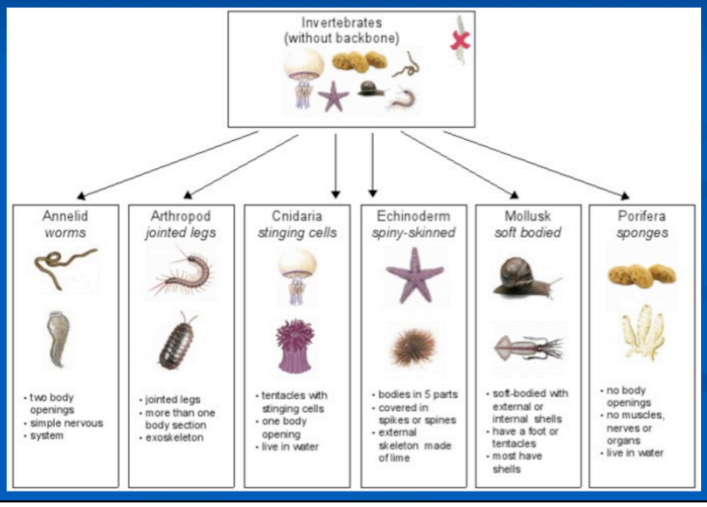
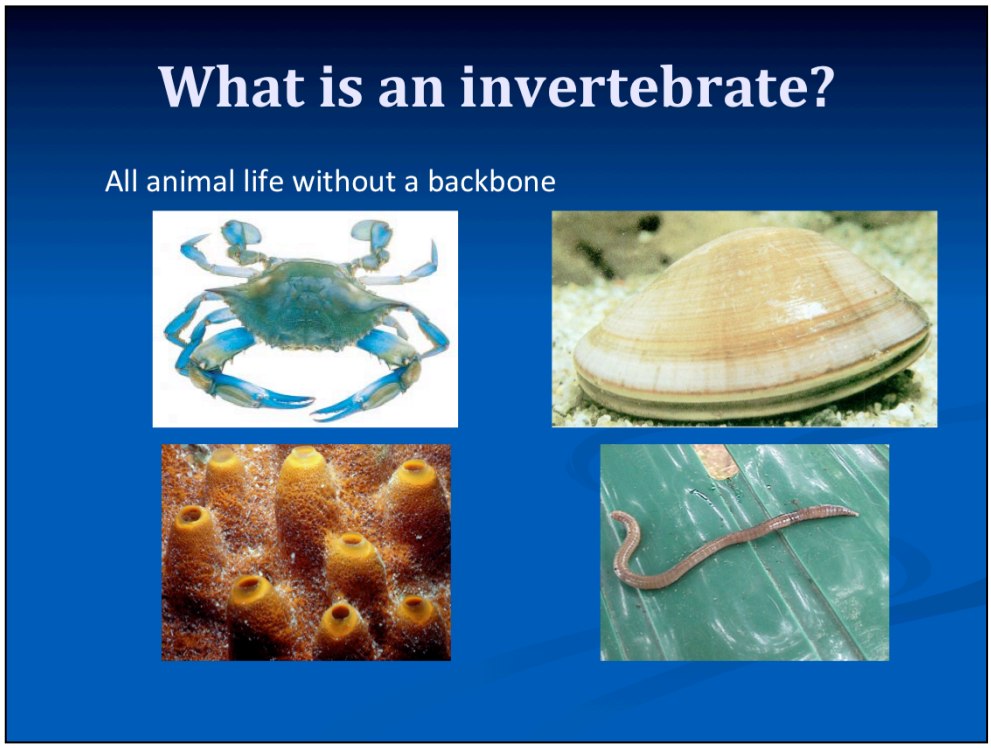
Invertebrates: Arthropods





Invertebrates are animals without backbones. This include jellyfish, octopi, mollusks, worms, spiders and insects. Invertebrates may have some type of internal or external support. There are far more invertebrate species than there are vertebrate species; 97% of all known species are invertebrates.

Invertebrates inhabit almost every ecosystem on earth; the majority are marine animals. The typical reproductive strategy for invertebrates is to have mass numbers of offspring all at once, maybe only once in their life.

The largest Phyllum of invertebrates are the **arthropods**. The Insect Zoo contains not only insects but other types of arthropods as well.

The Sculpture Learning Plaza has many invertebrates including: a leafcutter ant, a vallela, horseshoe crab, nautilus, vampire squid, giant clam, giraffe weevil, scorpion, centipede, tardigrade, and a coconut crab.

Arthropoda means "jointed feet". The arthropods are the most diverse and numerous group of animals on earth. All arthropods can be divided vertically into two equal parts or mirror images (this is known as **bilateral symmetry**). An arthropod is an invertebrate having a hard **exoskeleton**, a segmented body and paired jointed appendages; the exoskeleton is made of a substance called **chitin** (pronounced kīt′n). The exoskeleton provides armored protection and provides a site for muscle attachment allowing adjacent segments and joints to act as levers, thus improving locomotion. The exoskeleton has a waxy coating, which makes it impermeable to water and provides a resistance to water loss.

