The spider

Introduction

Many people confuse spiders with insects. The easy way to recognize the spider from an insect is that spider has 4 pairs of legs and an insect has 3 pairs. One major difference is that insects have compound eyes whereas the spider has singular eyes with lenses. Unlike insects, spiders do not have antennas.

Sesia apiformis, wasp butterfly, an insect

Dolomedes fimbriatus, a spider

There are also many similarities. Both have an external skeleton (exoskeleton). The hard part of the body is on the outside while mammals have their skeleton (bones) inside the body. The heart is located on their back. Breathing is performed with trachea and / or book lungs. The oxygen transport protein is hemocyanin and not the mammalian transport protein hemoglobin.

In 1758-59 Carolus Linnaeus published the 10th edition of ***Systema Naturae*** in which he classified animals. Over the years the biologists improved the systematic study of the Animal Kingdom. According to this study we have single cell animals at the bottom and at the top are humans with very complex cell systems. With the aid of DNA analysis the positioning of each animal has become even more precise than before. It is called a taxonomical classification of the Animal Kingdom.

It consists of several divisions. A division is called phylum.

Phylum Arthropoda consists of animals with exoskeleton (hardened exterior) that have segmented bodies and jointed appendages. The segments are fused to form body parts. The first part is the head, followed by thorax and the hind part is abdomen. There are appendages on these segments, which are specialized to perform specific functions such as walking, jumping, eating and lots of other activities.

Phylum Arthropoda is divided into 5 major classes.

Class	*Crustacea*	*Arachnida*	*Diplopoda*	*Chilopoda*	*Insecta*
Examples	Lobsters, crabs	Spiders	Millipedes	Centipedes	Flies, maggots
Body parts	Cephalothorax and abdomen	Cephalothorax and abdomen	Head and body	Head and body	Head, thorax and abdomen
Pair of legs	Many, usually 5 pairs	4 pairs	Many, 2 pairs per segment	Many, 1 pair per segment	3 pairs, 1 on each thoracic segment
Antennae	2 pairs	None	1 pair	1 pair	1 pair
Described number of species	25,000	70.000	5000?	5000?	800.000

Class Arachnida is divided into 10 orders.

1. Araneae	*2. Scorpiones*	*3. Pseudo-scorpiones*	*4. Solfiguae*	*5. Schizomida*
Spiders	Scorpions	Pseudo-scorpions	Solifugids	Tartarida
6. Amblypygi and Uropygi	*7. Palpigradi*	*8. Ricinulei*	*9. Acari*	*10. Opiliones*
Whip scorpions	Mini whip scorpions	Rinucleids	Mites en ticks	Harvestmen

Accordingly the spider is placed in phylum Arthropoda, class (classis) Arachnida, order (ordo) Araneae. This order is further divided into 3 sub-orders. The Mygalomorphae (the primitive spiders), the Aranaeomorphae (the modern spiders) and the Mesothelae, with one family of spiders the *Liphistiidae*. Every spider belongs to a family, which is further divided into genus, followed by species. The European garden spider belongs to the family Araneidae, the genus *Araneus* en the species *diadematus*. As a rule genus and species are printed in italics.

In our world around 70000 species of the class Arachnida are described. 90% of these species belong to the order Acarina (mites and ticks) and the order Araneae. In the order Araneae 1960 primitive spiders and 40000 modern spiders are known.

One can find spiders in much larger numbers than expected. A study in Great Britain counted in a meadow 130.8 spiders per square meter. An average spider consumes 0.089 g insect per day. After some calculations we can conclude that in the Netherlands, with an area of 36150 square kilometers and 15 million human habitants, there are 5000 billion spider habitants. These spiders could consume all Dutchmen in three days. Lucky for us that our spiders do not eat us.

Spiders mostly prey on insects. Most insects are useful, although some may be annoying. Therefore, it is difficult to say if a spider is valuable or not. However, spiders do control the insect population to some extent which makes them helpful, at least, in maintaining the right balance in our eco system.

Scorpion, *Euscorpius italicus*

We will have a close look at the near relatives of the spiders in Europe. Around the Mediterranean we can find the scorpion (order Scorpiones). Its body has a large head-breast part (prosoma) and a segmented abdomen (opisthosoma) to which a tail is connected. At the end of the tail there is a stinger. Connected to the prosoma are four pairs of sturdy legs, one pair of feelers and one pair of scissors.
A closer look reveals two tiny black eyes, although, some varieties of scorpions have more than one pair of eyes. The sting with poison is mainly used for protection and for killing large prey. The scorpion sting is unpleasant for humans and can result in possible death.
A rather unknown scorpion order is the pseudoscorpion (order Pseudoscorpiones). This small creature is a few millimeter long and lives between detritus like leaves, bark, moss, mole- and bird nests. They have relatively long scissors that can be as long as the rest of the body for the males. They do not have tails or stingers.

Tick, *Ixodes ricinus*

Velvet mite, *Trombidium holosericeum*

Even smaller than the pseudoscorpion are the ticks and the mites.

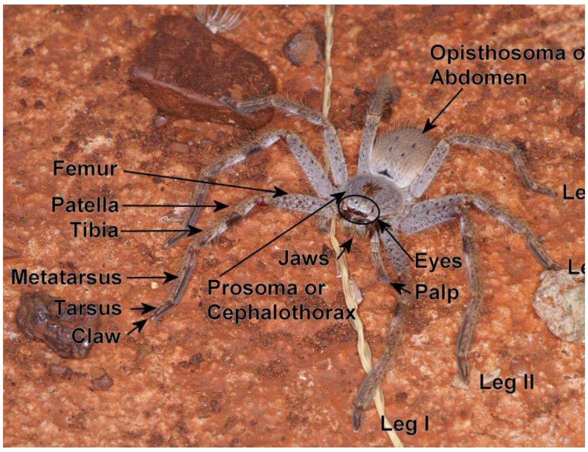
Mites are found in a great variety of forms in all kinds of habitats like deserts, in water, between rocks, in flour and in carpets, et cetera. A species of mites, commonly known as house dust mites, can be found in our houses and in our beds in huge numbers where they feed on human dander. Mites can be detected even in human hair sacs and sweat glands. The excretions of these mites are a major cause of asthma and allergy.
An easy to spot mite is the red velvet mite and it can be found in the garden. Ticks may cause Lyme disease.

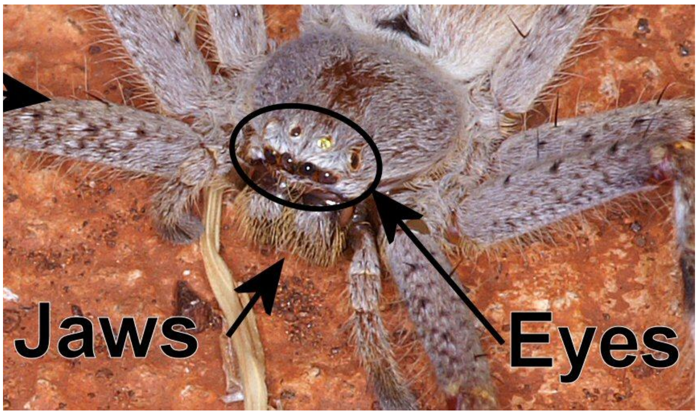
Harvestmen (order Opiliones) are often mistaken for spiders. Unlike spiders, the two parts of the body (cephalothorax and abdomen) of a harvestman are fused together into one part. They also have eight legs, feelers and mouth parts that work like a pair of scissors. Most species have short legs but some of them may have very long legs. Opiliones do not have any poison glands. At the top of the body there is one pair of eyes that are pointed sideways. They have no silk glands or spinners. Harvestmen eat everything (omnivorous). They catch small insects or eat the decays of any dead animal, animal dung, bird droppings, other fecal material, and all kind of plant material and fungi. The harvestman is mostly nocturnal, being active during night.

