

PHYLUM ARTHROPODA - CHELICERATA

Introduction

The chelicerates have two distinct body regions; the anterior prosoma (cephalothorax) and posterior opisthosoma (abdomen) that may be divided into a mesosoma and metasoma. The anterior most appendages are the pedipalps and chelicera, which give the phylum its name and distinguish it from the mandibulata. Chelicerates don't have antennae and internally this is reflected in the loss of the deuterocerebrum. Chelicerates all have four pairs of uniramous walking legs on the first tagma. In most chelicerates appendages on the opisthosoma have disappeared or been reduced to either structures adapted for gas exchange or spinning silk.

The subphylum includes a variety of animals such as spiders, and scorpions along with primitive horseshoe crabs and the unusual sea spiders. In almost all cases chelicerates are predators and some, the ticks and the mites, have become specialists at miniaturisation using it to exploit their predatory habits. Chelicerates are fluid feeders and either liquefy their prey before ingestion or squeeze the juices from their food using their mouthparts.

The success of both Tracheata and Chelicerata on land is due to their waterproof outer cuticle. It is generally believed that the first terrestrial arthropods were chelicerates. With that being said the ultimate success of the group lay in their ability to capture and feed on the explosion of insects that was to follow the first chelicerate invasion of land. In particular their ability to trap insects with sticky threads, silk, allowed spiders to tap into a food resource which, to that point in time, few other organisms had used.

Merostomata

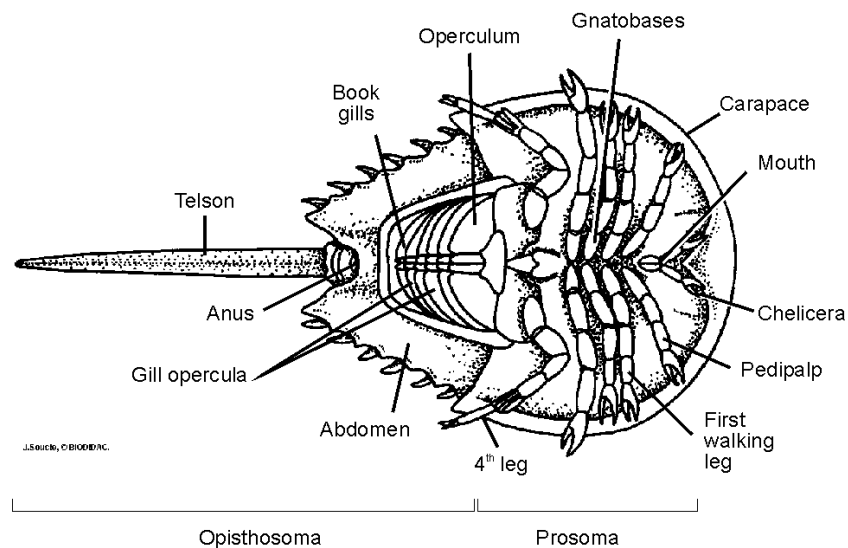


Fig. 1. External anatomy of the ventral surface of the horseshoe crab, *Limulus*. © BIODIDAC

Limulus

Don't let the common name of *Limulus* fool you. The horseshoe crab isn't a crab it's a chelicerate, but a very ancient one. There is one species that comes ashore on the east coast of North America and two more inhabit Asian oceans. These living fossils are all that remains of an ancient chelicerate lineage. Their bodies are covered by a massive tough exoskeleton that protects the underlying structures when they are on the ocean bottom or burrowing into the soft sands.

External anatomy

The body of all chelicerates is divided into two main tagmata, the anterior **prosoma** (or cephalothorax) and the posterior **opisthosoma** (or abdomen). Because it's located behind the anal opening the long tail isn't a segment, or tagma; it's a **telson**. The cuticle of the horseshoe crab is hardened and its leathery texture is due to high amounts a sclerotized protein.