The exoskeleton is hard and rigid and is unable to expand and grow once formed. To accommodate for this growth, arthropods must molt (**ecdysis**) or shed their exoskeleton periodically. As a result, insects grow in spurts. Molting is a time of vulnerability and danger and is one disadvantage of the arthropod design as the new shell takes time to dry. Jointed legs, acting like hinges, provide flexibility and allow for movement much like that in a medieval suit of armor.

Due to the lack of a sturdy, internal supportive structure, most vertebrates are small; there is an upper limit to the efficient size of an exoskeleton, so all arthropods are small compared to the maximum sizes achieved by vertebrates. This small size allowed them to inhabit many more types of specialized niches than were available to a larger organism.

Arthropods were the first animals to come ashore and the first to fly. Their hard exoskeleton prevented them from drying out and they evolved a way of getting oxygen without water by breathing air.

Arthropods might seem a little scary to some, but they are important components of ecosystems. Some are decomposers and help in recycling nutrients. Some play an important role in pollination of plants, while others play and important role in soil aeration. Lastly, they are a major source of food for some birds, amphibians, reptiles and mammals.

What are some examples of an arthropod used as a food source for humans? Answer: lobsters, crayfish, shrimp and chocolate covered ants

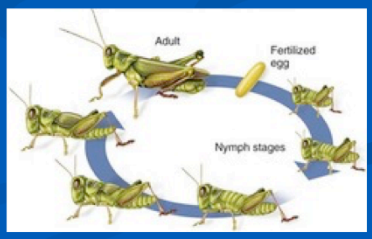
What are some examples of a material used by humans that were produced by an arthropod? Answer: honey, beeswax and silk

The five major Classes of arthropods include: arachnids, millipedes, centipedes, crustaceans and insects.

Arthropod characteristics: jointed, paired appendages, hard exoskeleton, bilateral symmetry and body divided into distinct regions

Metamorphosis

- Many invertebrate groups exhibit **metamorphosis** during their life cycle; they change shape or appearance significantly during different stages; this allows the young and adults to not compete for resources and helps increase the chances of finding food
- **Complete metamorphosis** is exhibited by many insects species; there is an egg, larval, pupal, and adult stage that are all distinct
- **Incomplete metamorphosis** is also present in many arthropods; most stages just look like smaller adult forms, but there is an egg, several nymph stages, and an adult form

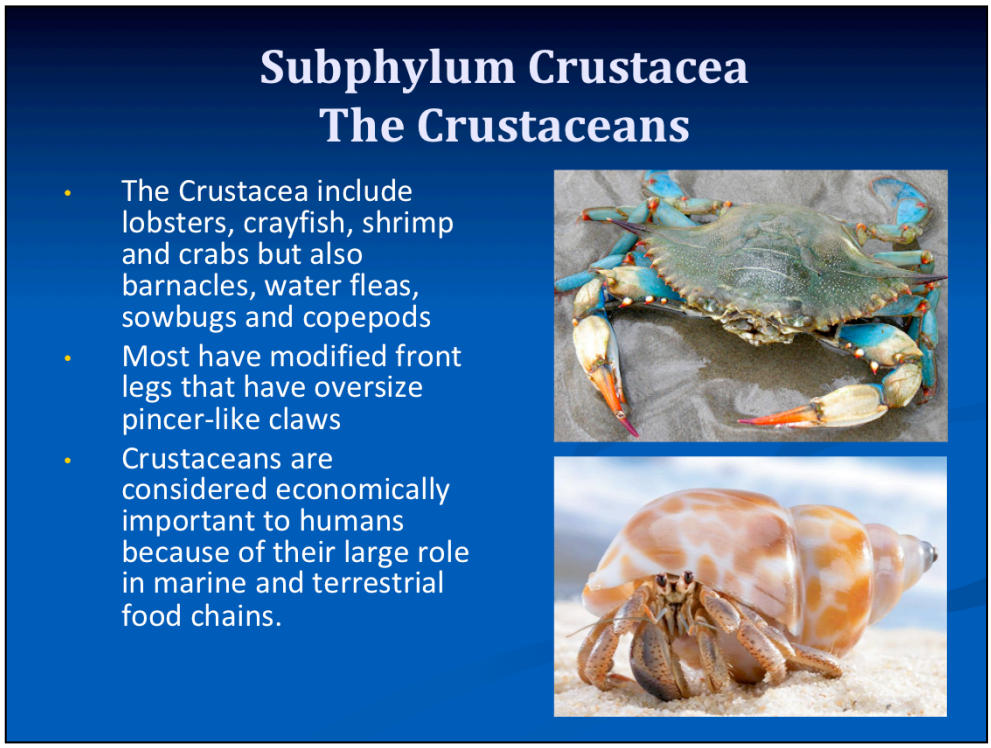


Metamorphosis is the process of transformation from an immature form to an adult form in two or more distinct stages. Many invertebrate groups as well as amphibians exhibit metamorphosis during their life cycle; the young and adults may occupy a completely different habitat or use different food resources, resulting in less competition within the species.