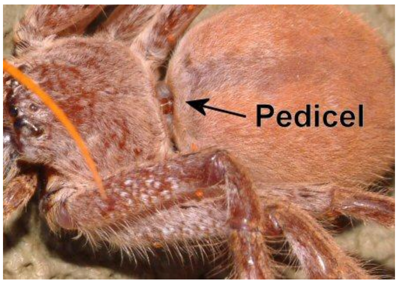

Harvestman, *Mitopus morio*


Harvestman, *Phalangium opilio*

The body



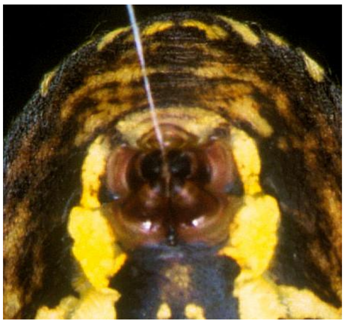


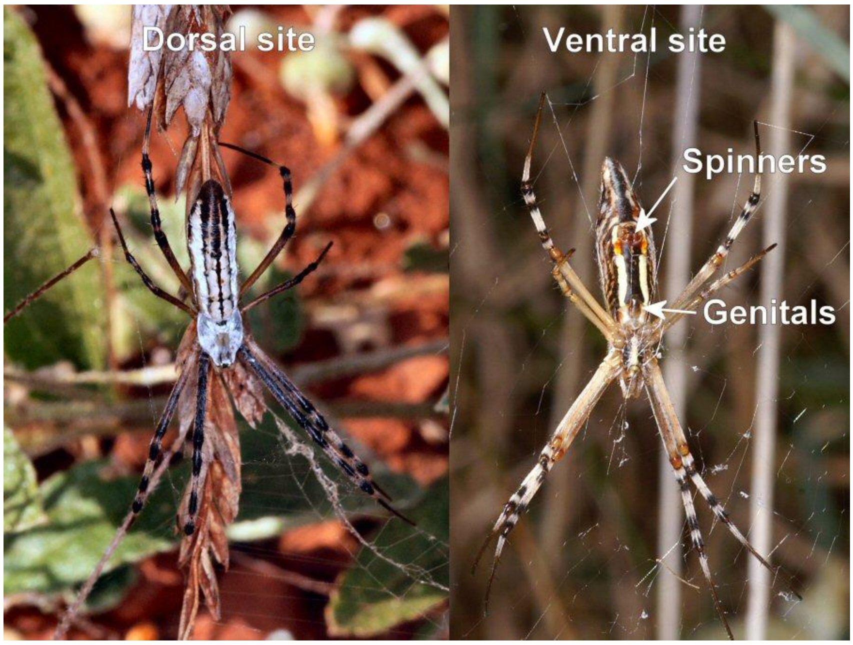


The body of a spider has two distinct parts. The first, front, part consists of a fused head and breast part, called as prosoma or cephalothorax. It is made from a hardened material, called chitin. The second, rear, part is the soft abdomen, called opisthosoma. A tiny tube called pedicel connects the cephalothorax and abdomen. The eight legs, the two jaws (chelicerae) and the two feelers (palps) are connected to the prosoma. The males have a bulb at the end of their palps. These are filled with semen before copulation and are used to inject the semen into the sexual organs of the female.

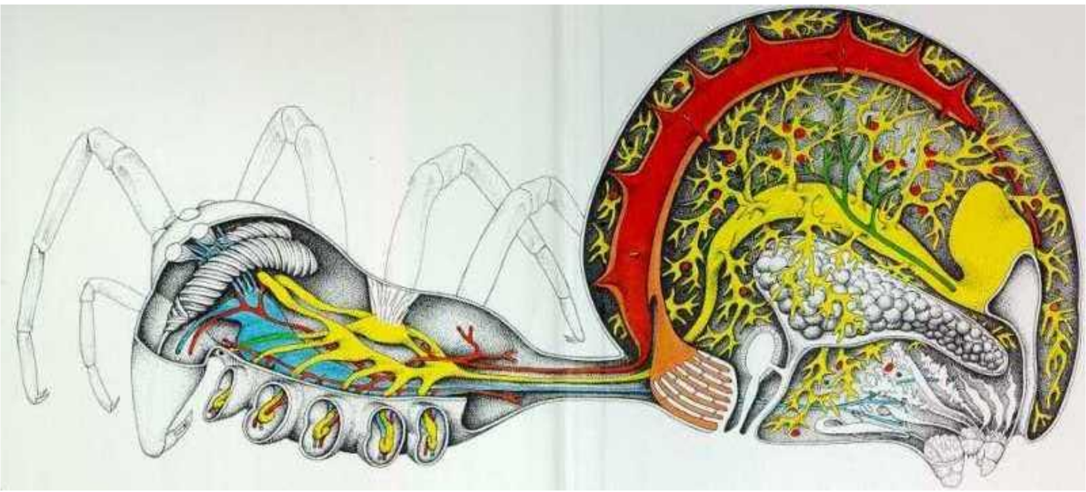
Some spiders have six eyes but most of them have eight eyes located on the front of the prosoma.
The back or top of a spider is the **dorsal** side and at the bottom is called the **ventral** side. The genitals of the spider (**epigynum**) are located just behind the legs on the ventral side.

Detail of the epigyne and book lung slits of *Argiope bruennichi*

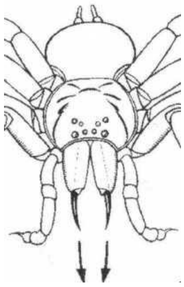

Detail of the spinners of *Argiope bruennichi*

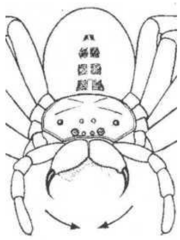


Inside the body there is an extensive nerve system (blue).
The brains are located in the prosoma and the heart at the front upper side of the abdomen (red). The heart beats with a frequency between 30 and 70 beats per minute. When the spider is tensed or exhausted the heartbeat can go up to 200 beats per minute.
The silk making spinners (white) are located at the rear of the abdomen. These are connected to glands that produce different proteins. When these proteins are mixed, it polymerizes to form silk. When pressed through the spinner, the fluid silk produces a thread.
The sexual organ and the egg-producing organ (white) are located between the book lungs (red) and the spinners.
The alimentary canal (yellow) runs through the whole body. At the end of the alimentary canal, is the excretory system (green).