Prosoma The dorsal surface of the prosoma forms an enlarged horseshoe shaped **carapace** that covers the legs underneath. A single **medial**, and paired **lateral** ridges are visible on the carapace. The shape of the prosoma helps the animal to shovel its way into the soft clean sands where it lives. At the outer edge of the **lateral ridge** on the dorsal surface is a pair of **compound eyes**. Merostomata are one of the few chelicerates that still have compound eyes, but they may not be homologous to the compound eyes that are found in the rest of the Arthropods. If the eyes are homologous, then the differences may be related to the burrowing and being active only at night. At the anterior tip of the medial ridge are the **median eyes**. These simple eyes may be hard to see if there is debris or organic matter encrusted on the surface of the carapace.

On the ventral surface of the prosoma are the six pairs of appendages typical of all chelicerates. The **chelicera** are small, consist of only three joints and are located in front of the mouth. Behind them are the larger, six segmented **pedipalps** that have a similar structure as the four pairs of legs behind them. Starting at the base, the segments are: **coxa, trochanter, femur, patella, tibia, and tarsus**. In mature horseshoe crabs the male pedipalp is modified as a **clasper** with the last segment becoming thicker and hook-like. It's used to hold onto the carapace of the female during mating. The tibia and tarsus forms the chelate tip of the legs and is used to manipulate food and pass it to the base of the legs where the basal segments of each leg forms a spiny **gnathobase** used to grind and tear food before it is passed to the **mouth** underneath. If your specimen isn't too brittle try spreading the legs to see the mouth. Although similar in the number of segments and the presence of the gnathobase the last pair of legs have two unique modifications. On the base of the leg, and on the outer surface, is a flattened, spatula-like structure that is used to clean debris from the gill surface. The second modification is found at the tip of the leg where the second to last segment consists of four flattened plates, **flabella**, that help to push the horseshoe crab as it burrows in soft sands.

Opisthosoma Along the edge of the opisthosoma the moveable **spines** identify the segments that have fused to form this part of the horseshoe crab's body. The cuticular dimples on the dorsal surface identify internal **apodemes** for muscle attachment. The opisthosoma is composed of nine segments. On the ventral surface and at the base of the last pair of legs is a moveable cuticular extension called the **chilaria** and it's all that remains of the first segment of the opisthosoma. Behind this are six flap-like plates. Lift up each and look at what is underneath. Under all but the first you'll find the **book gills** and **gill filaments** used for gas exchange and the flapping motion of the **opercula** pump water over the respiratory surface. The first pair of plates is the **genital opercula**, and paired **gonopores** can be seen underneath along the midline and about halfway back from the margin of the plate. The **anal opening** is located at the base of the telson.

Arachnida

The second class of chelicerates includes about 98% of all chelicerate types including the scorpions, spiders, ticks and mites. These animals show an immense diversity and are also considered the most unliked of all the arthropods. The common features of the group include two body tagma, except in the mites and ticks where the abdomen has become fused into one body region. The appendages on the opisthosoma have been modified into either spinnerets or pectines. All of the arachnids are fluid feeders and many liquefy their prey before consumption.

Scorpions

Like the horseshoe crab, segmentation is still visible in the tagma of the scorpion and this reveals how ancient these chelicerates are. Scorpions were some of the first animals to invade the terrestrial environment, feeding on soft-bodied invertebrate living in moist locations.

Chronologically then, they are the first arthropod on land, but it would be the insects that would be the most successful at exploiting the environment and as their numbers grew they became food for the scorpions.

