); C, a stink bug (Hemíptera); D, an earwig (Dermáptera); E, a dung beetle (Coleóptera). (A, C, and E courtesy of Illinois Natural History Survey; B, courtesy of USDA; D, courtesy of Knowlton and the Utah Agricultural Experiment Station.)

METAMORPHOSIS

Insects have developed a unique life cycle in which they change forms between the larval and adult stages, known as metamorphosis. There are three main types of metamorphosis found in insects: Ametabolous insects do not undergo metamorphosis. Instead, the insects just continues to molt, making a larger but identical form of itself as it ages. This ancestral state is found in the orders Protura, Collembola, Diplura, and Thysanura.

Hemimetabolous insects undergo incomplete metamorphosis. Larva molt through 4-5 stages, called instars, until they finally molt into an adult. The larva of mayflies, damselflies, and dragonflies are aquatic, and are called naiads. The other hemimetabolous insects (including grasshoppers, termites, earwigs, lice, aphids, and true bugs) have terrestrial larvae called nymphs.

Holometabolous insects undergo complete metamorphosis. They have larval, pupal, and adult stages. The key development in true metamorphosis is the internal development of wings. During the pupal stage, the body of the larva undergoes a large rearrangement, often producing very different looking adults. Beetles, moths, butterflies, flies, fleas, bees, and ants all undergo true metamorphosis.

- Look at the specimen of Diptera and Hymenoptera in glass vials. Note the large difference between the larva, pupa, and adult. Why might an organism develop such a complex lifecycle?

- Holometabolous larvae often have much larger bodies than adults. Why might this occur?

INSECT FLIGHT

Many insects have developed wings in their adult stage of life. Wings are not modified appendages, but rather extensions of the chitonous exoskeleton found on the thorax. There are three main theories of how insect wings may have evolved:

1) Thremoregulation: insects are ectothermic, and therefore must rely on their surrounding environment to heat their bodies. Wings may be a way for insects to catch more light and heat up their bodies. Eventually they were turned into instruments for flight.
2) Protection: wings may have been used for insects to jump away from predators and glide down to the ground below. They also may have stabalized jumping insects. Eventually muscles were developed for flapping and they became wings.
3) Gill-flap theory: wings may have evolved from aquatic insects that used them to row themselves through the water or ventilate their gills. Once they moved to land, they were coopted for flight.

- Observe the insects on display. What other uses may insects have for wings today?

- Most insects have two pairs of wings, but Diptera only have one. The second pair of wings are vestigial and used to measure torque when flying, so that the insect can keep its balance. Observe Dipteran wings on display under the dissecting scope.

SENSORY ORGANS

Insects have different degrees of vision. Some only have ocelli, organs that can only tell light from dark. Others have compound eyes, which are thousands of light receptors combined into a single pair of eye-like structures. Most insects do not have vision in the red zone. However, some butterflies can see everything from red to ultra-violet.

- Look at the compound eyes on various insects. Look at an example of ocelli on the dissecting scope.

Some insects, such as crickets, have organs to hear. Part of the cuticle (exoskeleton) is very thin can pick up vibrations, which are sent to the central nervous system. Insects cannot hear tones (they cannot detect frequency differences), so they use temporal patterns instead. The next time you are walking around on a warm night, listen to the different patterns produced by crickets.

The most known sensory organ of insects are their antennae. Antennae are often used as chemoreceptors, and "taste" the air and land around them. Some antennae are very intricate structures with a large surface area to pick up small amounts of pheromones released by other individuals of their species. Insects also have small hairs used to sense movement and position of their bodies. Much like the whiskers on a cat, they can detect what is touching their bodies.

- Observe the pheromone receptors on the moth. What other uses might antennae have?

POLYMORPHISM

Insects have two special cases of polymorphism, the first of which is sexual dimorphism. You first saw sexual dimorphism in angiosperms, when the male and female flowers of some plants looked different. Darwin was one of the first scientists to pay attention to sexual dimorphism in insects. He described the presence of horns in staghorn beetles, different song in orthopterans and cicadas, and different wing patterns in lepidopterans and odonates. The elaborate features usually found in the males are associated with sexual competition rather than survival.

- Look at the difference between male and female butterflies and moths. Why do you think one sex has such bright patterns while the other is dull colored?

- Look at the different antennae of the moths. Males often have branched antennae known as pheromone receptors. What is a possible advantage of this struture?

Eusocial insects also experience morphological differences between the castes. Isoptera (termites) and Hymenoptera (sawflies, wasps, bees, and ants) both have eusociality. All termites are eusocial: they are divided into reproductives (kings and queens which are winged), soldiers (large termites with large heads and fighting structures), and workers. Termites do not have a differentiation between sexes within the caste structure.

Ants, on the other hand, have a major difference between the sexes. The males only live for a very short time to mate with the queen. The females make up the workers and soldiers, and the reproducing female is the queen. Soldiers tend to be larger and have larger heads than workers, although not all ants have both castes.

Some bees and wasps are also social, although there is little caste differentiation. In wasps, the workers all have the potential to reproduce. The queen is established by winning a dominance fight between egg-laying females. In bees, the queen is fed a special diet during development, called royal jelly. Again, the females are usually workers and the reproducing males are called drones.

- What is an advantage of having caste differentiation? What is a disadvantage?

Eusocial insects also must have a way to communicate between them to have organized division of labor. Some bees do a dance on the hive to show others where it found a good source of pollen and nectar. Other insects such as termites communicate using hormones and other chemicals.

- A certain type of blue ink has a chemical structure very similar to a hormone used in communication in termites. Observe the termite following the trail of what it thinks is another termite. Why does it follow the pen mark, seldom straying? What could cause it to stray?

PLANTS REVISITED

Insects are closely associated with flowering plants. Plants are often their major food source (although some are carnivorous or scavengers) and sometimes provide shelter. However, the relationship between them is not always cordial. Herbivorous insects can cause a lot of damage to their host plant as they feed on the leaves and flowers. Therefore plants and insects are often described as being in an evolutionary arms race to survive each other. Plants produce chemicals and morphological features to protect themselves from insects, and insects develop tolerance to the plants mode of defense.

- Feeding preferences of insect herbivores: Take one leaf from each of two kinds of plants in the lab (approved by your TA) and place half of each one in a different side of a petri dish or large finger bowl. Place one of the living herbivorous insects in the center. Which leaves does it prefer? Does it matter what orientation you set the insect in? Will it return to the same leaf if you disturb it?

- Thought question: with what you know about plant-insect competition, what problems could it pose for the use of pesticides when farming?

- Recall the pollination syndromes discussed in the angiosperm lab. Take another look at the syndromes, except pay attention to the morphological features of the insects. Why would bees need a large flower? Why do butterflies prefer long tubes?