The jaws and poison



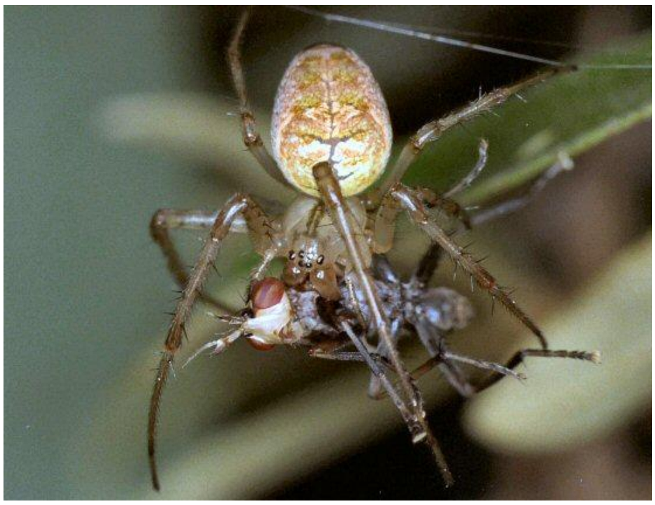


Modern spider, *Neosparassus salacius* | Primitive spider, *Atrax robustus*

Primitive spiders, Mygalomorphae, have forwardly pointing jaws that move forwards and backward in contrast to the modern spider. Therefore they can not crunch a prey. They wait until the prey contents are dissolved before they can suck it empty.

Primitive spider, Brachypelma smithi

Modern spider, *Tegenaria atrica*



Jaws of *Meta segmentata*

The poison of a spider contains protein, amines and polypeptides. Some of these molecules are capable of disrupting the communication between the nervous system and the muscles, which causes paralysis. Other molecules cause death of cells, which leads to necrosis. After the prey is killed the spider spits enzymes from its mouth into the victim. Enzymes dissolve the contents of the prey. Mammals dissolve their meal in a stomach using the enzyme pepsin. The spider digests the proteins in the prey itself and sucks it empty.

How lethal is the poison of a spider? This is difficult question to answer. A poison is given a number LD50 to express its toxicity. LD50 stands for quantity of a lethal dose needed to kill 50% of a tested population. The poison of a black widow spider has a LD50 of 0.9 mg per kg mouse. Therefore 0.013 mg poison is enough to kill one mouse. The spider needs 2 mg to kill a frog. So the lethality differs among animals. Such a test has never been performed on humans. Therefore it is difficult to calculate how poisonous a spider is to humans.

Jaws of the house spider *Tegenaria atrica*

The lethality of spider's poison to humans is much exaggerated. However there are spiders that can hurt humans. The Latrodectus species (Black widow), the Australian Sydney funnel web spider, *Atrax robustus*, are best to be avoided. These spiders use a substance that disturbs the nerve system, which can cause heart rhythm disturbances, cramps, shaking, pain and dizziness.

The black widow, *Latrodectus hasselti*

Crab spider with prey

There are also many spiders that give a nasty bite comparable to the stinging of a wasp. Most of the venom injected with these bites causes cell death and gives rise to a wound that does not heal properly and becomes easily infected. In Europe there is the water spider, *Argyroneta aquatica*, which has a very nasty bite. Immediate cooling of the wound is the best medicine.

Most modern spiders crunch their catch with their jaws. Other spiders wrap their prey in silk, taking care that the victim does not bite them. Orb weaving spiders make a parcel of the prey and wait until the prey is dissolved before sucking it empty. Crab spiders do not use silk but use a rapid working poison. Spiders of the family *Uloboridae* do not have any poison and put their trust completely on their silken thread.

The injected enzymes dissolve the prey and then it is sucked empty. The mouth of a spider is located between the palps which are connected to the stomach muscles that perform the sucking. Between mouth and stomach is a filtering device that is made up of thousands of fine hairs.
Only particles smaller than 1 μm can pass through this filter. This filter is so precise that even the particles in India ink will be filtered out so that only water can pass through. With these filters the spider prevents bacteria, viruses and other harmful life forms from entering its own body.

Orb weaving spiders like this *Argiope syrmatica* wraps her prey before sucking it empty.

The filter is regularly cleaned with the spider's upper and lower lips.
Because the food that is taken up can be large in comparison to its own body volume, the abdomen of the spider can swell enormously. The digested proteins are stored in a special place. This makes it possible for the spider to live for several weeks on a single prey. The waste substances are chemically converted to harmless crystals and are stored in special cells. These white colored guanocytes are located in-groups and can be seen through the skin. This shows up as a very special pattern on the back of the orb weaving spiders.

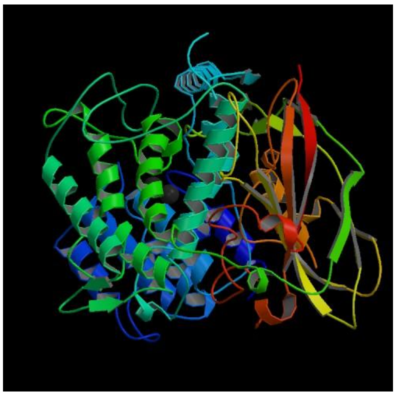
Special excretory organs separate these waste substances from the blood. The spider kidneys consist of two long thin tubes, called Malpighian tubule.

Blood circulation

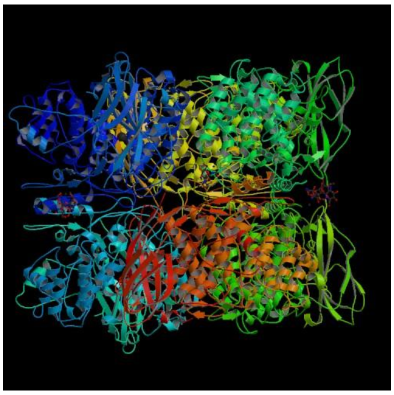
Bleeding male house spider, *Tegenaria atrica*

The spiders have circulating blood in their bodies. The colorless blood, called hemolymph, transports nutrients, hormones, oxygen and cells. The blood also serves another purpose. It is used locally to raise the blood pressure during moulting (shedding of old skin) and stretching the legs.

In mammals haemoglobin molecules, present in the red blood cells, transport oxygen. The spider uses a more complicated protein called hemocyanin. Unlike haemoglobin, hemocyanin is not stored in a cell but flows freely in the blood of a spider. Hemocyanin is a protein that is made up of 24 sub-units with a molecular mass of 1.704.000 compared to the molecular mass of oxygen, which is only 32. Human haemoglobin is made up of 4 sub-units with a molecular mass on 64.500. Haemoglobin is a molecular disc, made of nitrogen, carbon, hydrogen and an iron atom at the center. The oxidized iron gives the molecule its characteristic red color. Hemocyanin also contains nitrogen, carbon and hydrogen but has a copper atom at the center instead of an iron atom. The oxidized copper gives the molecule a blue color. Hemocyanin binds oxygen but only releases it after it receives the right chemical signal. For every of the 24 sub-units there is special chemical signal. Depending on the need for oxygen a cell can give more or less signals. Beside these signals the release of oxygen is also controlled by temperature. Every sub-unit has a specific temperature optimum.

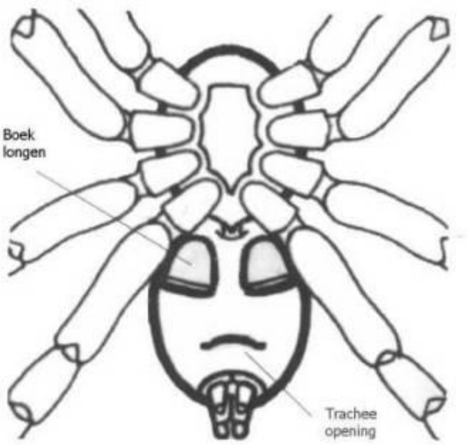


One sub unit of hemocyanin.