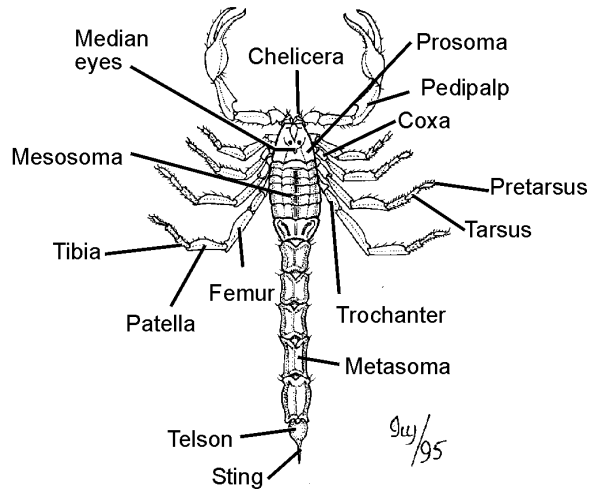


Fig. 2. External features of the dorsal surface of a scorpion. © BIODIDAC

External anatomy

Like other chelicerates a scorpion's body is divided into two tagma, the anterior **prosoma**, or cephalothorax, and posterior **opisthosoma**, or abdomen. The opisthosoma is further divided into an anterior **mesosoma** and distal **metasoma** with the **sting** at its tip.

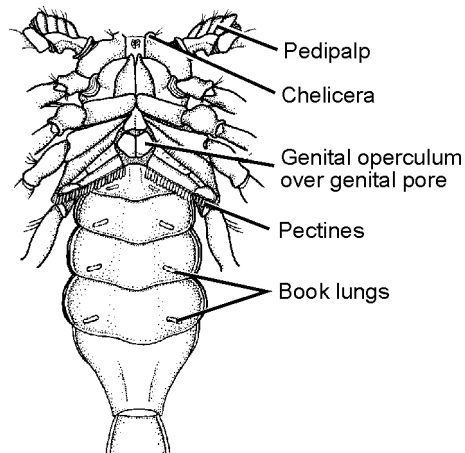


Fig. 3. External anatomy of the ventral surface of a scorpion. © BIODIDAC

Prosoma A cuticular **carapace** covers the dorsal surface of the prosoma and has four pairs of simple eyes, **ocelli**, on its surface. A pair of **medial eyes** is located on the dorsal midline and the other three pairs are located on the anterior and lateral edge of the prosoma. Six pairs of

appendages are attached to the prosoma, the **chelicera**, **pedipalps** and four pairs of **walking legs**. When viewed from the ventral surface the base of the various appendages surround a small **sternal plate**.

The hardened **pincers** of the chelicera are attached to a large segment that forms the top of the buccal cavity and are used to tear and rip food. The second pair of appendages are the six-segmented **pedipalps** consisting of a basal **coxa**, **trochanter**, **femur**, **patella**, **tibia** and **tarsus**. The last two segments of the pedipalps form the pincer-like chela used to capture prey and the coxal plates form the sides of the buccal cavity. The eight segmented **walking legs** are attached to the body by the **coxa** and additional segments include the **trochanter**, **femur**, **patella**, **tibia**, **metatarsus**, **tarsus**, and **pretarsus**. Cuticular extensions of the coxa on the first and second pairs of legs form the bottom of the buccal cavity and their **gnathobases** grind food prepared by the chelicera and extract the juices that are swallowed. Like other chelicerates, scorpions use extracorporeal digestion to predigest the food and hydrolytic enzymes released through openings in the gnathobases assist the extraction of the liquid meal.

Opithosoma Each segment of the opithosoma consists of a dorsal cuticular plate, the **tergite**, connected by a **pleural membrane** to the ventral **sternite**. The most conspicuous feature on the ventral surface of the mesosoma are the paired **pectines**. They resemble a comb, with a series of cuticular teeth that are embedded in a rod attached to the second segment of the mesosoma. The pectines have a rich nerve supply that extends into each of the teeth suggesting a sensory role for the structure, although just what it detects is still not clear to zoologists. In front of where the pectines are attached to the mesosoma, and on the first mesosomal segment, are two cuticular plates, the **genital opercula**, that covers the openings to the reproductive system. Both the genital opercula and the pectines are modified appendages. The remaining mesosomal segments have no appendages but on the ventral surface of segments three to six are the **spiracular openings** to the **book lung**.