Complete metamorphosis is exhibited by many insects species; there are four distinct life stages. Some insects with complete metamorphosis are: beetles, flies, bees, and butterflies.

Incomplete metamorphosis is also present in many arthropods; the young go through three life stages. Each stage looks like a smaller version of the adult. Some insects with incomplete metamorphosis are: crickets, true bugs, cockroaches, and termites.

Early insects didn't metamorphose; they hatched from eggs and looked like miniature adults. In many insects, metamorphosis is associated with the evolution of wings which are restricted to the adult reproductive state. Metamorphosis is so successful as a reproductive strategy that, today as many as 65% of all animal species are metamorphosing insects.



The Crustaceans include lobsters, crayfish, shrimp and crabs but also barnacles, water fleas, sowbugs and copepods. Most species are marine, but some are freshwater, and a few are terrestrial such as the sowbugs or pillbugs. Most crustaceans have modified front legs that have oversize pincer-like claws. The mantis shrimp, has such a strong claw and fast reaction to spear prey, it can break aquarium glass if it hits the sides.

The eggs and larvae of crustaceans make up part of the plankton found floating in the oceans, which is a major food source for fish and baleen whales. Krill (small crustaceans) are an important part of this food chain as well. They feed on plankton converting it to a form suitable for many larger animals such as the gray whale that we see off the coast of the San Francisco area.

Because crustaceans vary so widely in size, they can fulfill many niches within the water and on land. Many smaller crustaceans have the ability to recycle nutrients as filter feeders, while larger crustaceans can act as a food source for large aquatic mammals.

The Zoo usually has a hermit crab or a sowbug. The Sculpture garden has a coconut crab.

CRUSTACEA Characteristics (*crayfish, crabs, shrimp, barnacles, sowbugs, copepods*)

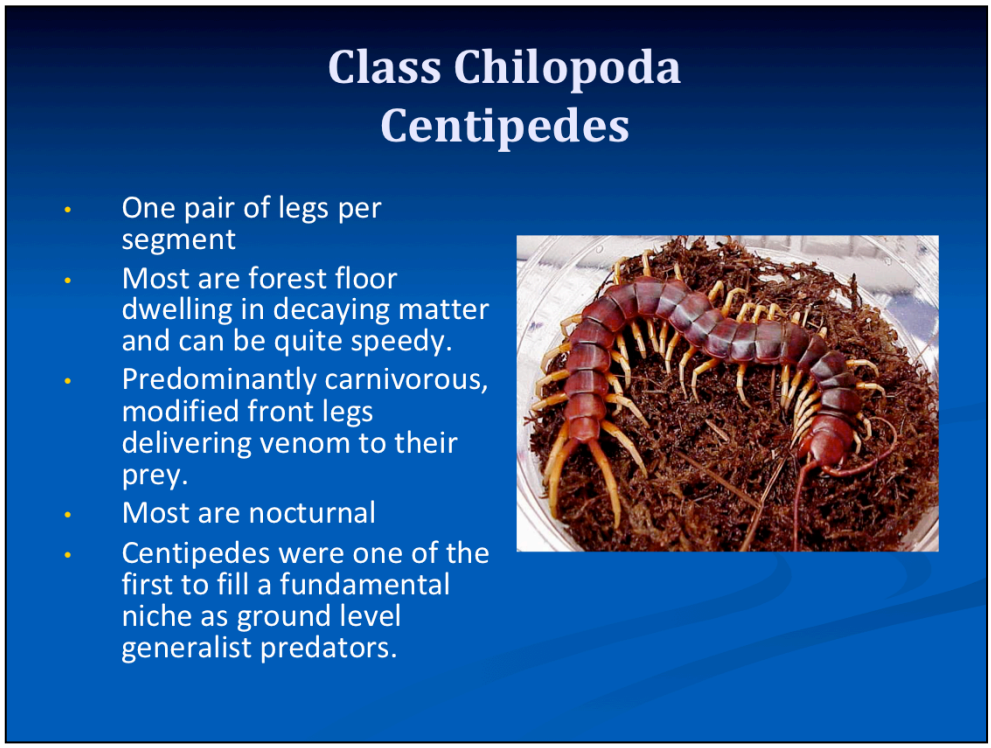
5 or more pairs of legs

2 body regions (cephalothorax, abdomen)

No wings

2 pairs of antennae, usually

Mostly marine, some freshwater, a few terrestrial



Centipedes were among the earliest terrestrial animals. They have flattened, multi-segmented body but only have one pair of legs on most body segments. Interesting fact, they always have an odd number of pairs of legs. Most are forest floor dwelling and in contrast to the slow millipedes can be quite fast. Most are predatory with modified front legs delivering venom to their prey. They also form an important item of diet for many species such as beetles and snakes. Centipedes consume a tremendous amount of soil-dwelling larvae. Their tunneling aerates the soil, allowing water and nutrients to reach the roots of plants and grasses.

The Insect Zoo typically has one species of centipede on display, usually the red-headed centipede. The Sculpture Garden has a centipede.