Theoretical model of six subunits. (Volbeda, A., Hol, W.G. 1HCY PDB file).

Spiders have an open blood circulation system. Blood vessels do transport the blood to a specific place but thereafter the blood flows freely in the open spaces between the organs.



The heart is located on the back of the abdomen. This is an open tube called pericardial-sinus with valves, which is hung in a cavity. Elastic muscles around this cavity contract, enlarging the tube. Because of the valves in the tube the blood can flow in only one direction. If the tube is filled with fluid the muscles relax and the blood is pressed out of the tube. The heart has it own nerve center that can let the heart beat independently from the brains. There are connections with the brain that can raise the heart frequency. This can be registered if the spider becomes excited and its heart frequency rises.

Book-lung and trachea entrances (13)

The lungs

In mammals the uptake of oxygen in the blood and the release of carbon dioxide from the blood take place in the lungs. Spiders use other organs. Above the spinners there is a slit that can be opened and closed. Long small tubes run from this slit into the body. These tubes are called trachea. The gasses are exchanged with the blood by diffusion.
Besides trachea many spiders also have book lungs. These are hollow leaf-like structures through which the blood flows. These book lungs hang in an open space that is connected to a tube. The other side of the tube is in open contact with the air. The entrance is located below the abdomen.

Book lung of *clubiona sp.* (bg)

There are spiders with either book lungs or trachea but most spiders have both.
Primitive spiders have only two pairs of book lungs. Modern spiders have developed trachea systems. Most of them still possess one pair of book lungs.
The trachea supply oxygen faster than book lungs. The modern spider uses these two systems together. This allows for the utilization of more oxygen and gives the advantage of quicker and longer reactions than the primitive spiders which have only book lungs.
Fast running and jumping spiders have a good developed trachea system. The small spiders of the family *Symphyltognathidae* are exceptional. They do not posses book lungs but have a well developed and very well performing trachea system.

The size of the heart depends on the size of the developed trachea system. Spiders with a good developed system do not need a large heart because the pumping capacity can be smaller. Less blood is needed to supply the organ with oxygen.

Moulting

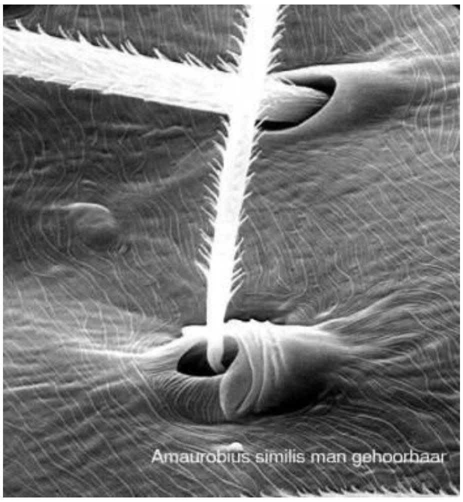
Because of the hardened skin made of chitin, the spider can not grow larger. Therefore the spider needs to shed external skeleton (exoskeleton) regularly (ecdysis) so that it can grow. The spider changes its skin 5 - 7 times in her life.
Spiders that can grow very old, like Tarantula's that may live for 25 years, change skin every year. This is not because she keeps growing but, like our clothes, the skin becomes worn out.

Skin of a spider

The color of the spider becomes darker before the changing of its skin. Enzymes dissolve the layer between the skin and the rest of the body. The new skin begins to form below the old one. It is extremely folded because it has to be larger than the old coat. The nerves stay connected to the sensory organs on her old skin so that she is not deprived of essential signals from the sensory organs on her legs. Just before shedding the old skin the spider hangs itself upside down with a thread. After several minutes the abdomen contracts to around 70% of it original size. The blood is pumped to her head raising the pressure from 20 kPa to approximately 40 kPa (0.4 atm). The skin starts tearing at her jaws and the crack enlarges to the abdomen. If the skin is loose from the head-breast part (prosoma) the blood pressure is raised in the abdomen. When the skin has become completely loose the spider falls out of her old skin. These old skins are the "dead" spiders you can see hanging to wires and small branches.

Spiders can often be seen with one or more missing legs. After moulting these lost legs regenerate. After the first change of skin, newly formed legs are smaller than the original legs. After the second moulting these differences in length are hardly observable.

Nervous system and sensory organs



There are two concentrations of ganglia in the prosoma (head-breast part or cephalothorax) which forms the brain. A number of nerves extend from the brain to the legs, eyes and the rest of the body. The brain takes up a volume of 20 - 30% of the prosoma.

Spiders have several sensory organs to get an impression of the surrounding in which they live.

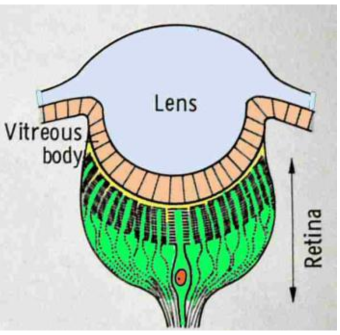
A spider does not have ears. Mammals hear with help of hairs that are located in the ear where pressure waves in the air are converted to electric signals. These signals are then sent to the brain and interpreted as sound. A spider hears with very tiny hairs on her legs (thrichobotria). She is very capable of localizing the origin of a sound by interpreting the movement of the air produced by that sound.

Hearing hair of *Amaurobius similis*
(bg)

Wolf spider (*Lycosidae*)

Lynx spider (*Oxyopidae*)

Jumping spider (*Salticidae*)



The eyes of spider differ greatly between families. Spiders who hunt without a web like wolf spiders (*Lycosidae*), lynx spiders *Oxyopidae)* and jumping spiders (*Salticidae*) have a well-developed eyesight. Jumping spiders can see nearly as well as humans. Experiments have shown that they are even capable of seeing colors. Cave spiders, which live in the dark, have no or hardly any eyesight. They depend completely on sound and feeling. The structure of the eye is in basic similar to our eye; behind a single cuticular lens lays a cellular vitreous body and the visual cells.

Together with pigment cell this forms the retina. The spider has two types of eyes; the main eyes and the secondary eyes. The main eyes are always the middle largest ones of the eight eyes the most spiders possess. There are a few families of spiders with six eyes

Tiny eyes of *Araneus diadematus*

Reflecting eyes of *Clubiona stagnatilis* caused by the flashlight

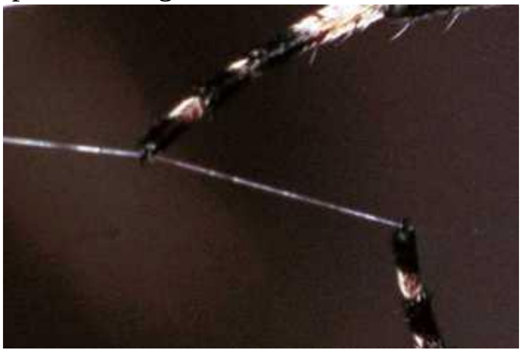
Sometimes the secondary eyes have a light reflecting layer (tapetum). This can be easily observed if one shines with a light in the eyes of a spider during the night.
Our well-known orb weaving spiders, like the *Araneus diadematus*, have very small eyes. They do not depend heavily on their eyesight to catch their prey. They have a good developed feeling mechanism that makes them capable of detecting the movements in her web.
Spiders detect smell with scent sensitive hairs located on their legs. A sense of taste in their mouth is missing. A spider feels her prey with chemo sensitive hairs on her legs and senses if the prey is consumable.