Each of the five segments of the metasoma is formed from the fused cuticle of the dorsal tergite and ventral sternite; there is no pleural plate or membrane. The **sting** located at the tip of the metasoma. The sting is not a segment and is also referred to as the **telson** because of its location posterior to the anus. The sting consists of a hollow **bulb** and **barb** and the poison located in the bulb release their poison through an opening at the tip of the barb. The anus is located in the membranous region between the sting and the last metasomal segment. Most scorpions feed on insects and small invertebrates and when prey is located they grasp it with the chelae of the pedipalps and the opithosoma is bent over the head and the captured prey is stung. Food is torn off and passes in to the buccal cavity, mixed with salivary secretions and digestive enzymes to liquefy it, and strained by setal hairs on the gnathobases before it enters the digestive tract.

Spider *Argiope*

Nothing evokes fear and anguish in more people than spiders - arachnophobia. Spiders are aerial predators of insects and have mastered the terrestrial environment. They are covered with an alpha-chitinous exoskeleton with the waxy epicuticle essential for survival on land. The compound eye typical of other arthropods is missing and instead they rely on tactile information from the webs they spin. If vision is important they use their simple eyes. Instead of mandibles

they use chelicera as their main feeding appendage. Spiders are variable in their morphology and the common garden spider, *Argiope* sp., allows us to identify most of the characteristics of animals in the group.

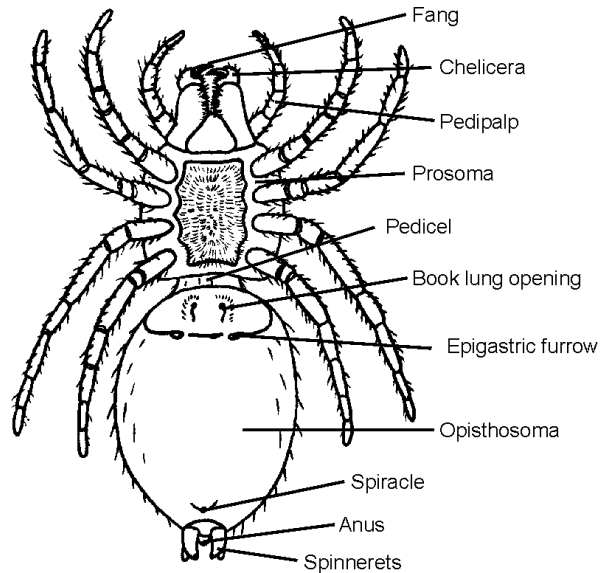


Fig. 4. External anatomy of the ventral surface of a spider. © BIODIDAC

External anatomy

One of the things you'll immediately notice about your spider is that its legs are positioned above the body, rather than underneath! In a unique way that optimizes the small space inside in side the spider's leg a single muscle moves the leg. The result, instead of having one muscle to raise the leg and another to lower it, muscles move the leg down and the elasticity of the leg moves it back up. When they die the muscles relax and the spring of the leg raises it over the body. The spiders cuticle is leathery and their bodies aren't covered with the tough, thick cuticle typical of insects and large Crustacea. The chelicerate body is composed of two tagma, an anterior **prosoma**, or cephalothorax, and posterior **opisthosoma**, or abdomen.

Prosoma The dorsal fused segments form the **carapace** and the depressions and indentations on the surface mark the position of underlying **apodemes** and the leg muscles attached to them. At the anterior end are four pairs of **simple eyes**. Although it may look like there are only six, the most lateral "eye" is actually a combination of two. Some of the eyes look forward, others up or down and to the side. The position and size of the eyes varies in spiders, but there are always eight.