CHILOPODA Characteristics (*centipedes*)

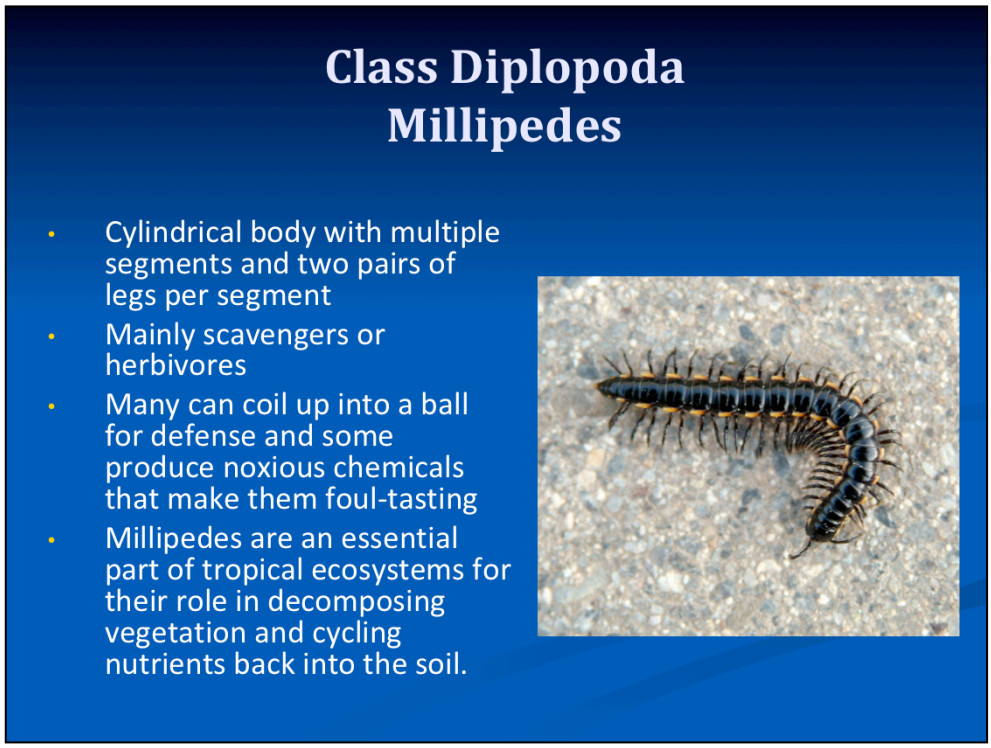
1 pair of legs on most body segments

Flattened, multi-segmented body

No wings

1 pair of antennae

Terrestrial



Millipedes have two pairs of jointed legs on most body segments. Despite having so many legs, they are slow. Millipedes have one pair of antennae and no wings. They are mainly scavengers or herbivores. Most eat decaying leaves and other dead plant matter (**detritivores**); as decomposers, they break down dead plants and animals and turn them into soil nutrients and thus are an important component in healthy ecosystems.

Many can coil up into a ball for defense and some produce noxious chemicals that make them foul-tasting.

The Insect Zoo usually has a species of millipede on display; usually the giant African millipede.

DIPLOPODA Characteristics (*millipedes*)