The legs

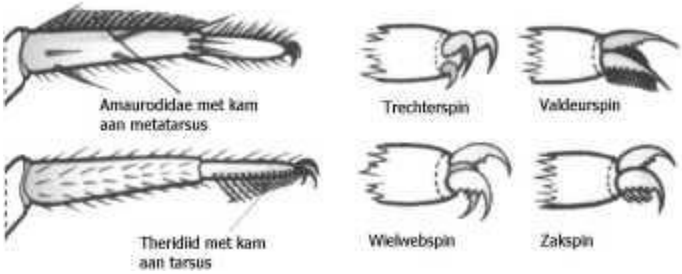
Beside the above-mentioned hairs on the legs, spiders have more features worth studying. The legs consist of seven segments. Beginning from the body these are in the following order and called coxa, trochanter, femur, patella, tibia, metatarsus and tarsus.

Tiny hairs on the tarsi of *Pardosa sp.* [bg]

Who has never found a house spider crawling in the sink incapable of getting out? But jumping spiders are never found in the same sink. There must be a difference in the structure of the legs between families.
For example, there are thousands of fine hairs on the tarsi of the wolf spider. Every hair sticks to the smooth surface of thin water surface (adhesion). This adhesion to water is the secret of walking/climbing over smooth surfaces, which has been shown by experiments. In this experiment a part of the smooth surface was treated with a water-removing chemical. As a result spider fell off the treated area. When the water film was restored the spider was again able to climb the surface.



Claws of the orb web spider *Larinioides sclopetarius*



Legs ends of some spiders

Orb weaving spiders have claws on their tarsi. This is the reason they cannot climb on smooth surfaces but are very capable of hanging on threads. The spider grabs a thread with its middle claw and squeezes the middle claw against serrated bristles, situated opposite the claw. This gives a firm grip. To release the thread the claw is elevated and the bristles push back the thread. The elasticity of the thread also causes it to spring back out of the clasp of the claw. And why does the spider not stick to its own web? The answer is simple; the spider avoids walking on the sticky lines and when it touches a sticky line by accident the contact area is too small to stick permanently.

The movement of the legs of a spider is partly hydraulic, partly by muscles. The spider stretches its legs by raising the blood pressure in the legs. A jumping spider can create a force that makes her capable of jumping 25 times her length. This hydraulic system works excellently and can be seen if we compare the legs of a grasshopper to those of a spider. The grasshopper has two gigantic legs with a lot of muscles packed in it. Looking at the jumping spider one cannot detect these extra muscles.

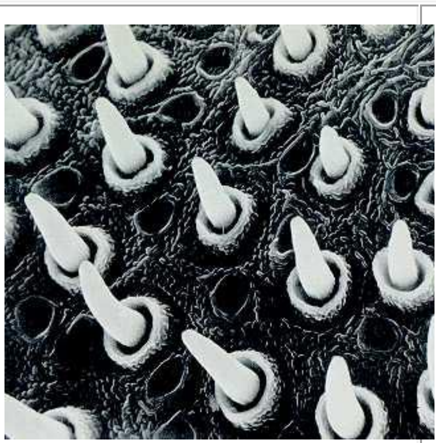
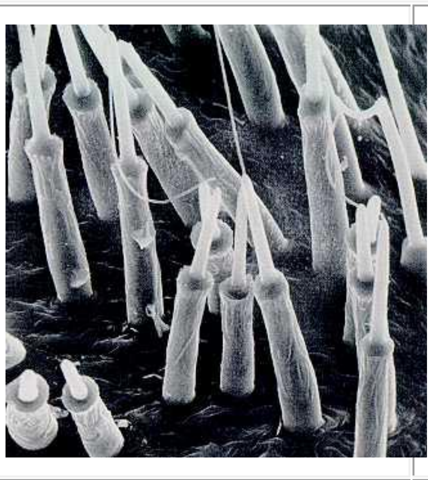

The legs of the jumping spider, *Philaeus chrysops* in comparison with the legs of the grasshopper *Miramella alpina*

Web and silk

There are several glands located at the spider's abdomen, which produce the silken thread. Every gland produces a thread for a special purpose. There are seven different known glands. Each spider possesses only some of these glands and not all seven together.
The glands known as:
Glandula Aggregata produces the sticky material for the threads.
Glandula Ampulleceae major and minor are used for the silk of the walking thread.
Glandula Pyriformes is used for the production of the attaching threads.
Glandula Aciniformes produces threads for the encapsulation of prey.
Glandula Tubiliformes produces thread for cocoons.
Glandula Coronatae is used for the production of the adhesive threads.

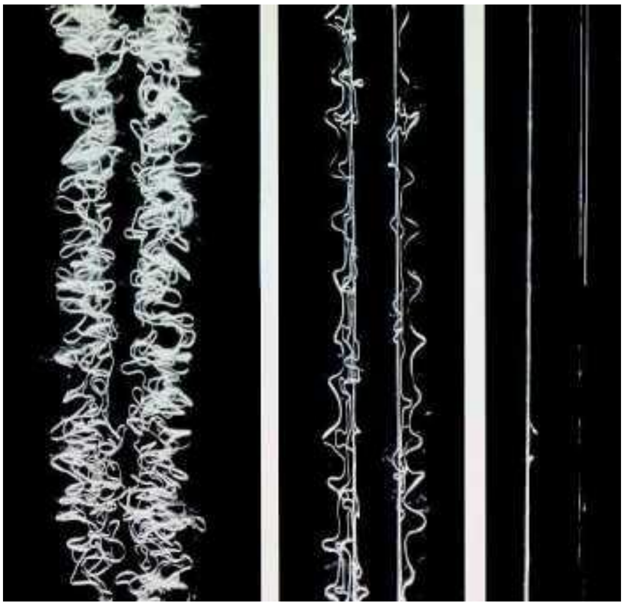
Spinners of *Steatoda grossa*

Normally a spider has three pairs of spinners, but there are spiders with just one pair or as many as four pairs. Every spinner has it own function. There are small tubes in the spinners, which are connected to the glands. The number of tubes varies between 2 and 50.000.

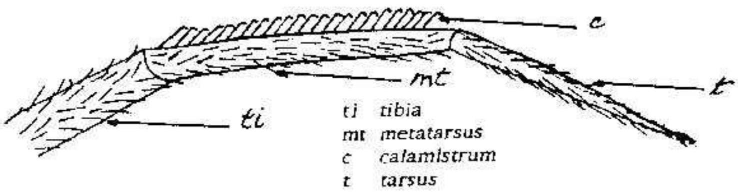
		
Detail of spinners (7)		fibroin

The human eye is capable of detecting objects at a distance of 10 cm with a diameter of 25 µm. The average diameter of a thread in a orb web is around 0.15 µm. The smallest measured thread was only 0.02 µm thick. We are able to see the web only because of the reflection of sunlight on the thread. These thin wires are capable of stopping a bee flying at full speed. This thread is not only strong but also very elastic. These properties make the material very tough.