In chelicerates the antennae are missing, as is the deutocerebrum of the brain that would innervate it. The prosoma has six pairs of appendages attached to it: the **chelicera**, **pedipalps** and four pairs of **walking legs**. The chelicera hang vertically on the front of the prosoma and their distal tips are modified into **fangs**. They are attached to the prosoma by the large basal

segment. The **poison glands**, which produce a mixture of digestive enzymes and neurotoxins, are located in the basal segment and a duct carries its secretions to an opening at the tip of the fang.

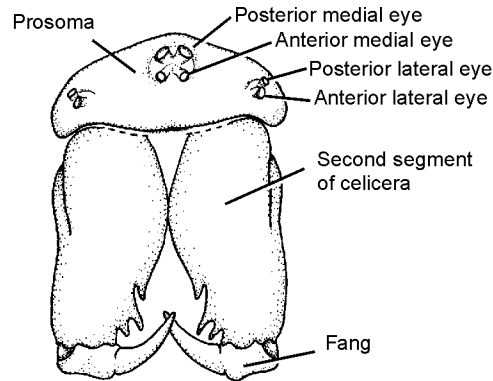


Fig. 5. Anterior view of the spider prosoma. © BIODIDAC

Look at the head from the ventral surface and locate the enlarged base of the six-segmented pedipalp that covers the mouth. This enlarged segment is called either a maxilla or **gnathobase**. Calling it a gnathobase prevents confusion with the maxillary appendage found in other arthropods. The gnathobases cut and squeeze the food to extract the juices that the spider ingests. **How do spiders increase the fluidity of their meal?** The pedipalp is **sexually dimorphic** in most spiders. In females it looks like the other legs, in males the terminal end is expanded and used in sperm transfer. (Most commercially supplied preserved spiders are all female.)

A **labium** is located between the gnathobase of the pedipalps forming the lower lip of the buccal cavity. The upper lip, **labrum**, is located behind the chelicera and may be hard to see. If your specimen isn't too brittle, open the buccal cavity and try and locate the labrum inside.

A large **sternal plate** covers the ventral surface of the prosoma. Around its margins is the **pleural membrane** that connects the dorsal **carapace** and ventral sternum. The pleural membrane is hard to see because it surrounds the coxal joints of the four pairs of seven-segmented walking legs consisting of the **coxa**, **trochanter**, **femur**, **patella**, **tibia**, **metatarsus**, **tarsus** and its **claws**.

Opisthosoma Although the membranous cuticle of a spider hides it, the opisthosoma is composed of twelve segments consisting of dorsal **tergites** connected by pleural membranes to ventral **sternites**.

The first segment of the opisthosoma is modified into the waist-like **pedicel** that connects the opisthosoma to the prosoma. The openings to the **book lungs** are a pair of slits at the end of a cuticular fold and two triangular cuticular plates that mark the position of the underlying book lungs. The book lungs are formed from sheets of thin cuticle, lamellae, arranged like the pages of a book, the origin of the structures name. In female spiders the cuticular extension between the spiracular openings is the **epigynum** that covers the **gonopore** and contains the opening to the seminal receptacles.

At the posterior end of the opisthosoma are the three pairs of **spinnerets** and the **anal papillae**. The two largest spinnerets are composed of two segments and located towards the anterior and posterior and surrounding the unsegmented middle spinnerets. To see the middle spinneret you'll have to move the anterior and posterior ones out of the way. The spinnerets origins are thought to be the appendages that were originally on these segments. Look closely and you'll see a variety of bumps, the **spigots**, on the surface and each produces a different type of silk from the silk glands underneath.

Locate the anal slit on the tip of the anal papillae. In front of the spinnerets is a single medial **spiracular opening**. Spiders often have two types of respiratory systems including the book lungs that we've already mentioned and a tubular **tracheal system**. This spiracle is the opening to the tracheal system.