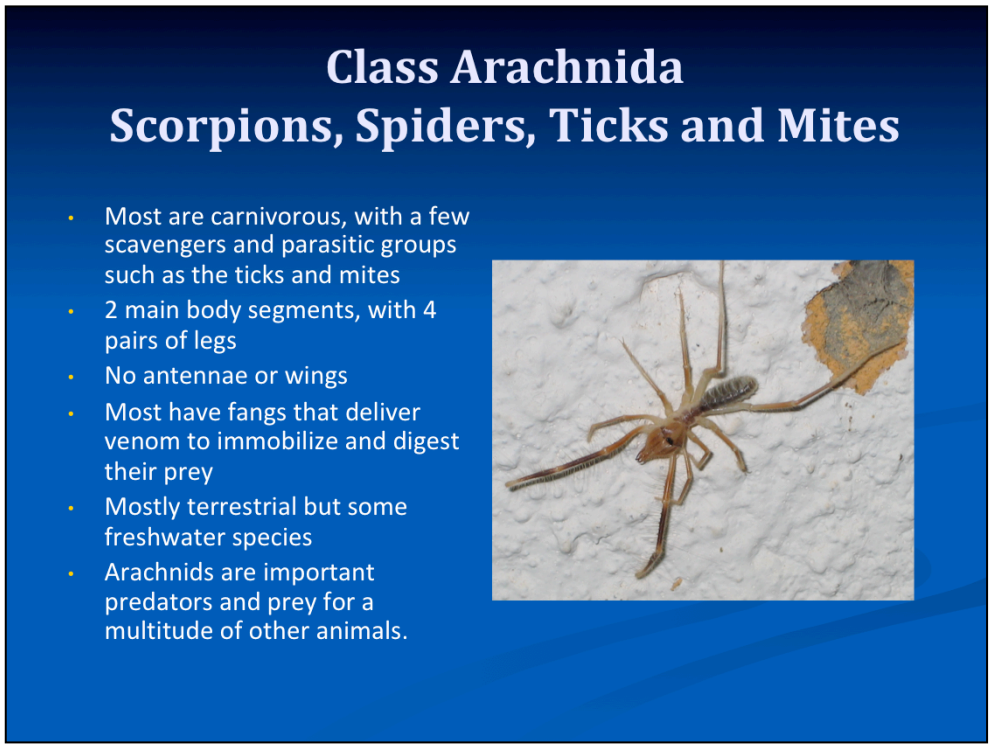
2 pairs of legs on most body segments

Cylindrical, multi-segmented body

No wings

1 pair of antennae

Terrestrial



Arachnids were among the first arthropods to move onto land. Arachnids include the spiders, scorpions, mites, and ticks. The scorpion being one of the most ancient of living arachnids.

The arachnids have two main body segments, with four pairs of legs and no antennae or wings. Most species are predacious and typically feed by releasing digestive enzymes over or into their prey and then sucking the predigested liquid. They have fangs that deliver venom to immobilize and digest their prey.

The Insect Zoo has several species of tarantula, a black widow, wolf spider and at least one species of scorpion on display. The Sculpture Garden has a scorpion.

ARACHNIDA Characteristics (*spiders, scorpions, mites, ticks, whip scorpions, solpugids*)

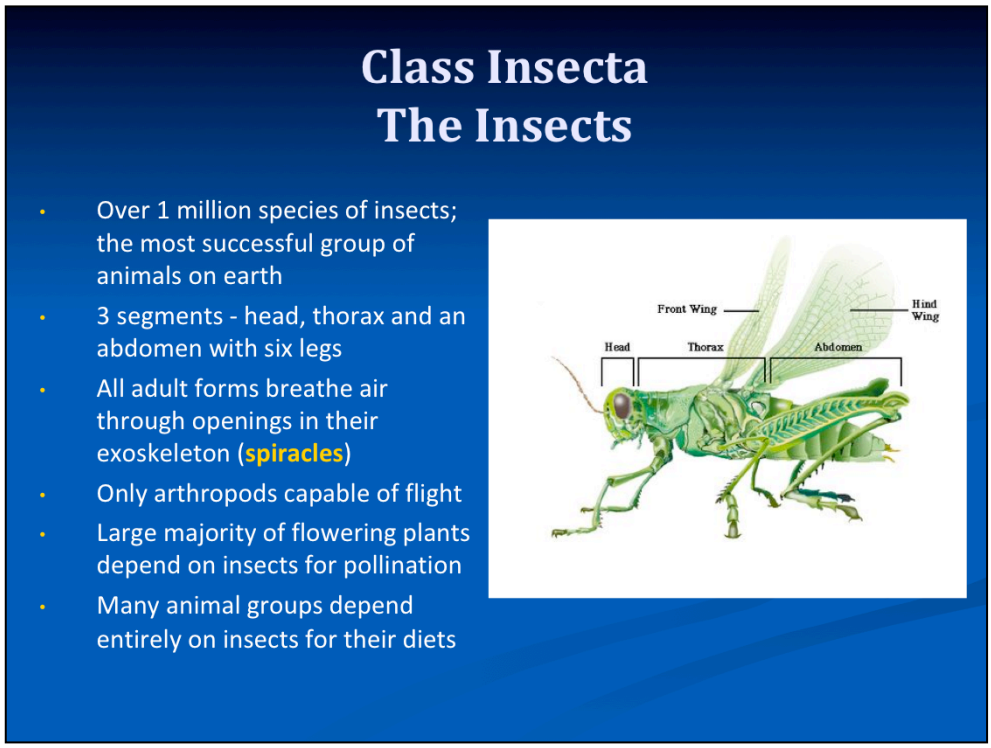
4 pairs of legs

1 or 2 body regions (cephalothorax, abdomen)

No wings

No antennae

Mostly terrestrial, some freshwater



The insects are the largest group of arthropods with over one million species. The Class Insecta includes beetles, butterflies, wasps, grasshoppers, flies, termites, and dragonflies. They are the most successful and diverse group of animals on Earth; They represent one half of all living organisms on the planet. Termites and ants account for the greatest amount of living biomass on the planet.

Insects have three body segments, a head, thorax and abdomen with three pairs of legs. The life cycles of insects vary but most insects hatch from eggs.

Insects are the only arthropods capable of flight and were the first animals to develop flight. Flight is a major component of their success. Insects have one or two pairs of wings but these may be absent in some species.

Humans regard certain insects as pests as insects eat more plant material than any other animal while others aid in spreading diseases (ie mosquitos and flies) that effect humans, livestock and plants. However, insects play important roles in their ecosystems. For example: a large majority of flowering plants depend on insects for pollination and many animal groups, such as many birds & the giant anteater, depend entirely on insects for their diets; they are **insectivores**.

The Insect Zoo has several species of insects including the red harvest ant, leaf insects and velvet ants. The Sculpture Garden has a giraffe weevil and leafcutter ant.