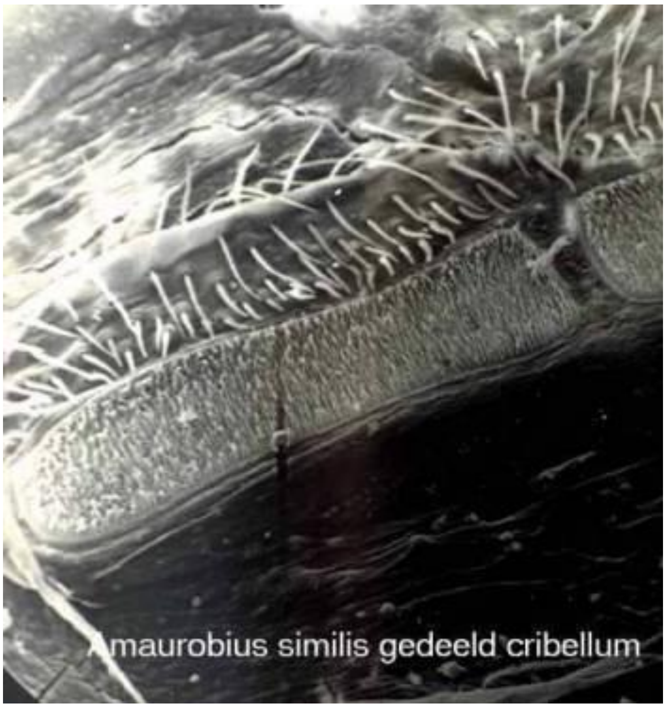
What is the thread made of? It is a protein of a molecular mass of 30.000 Dalton in the gland. Outside the gland it polymerizes to a molecule named fibroin with a molecular mass of around 300.000 Dalton. It is still not clear what activates polymerization process.



Stretching of silk, 1, 5 and 20 times.(7)



Fourth leg of a cribellate spider

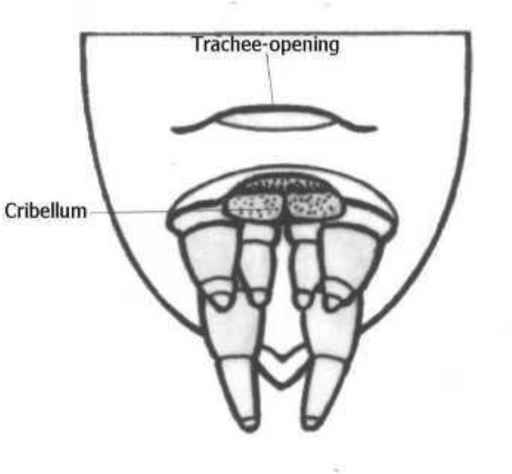


Cribellum of *Aumaurobius similis* (bg)

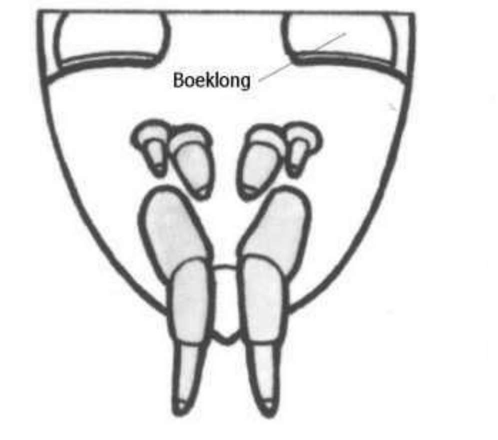
Why does the silk made of protein not decompose by fungi and bacteria like all other proteins? We conserve protein by cooking, salting, drying or adding acid. In spider silk there are three substances that are important for its durability: pyrolidin, potassium hydrogen phosphate and potassium nitrate. Pyrolidins can be found in dyes and plant poisons and are very hygroscopic (binds water). This substance prevents the thread from drying out. Pyrolidin is also found in high concentration in the glue of catching threads. Potassium hydrogen phosphate makes the thread acidic and prevents fungal and bacterial growth. A low pH causes denaturation (become insoluble) of proteins. A phenomenon we can observe in sour milk. Potassium nitrate prevents this and the proteins are salted which prevents bacterial and fungal growth.

The thread of the orb web spider *Araneus diadematus* is very elastic and can be stretched 30 - 40% before it breaks. Steel can be stretched only 8% and nylon around 20%. In the picture one can see the thread of the spider *Stegodyphus sarasinorum* that, because of its weaving technique, can be stretched up to 20 times it original length.

A lot of orb weaving spiders recycle their webs. The weaving of a web takes up a lot of the spider's resources. Since they need to renew their web regularly, they eat the silk to utilize the protein. Only the main thread of the web is left intact. They usually weave a new web each morning, unless there has been little activity and the web can be easily mended. By studying their threads two groups of spiders can be recognized, the Cribellate and the E-cribellate spiders.
Cribellate spiders comb their silk to a woolly structure. To do this they have a comb (calamistrum) on the metatarsus or the tarsus of the fourth legs and an extra silk producing organ (cribellum) just in front of the spinners, which appears as a transparent plate. The comb pulls the silk out of the cribellum and the silk is combed to a woolly structure. The combed silk is made up of thousands small threads enforced by some thicker ones. There is no glue on the threads but the insect gets stuck with the hairs on their body in the silk. The thicker threads in the silk prevent the insect from tearing the silk.



Cribellate spider [13]



E-cribellate spider [13]

Orb web of *Araneus diadematus*

In Madagascar there were some attempts to milk *Nephila's* for the production of silk. A thread was pulled out of the spinner of the spider by hand. If the spiders silk was exhausted, she was put back in the forest and the next spider was milked. The gathered silk had a beautiful golden color. This project was also banned because of many problems.

Applications of spider silk

Spider silk was and is used for several applications. Polynesian fishermen use the thread of the golden orb web weaver *Nephila* as fishing line. In the New-Hebrides spider web was used to make nets for the transportation of arrow points, tobacco and dried poison for the arrow points. Some tribes in New-Guinea used webs as hat to protect their head from the rain.

During World War II the threads of *Araneus diadematus*, *Zilla atrica*, *Argiope aurantia* and other orb weavers were used as hairs in measuring equipment. The Americans used the threads of the black widow (Latrodectus) in their telescopic gun sights.