Mites and ticks

Mites and ticks form a group of smaller sized arachnids important for both medical and economic reasons. They include parasitic forms as well as species that are destructive to food and other products. Mites are usually smaller than ticks and in both the standard divisions of the body, characteristic of the chelicerates, have become obscured. *Dermacentor andersonii* is our example of a tick and mites are represented in this lab by the follicle mite, *Demodex folliculorum* and the scabies mite *Sarcoptes scabiei*.

Dermacentor or *Ixodes*

Either species can be used to identify the main features of a tick. The main difference between the two is that *Dermacentor* has eyes on the side of the scutum. In both the body is dorsoventrally flattened and the usual divisions of prosoma and opisthosoma that we associate with the chelicerata have all but disappeared. Instead a **capitulum** or **gnathosoma**, is distinct from the part of the body with the usual four pairs of legs, the **idiosoma**.

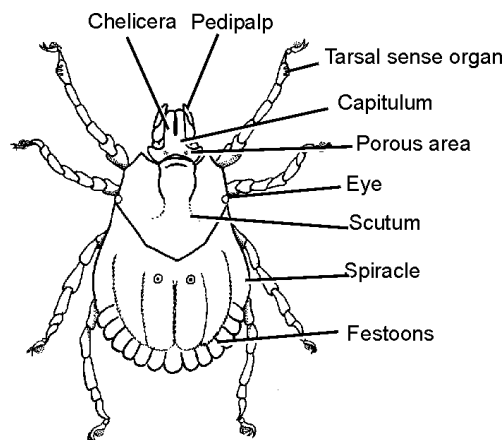


Fig. 6. External anatomy of a tick.
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Gnathosoma

The most anterior part of the body is the gnathosoma and consists of three segments. The first is hard to see but the second and third have the **chelicera** and **pedipalps** attached to them. The gnathosoma is attached to the idiosoma by the **basis capituli** which forms a cuticular ring and fits into a groove in the anterior part of the idiosoma. Two patches of the basis capituli are covered in small pores and referred to as the **porose area**. These are openings to dermal glands that lie underneath the cuticle at this point.

Ticks feed on blood and a combination of the hypostome and chelicera form a drinking straw that is anchored into the hosts skin. Locate the **hypostome** underneath the chelicera. The hypostome is an extension of the sternum and if you look closely at it you'll see the backwards directed teeth that are found on the surface. **Why are the teeth oriented in this direction?** The needle like **chelicera** has two segments. The pedipalps have four segments and form the sides of the piercing mouthparts. The second and third segments each have a groove on their inner surface that surrounds the hypostome and chelicera. The fourth and most distal segment is very small and located at the tip of the pedipalp.

Idiosoma

The rest of the body is the **idiosoma** and it includes the four pairs of legs, the posterior part of the original arachnid prosoma, and the opisthosoma. In males the **scutum** covers the anterior part of the idiosoma, in females the scutum only partially covers the idiosoma. This restricts the size of the blood meal that a male can consume compared to a female. The edge of the idiosoma is sculpted with eleven rectangular **festoons** and near the anterior and lateral edge of the scutum are a pair of **simple eyes**. Near the middle of the dorsal surface of the idiosoma is a pair of openings, the **fovea** through which secretions of the foveal glands are released.

On the ventral surface is the single **genital opening**, positioned near the anterior midline behind the last pair of legs. The anus is positioned in the center of the idiosoma near the posterior end and has two cuticular anal plates on either side of the opening. The genital pore, anus and anal plates are not found on the immature **nymph**. Behind the last pair of legs are the spiracles and their surrounding spiracular plates.

The first pair of legs have seven segments and the tarsus at the tip has the cup shaped Haller's organ and two tarsal claws. Haller's organ is a sensory structure and is used by the tick to locate an appropriate host on which to feed. The remaining legs don't have the sensory organ and have an extra tarsal joint which results eight segments.

Demodex folliculorum and *Sarcoptes scabiei*

The ultimate in chelicerate miniaturization are the mites.