INSECTA Characteristics (*beetles, butterflies, wasps, grasshoppers, flies, termites, dragonflies, etc.*)

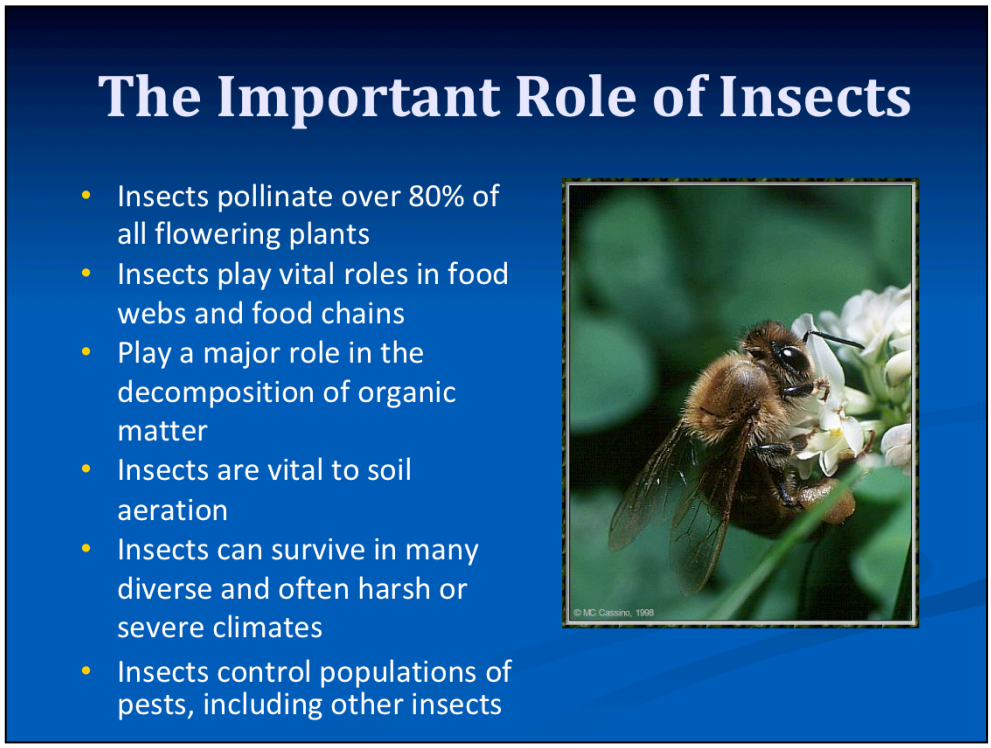
3 pairs of legs

3 body regions (head, thorax, abdomen)

1 or 2 pairs of wings (sometimes absent)

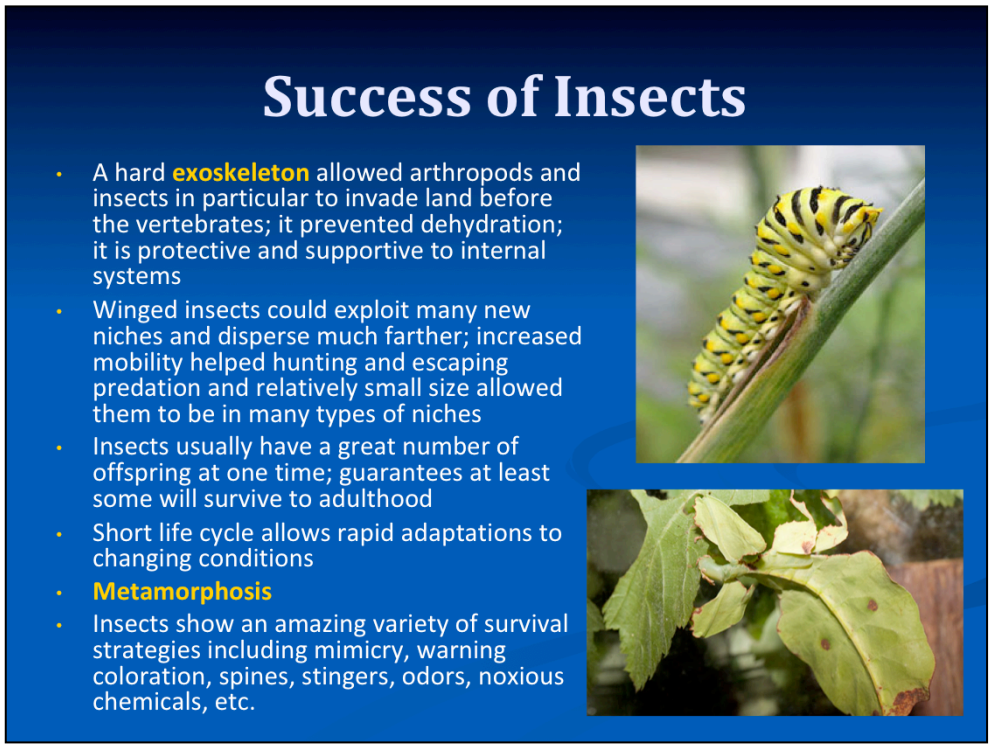
1 pair of antennae

Mostly terrestrial or fresh water, a few marine



Despite their negative reputation, insects are vital to the natural world; they are responsible for pollinating over 80% of all flowering plants. They play a vital role in food webs and in the decomposition of organic matter; termites break down dead trees, many beetles help to decompose decaying animals, plants and fungi, returning nutrients back to the earth. They are vital to soil aeration. Dung beetles are widespread and are part of nature's cleanup crew. Besides clearing the ground, the beetle fertilizes the soil and improves the nutrient recycling and soil structure. They can survive in many diverse and often harsh or severe climates. Insects control populations of pests, including other insects.