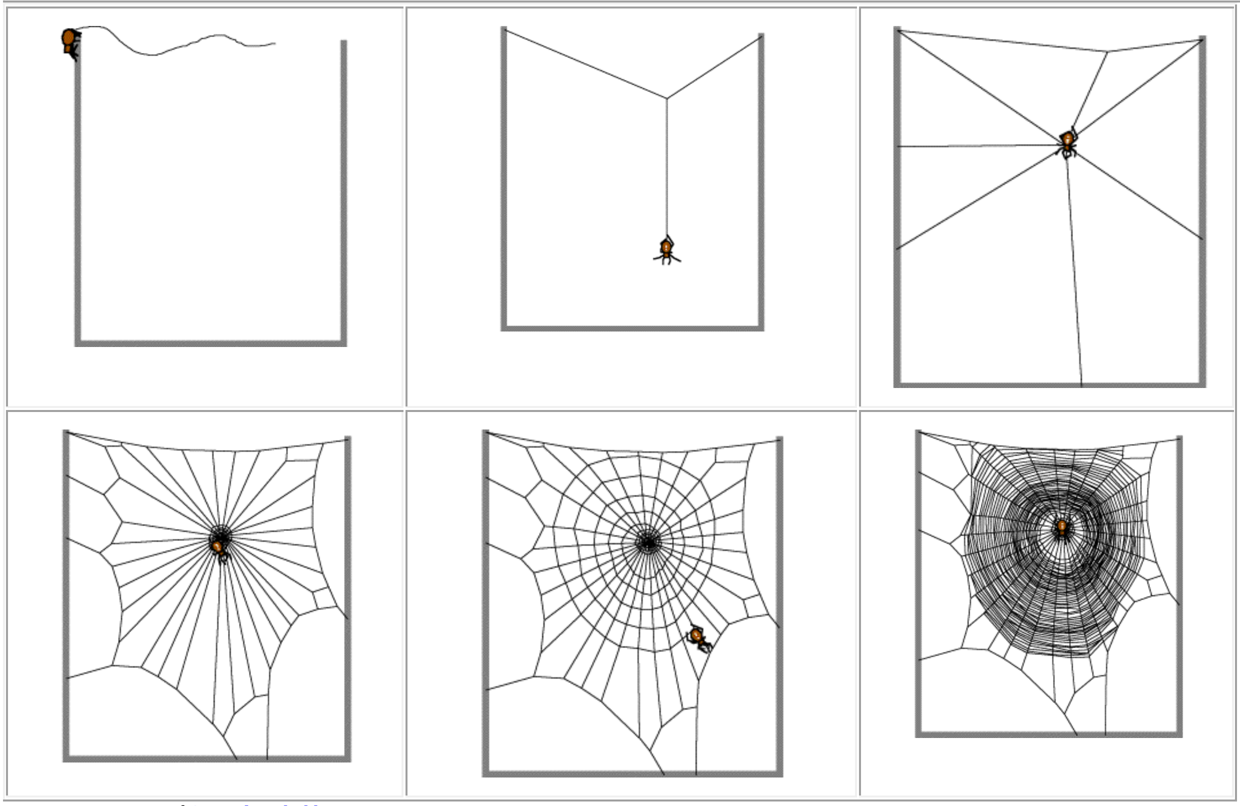
In 1709 a Frenchman, Bon de Saint-Hilaire, demonstrated the possibility of making fabric from silk. Many cocoons were boiled, washed and dried and the thread was collected with fine combs. Some socks and gloves were produced. A study to the economic yield of this method revealed that this would never be profitable. It was calculated that 1.3 million spider cocoons were needed to produce one kilogram of silk.

The web

Three simple forms of web can be recognized. The sheet web, the orb web and the spatial web.
The most well known form is the orb web. How is this web constructed?
The most difficult part is the construction of the first thread. This is a sturdy horizontal thread on which the rest of the web is hanging. How does the spider connect this thread between the two connecting points? She can not fly. Does she connect a thread at one place, walk down with an enrolling thread behind her to the other side where pulls the thread horizontal and connects it?

No, the answer is simpler. She makes use of the wind and some luck.

Orb web of *Araneus diadematus*



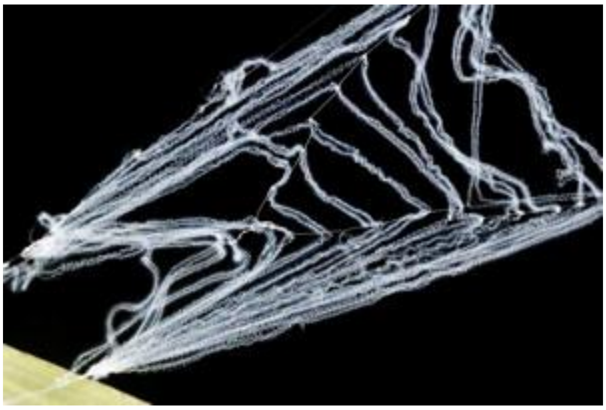
Pictures courtesy of Samuel Zschokke

The wind carries a thin adhesive thread released from her spinners while making the thread longer and longer. If she is lucky the thread sticks to a proper spot. Then she walks carefully over the thread, strengthening it with a second thread. This is repeated until the primary thread is strong enough. After this, she hangs a thread in the form of a Y below the primary thread. These are the first three radial of the web. More radials are constructed taking care that the distance between the radial is small enough to cross. Then non-sticky circular construction spirals are made. The web is completed when the adhesive spiral threads are placed. While the sticky spirals are placed the non-sticky spirals are removed. Not every web is constructed in this way; a lot of variations are possible.

Hiding place in leave and on the right side her orb web of *Singa nitidula.*

The web on the pictures above has an inverted Y that was connected to an electrical wire 10 meters higher. Besides the orb webs other catching web designs are used. A particular one is that of the net-casting spider *Deinopsis*. This spider constructs a web between her forelegs and hangs head down waiting for an insect to pass. The web is thrown over the victim and entangles it. The Bolas spider also has a special catching technique. As the name may suspects she throws the thread with an adhesive bubble at the end to her prey. The prey is decoyed by chemical substances (pheromones).

hiding place of a male and female *Cheiracanthium erraticum*



Web of net-casting spider *Deinopsis*.

Spatial web of the Therriid *Steatoda paykulliana*

Sheet web of the funnel weaver *Agelena canariensis*

Hiding place

Funnel weavers construct horizontal mats and wait in a funnel at the end of the web for an insect to land on the sheet.
The trapdoor spider hides in a tunnel that can be closed with a door. If the prey walks over a signal thread the door is opened and the spider grabs it.
Besides the flat, two-dimensional orb web the *Linyphiidae* and *Theridiidae,* the family to which the black widow belongs, use three-dimensional space webs.

Spatial web of the sheet web spider *Frontinella*.

Lynx spider *Oxyopes quadrifasciatus* with a line line.

Linyphiidae makes a horizontal dense sheet web with a lot of non-adhesive threads above it. If an insect flies against a thread it tumbles onto the mat and is grabbed. The *Theridiidae* construct a messy space web in which the prey gets entangled.

Life line

Spiders like the jumping spider, the lynx spider, the crab spider and many others do not use webs to catch prey. They use their eyes and speed to catch insects. The above mentioned spiders use their silk as a life line. While moving they release a thread that is attached to a secure spot. If they accidently fall down the life line makes it possible to return to their original position.

Cocoons

All spiders use their silk for the construction of a cocoon in which the eggs are laid.
The cocoon protects the eggs from heat, moisture, fungi and mechanical damage.
Some spiders choose to spin a large cocoon and guard the eggs inside this closed silken nest. Most spiders guard their cocoons but others leave the egg cases camouflaged behind.

Crab spider *Ozyptila praticola* with a life line

Typical cocoon of *Ero* (Pirate spider). It looks like it is protected by copper wire.

Robertus lividus making a cocoon for her eggs

Youngster emerging from their cocoon

The tent or dome spider *Cyrtophora exanthematica* in her retreat.

Lampona cylindrata guarding her eggs.

Transport

Spider can also use their silk for transportation. To reach other places spiders can fly by wire, called "**ballooning** ". The spider raises her abdomen and releases a thread in the breeze that grows longer and longer until the upward lift is sufficient and the spider is lifted. They can reach heights of up to 10000 meter and are transported to every spot on the world. They are often one of the first inhabitants of a devastated area like after the eruption of the Krakatoa in August 1883. In May 1884 scientist already reported microscopic spiders spinning their webs.
Gossamer is connected with ballooning and the word comes from "goose summer". It is the moment that millions of spiders are taking off or landing.
Bridging is a kind of ballooning but for shorter distances. Often in the morning when the light is right, one can see thousands of tiny threads between plants. this can be the dragline of a spider that jumped between the plants but when the 'bridge' is wider than 10 cm the spider did not jump but the line was probably from a young or tiny spider that used the silk line to make a bridge between the plants.