The follicle mite is a common cohabitant of ours and its found at the base of the course hairs surrounding the eyes and ears. It lives in the base of the follicle feeding on the secretions of the follicular glands. Examine the slide of the follicle mite. About the only recognizable chelicerate feature is the four pairs of stubby legs.

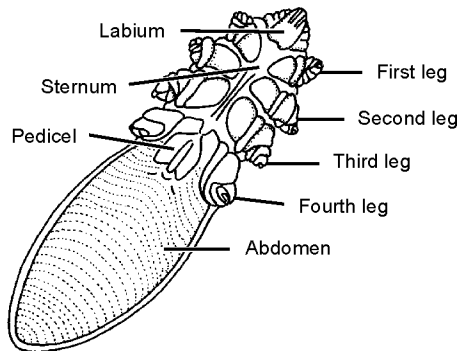


Fig. 7. Anatomy of the follicle mite *Demodex folliculorum*. © BIODIDAC

Sarcoptes scabiei is the causative agent of scabies where the mites burrow below the skin. Once again the legs are about the only visible chelicerate feature

Pycnogonida

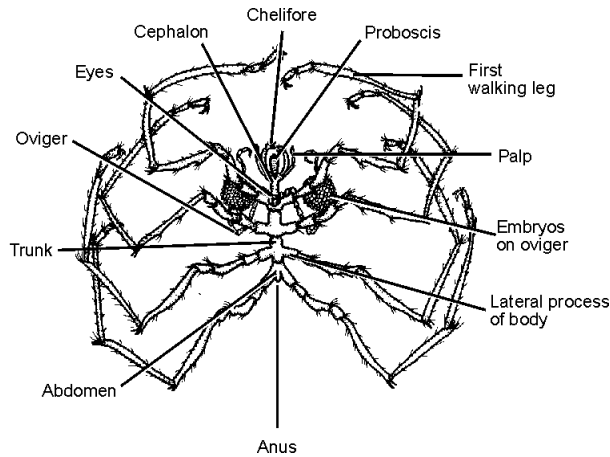


Fig. 8. External anatomy of a pycnogonid.
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The final class of chelicerates are the Pycnogonida, which are commonly called sea spiders. There hasn't always been agreement on how sea spiders fit into the taxonomic scheme, and in some classifications they are given their own phylum designation. In others, such as the one that we're using here, they are considered primitive chelicerates because of their chelicera, pedipalps, claws at the tips of their legs, and simple eyes located on the tubercle on the head. More recent classifications suggest that they may be more closely related to the mites and ticks and should be an order within the Arachnida; if that's the case, they're definitely chelicerates.

External anatomy

The body is narrow and consists of an anterior **prosome**, or cephalothorax, and reduced posterior **opisthosoma**, or abdomen, consisting of only a small stump with an anus located at its tip.

The prosoma is divided into two regions. The anterior most "**head**" region includes the **proboscis** with the mouth located at its tip. Behind this are the **chelicera** and **pedipalps**. Pycnogonids commonly feed on soft-bodied organisms such as cnidarians, polychaetes, bryozoans, and nudibranchs by using the **teeth** on the proboscis to rip into their prey and suck out the internal fluids; a feeding mechanism shared with other chelicerates. The shape and form of the proboscis varies depending on the type of prey each species of sea spider feeds on. The first pair of **walking legs** are also on the "head" along with the unusual **oviger legs** that are used in both sexes for grooming and in the male for brooding the fertilized eggs. On top of the head is a dorsal **ocular tubercle** with **four simple eyes** oriented to give a 360-degree field of view.

The rest of the prosoma is the "**trunk**" and under normal circumstances you would expect an additional three pairs of walking legs. In most pycnogonids this is the case; although there are some that have four or five more pairs! Walking legs are attached to lateral extensions of the body, **pedestals**, and the leg segments are named **coxa 1**, **coxa 2**, **coxa 3**, **femur**, **tibia 1**, **tibia 2** and **propodus**. Each is tipped with terminal claws.