The evolutionary success of insects in terrestrial habitats is largely explained by features such as wings, mechanisms to minimize water loss and the ability to become dormant during adverse conditions. Once on land, invertebrates became an available food source for vertebrates to transition from aquatic to a terrestrial environment. The success of flowing plants was aided by pollination from winged insects. The transition allowed vertebrates to escape competitive pressure from the water and explore niche opportunities on land.



A hard **exoskeleton** allowed arthropods and insects in particular to invade land before the vertebrates in pursuit of the plants that were beginning to invade the land as well; the exoskeleton helped protect them from drying out, gave them protection and support to internal systems.

With the development of wings, insects could exploit many new niches and disperse much farther; their increased mobility helped hunting and escaping predation. Their relatively small size allowed them to exploit many types of new niches.

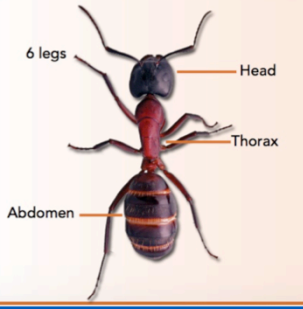
Insects have been extraordinarily successful from an evolutionary standpoint for a number of reasons. With a high reproductive rate and a huge number of offspring, a high genetic variability is ensured in any given population of a species. A large number of offspring at one time guarantees at least some will survive to adulthood. A short life cycle allows rapid adaptations to changing conditions; it allows for rapid responses to any sort of selective pressures.

Complete metamorphosis gave insects a significant survival advantage. The adults and larvae, being different, do not compete for the same food sources and have different predators. A disadvantage is the fact that they are vulnerable during the process. Incomplete metamorphosis lessens that disadvantage by eliminating a stage of the metamorphosis process.

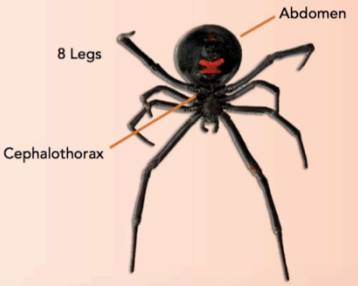
The insect world has an amazing variety of insects that have varying survival strategies including mimicry, warning coloration, spines, stingers, odors, and noxious chemicals. Can you find examples of invertebrates that use these strategies in the Insect Zoo? What strategy do the leaf and stick insects use to be among the best camouflaged animals? How does their movement imitate their surroundings? What role do the dung beetles play in an ecosystem? What beetle is important in preservation of some of the biofacts that we use?

INSECTS	SPIDERS
3 body parts (head, thorax, abdomen)	2 body parts (combined head and thorax, abdomen)
6 legs	8 legs
4 wings	No wings
2 compound eyes	Multiple simple eyes
Some insects are able to produce silk	All spiders have the ability to create silk
2 antennae	No antennae

Insects have 3 Body Parts



Spiders have 2 Body Parts



Since insects are the largest group of arthropods, their role is vital to the survival of large numbers of **insectivores** and other animals that prey upon them. This includes enormous numbers of mammals, birds, fishes, reptiles and amphibians; in addition, arthropods constitute the bulk of pollinators, so that the survival of crops as well as millions of natural flora species depend on diverse arthropod populations. Extinction of arthropod species threaten to make extinct hundreds of thousands, if not millions, of higher order birds, amphibians, reptiles and mammals.

The expanding human population and the effect this has on the environment as well as pesticides are the main reason for the decline of insects. The exact effect the human population and pesticides have had on the arthropod population is difficult to asses due to the vast number of the species themselves; many of which are not yet named nor described as yet.