Sex and reproduction

Also spider has to reproduce and therefore there are males and female spiders. Males are often smaller and more coloured than the females. Males can be easily recognized by what seems to be the fifth pair of legs. These are the palps with bulbs they use to inject sperm in the genital openings of a female.

Male *Philodromus albidus*, note the palps with bulbs that is typical for male spiders.

Female *Thanatus arenarius*; a female palp has no bulbs

The reproduction organs of a spider are located in front of the spinners. When time comes, the male starts wandering around to look for a female. This is the time when we may come across our house spider. Normally the spider does not like to be seen. But now he has to move and run through our house, searching for a partner and unwittingly panicking the habitants of the house. When he has located the female, he has to take care not to be mistaken for a prey by the female.
With different approaches per species, the male announces to the female that he is interested in mating. Males of some species offer a present, others tinkle with their feet in the web of the female and some perform a dance.

The male of *Xysticus cristatus* offers the female a caught insect. If she accept the offer the male wraps her with a few threads of silk to "tie" her up. This is a ritual act because these threads are too tiny to immobilize her. While the female consumes her present, the male copulates her.

If the signals are right and the female is ready for sex the male is allowed to approach.

Prior to copulation a male fills its bulbs with sperms by weaving a small web. On the web he drops some droplets of sperm from its genitals and sucks the sperm into the bulbs.

The male is ready to insert his palp in the female genitals.

Careful and tender approach

Araniella cucurbitina's making love

Pardosa lugubris with youngsters on her back

After mating, the males of some species must be extremely careful. Sometimes the female tries to kill the male for an easy meal. Often the male escapes. The males of some species do not care anymore to live longer and are eaten without objection. Other species live together happily for a long time after mating. There is a great diversity in sexual behaviour among species.

The males of most species do not live long after mating because their goal has been reached and their purpose fulfilled. Females often live longer than males.

The 'Black widow' spiders (*Latrodectus* species) gained their name because they eat their males after mating. Here the much smaller male happily wanders around the female that is guarding her egg-sacs.

Some females die after the eggs have hatched and some females are even eaten by their offspring. Others may live on for years. Most females guard their eggs and youngsters. Wolf spiders carry their egg-sac at their spinners and carry the young on their backs until their first change of skin.
Orb weavers often guard their egg sac. They can be seen hanging in their wheel-web but after the spiderlings are hatched the female abandon them and/or dies.

Pardosa lugubris with egg-sac attached to her spinners

A*rgiope bruennichi* guarding her egg-sac. (picture Iljitsj van Kessel)

Micrommata virescens guarding her just hatched youngsters

Theriid with youngsters

Araneus diadematus youngsters

Youngsters of *Argiope trifasciata* clustered to a yellow ball

Tetragnatha ZZ282 playing with her children.

Spider enemies

Spiders are soft bodied animals and can be eaten and consequently have many enemies. Nematodes (round worms) and mites are known parasites of spiders. The mites can easily be spotted on the spider as red dots.

Also birds, lizards, geckos, scorpions and centipedes catch spiders from the ground or out of their web.

There are wasps specialized in spider hunting, the spider wasps (Pompilidae), use the captured spider to lay their eggs in. The larvae hatched inside, feed on the paralyzed spider. (Photo Michael Barritt)

(Photo Seth van Ringelenstijn)

There are also flies (Acroceridae) that attack spiders and deposit the black coloured eggs, on vegetation or on the ground. The newly hatched larvae are very mobile; they crawl or even jump on a spider's leg. These larvae penetrate thought the legs the book lungs and consequently kills the spider.
The praying mantis, a great killer, eats any insect or spider it runs into, even another praying mantis that happens to be on its knees.

Wasp with spider.

Mantis, *Mantis religiosa*

The greatest threat to spiders is other spiders. When times are hard and food is scarce, it becomes hard for the spider to overlook it's next of kin.
A familiar spider in our house is the daddy-longleg, *Pholcus phalangioides*. She is a great spider killer. In the springtime, she is one of the last living spiders in our house. Every other insect or spider is consumed by her during the winter. In the end when famine strikes, they even kill each other.

Daddy-longleg, *Pholcus phalangioides* with *Tegenaria* as prey

Also in the family *Mimetidae* and *Ero* are specialized spider killers. *Ero* attacks a spider by biting it in one of its legs. Then it retreats and waits at a safe distance until the bitten spider is paralyzed in a few seconds. Then it returns to suck it empty.

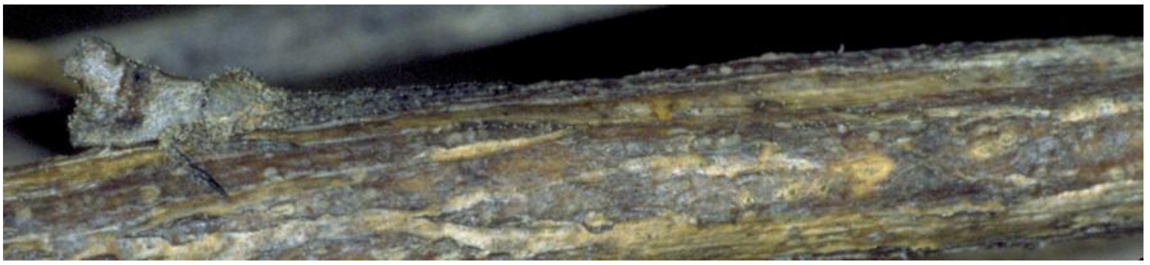
We humans, have a bad habit of disturbing the natural world for our own selfish ends. In doing so we destroy many habitats in which the spiders live. Insecticides in agricultural activities wipe out the whole populations of insects and spiders. Many species of spiders are currently on a Red list and are in danger of becoming extinct. Tarantulas from South-America have become rare because many of them are caught and sold as pet animal. In many counties the law forbids killing, catching and selling of endangered species.

Tegenaria atrica with *Pholcus phalangioides* as prey

Spider with mites

How to avoid enemies?

Spiders have developed several tactics to avoid becoming a prey themselves.
The most used tactic is to avoid being seen and this works very good because nobody realises that in an average meadow in Britain gives habitat to 130 spiders per square meter.



Camouflage your selves, like the above *tmarus piger* spider above, is a good tactic.

Colour yourself in the same colour as you surrounding is very effective.

Digging a hole in de ground or hiding in a crevice has the advantage you will stay dry.

Live in a hole and wait until somebody stumbles over the treads is an ideal combination of hiding and hunting.

Playing stupid and colour yourself extravagantly is only wise if your are a fast spider with excellent eyesight and, like this *Saitis volans,* have little flaps in your hind legs to glide away

Phryganoporus nigrinus hiding in soft silk under dirt

Hiding in a leave like this leaf-curling spider *Phonognatha_graeffei*
Photo Jurgen Otto

and if you are hiding with your wife in a beatifull nest you are sent out to investigate the disturbance. *Larinioides cornutus*

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Acknowledgements

All pictures are made by the author except the when noted with a name or with (number). These numbers refer to the literature above. Pictures noted with (bg) are electron microscope pictures donated by Bryan Goethals.

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