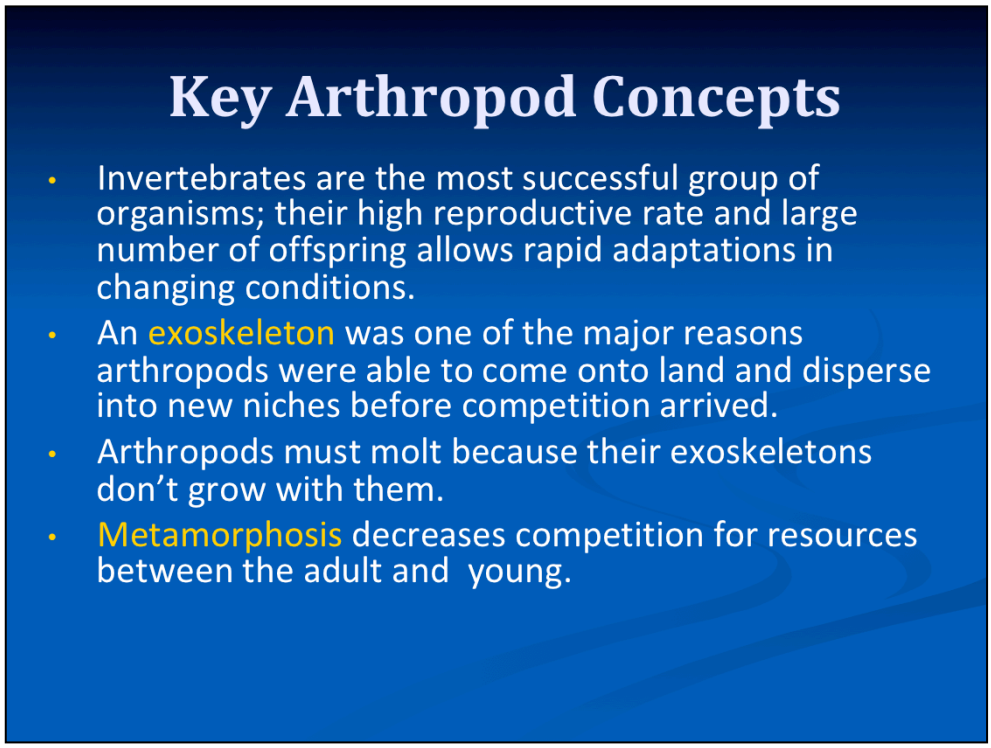
Warmer temperatures generally lead to more rapid development and survival in insects. Owing to their relatively short life cycles, high reproductive capacity and high degree of mobility, insect populations will be influenced by climate change and will be in a better position to adopt than other animal species. Global warming could disrupt the timing of pollination especially in alpine environments, with serious negative impacts to both plants and pollinators.

Colony Collapse Disorder (CCD) is the phenomenon that occurs when the majority of worker bees in a colony disappear and leave behind a queen, plenty of food and a few nurse bees to care for the remaining immature bees and the queen. Researchers are looking into the factors for CCD but the loss of the bee threatens not only pollination and honey production but also the production of crops dependent on bees for pollination.

The San Francisco forktail damselfly is a local endemic insect species at high risk of extinction. This damselfly is probably the rarest damselfly/dragonfly in North America. Dragonflies and damselflies play key roles in both terrestrial and aquatic habitats. They are predators as both nymphs and adults, feeding on a variety of prey including nuisance species such as mosquitoes and biting flies. In 2016, the San Francisco Zoo started a project to capture, breed, and release this damselfly into Mountain Lake, a newly restored site in the Presidio of San Francisco.

Pollinators are indicators of healthy ecosystems. Discover the number of native flowering plants and pollinators in your area and how you can help them thrive. This is one concept of Greenies Conservation Corner and the Fragrance Garden; you can inspire visitors to transform their backyard or patio into their own conservation corner. They can plant butterfly- and bee-friendly native flowering plants to attract pollinators and help maintain a healthy environment.

The Xerces Society for Invertebrate Conservation is science-based conservation organization that protects the natural world through the conservation of invertebrates and their habitats. The name comes from the now extinct Xerces Blue butterfly (*Glaucopsyche xerces*), the first butterfly known to go extinct in North America as a result of human activities. Their website (www.xerces.org) shows some of the latest projects and issues.



Corresponds with page 4 in Zoology Study Guide, the Arthropod Study Guide and Insect Touring Guide in the Docent Notebook. For specifics on the Zoo's arthropod collection read the Arthropoda Fact Sheets in the Docent Notebook.

Definitions:

Arthropod: an invertebrate animal having an exoskeleton (an external skeleton), a segmented body, and jointed appendages. include the insects, spiders, and crustaceans.

Bilateral symmetry: a property of an organism where the body plan can be divided into matching halves by drawing a line down the center; there is a right and left side that are mirror images of each other.

Chitin (pronounced kīt′n): the tough substance that is the main component of the exoskeleton of arthropods and lobsters and in the internal structures of other invertebrates.

Detritivore: an animal that feeds on dead organic material, especially plant detritus.

Ecdysis: the molting or shedding of an outer layer of skin, as by insects, crustaceans, and snakes.

Exoskeleton: is the external skeleton that supports and protects an animal's body.

Insectivore: a specific type of carnivore whose diet is mainly insects.

Invertebrate: animals that do not have a backbone.

Metamorphosis: the process of transformation from an immature form to an adult form in two or more distinct stages. **Complete metamorphosis** has four distinct life cycle stages: egg, larva, pupa, and adult, each differing in greatly in morphology. **Incomplete metamorphosis** only has three life cycle stages: egg, nymph, and adult nymph and is characterized by a lack of a pupal stage. Nymphs look like a smaller version of the adult.

Vertebrate: animals with a backbone; having a spinal column.