Spider Digestion & Food Storage

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Myths and misconceptions abound when it comes to how spiders ingest, digest, and store food. What many tarantula keepers see when they feed their charges often leads to misleading conclusions. For example, if a keeper feeds a large grasshopper to a tarantula, then returns the next day to find nothing apparent remaining, it's natural to assume the spider ate the entire animal, exoskeleton and all. In fact, spiders are liquid feeders. If no solid remains are found, it simply means that they are hidden somewhere in the cage.

In order for food particles to get past the extensive filter system of the spider's mouth, they have to be quite small. Only particles less than 1 μm (one micrometer) get past. That's one thousandth (10^{-3}) of a millimeter, or one millionth (10^{-6}) of a meter.

Feeding Behavior

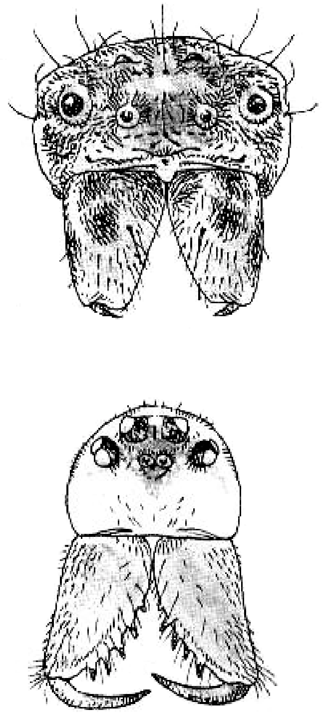
Spiders are split into two major feeding groups based on the method they use for prey manipulation. The feeding method of any particular species is based, perhaps erroneously, on the presence or absence of cheliceral teeth. Cheliceral teeth are sharp, hardened points in a line on the chelicerae above the fangs. The fangs fold in on top of the teeth, facilitating a firm, crushing grip on the prey.

In most, but not all spider species having cheliceral teeth (including tarantulas), the prey is ripped to pieces and manipulated into an unrecognizable ball, or bolus.

In spiders with no cheliceral teeth, although also included are certain species with cheliceral teeth, the body of the prey is perforated in one or more areas by the fangs. The prey is not torn apart, and if an exoskeleton is present, it looks much like it did in life after feeding is over.

Traditionally, arachnologists have used the presence of cheliceral teeth as the indicator of what method a spider species will use when feeding on prey, yet accept that some with cheliceral teeth are exceptions.

Cheliceral teeth may be a good indicator of feeding methods, or they may not. Many cobweb weavers (Theridiidae) have few or no cheliceral teeth, such as the largest members of the family, the widow spiders (*Latrodectus*). Even without cheliceral teeth, widow spiders are capable of tearing the prey to pieces, but they don't. I suggest some other adaptation, such as a more powerful sucking stomach, or specialized mouthparts, may be of equal value in explaining why some species tear the prey apart and others do not. This hypothesis needs scientific evaluation, but so does the cheliceral teeth hypothesis.



Above: A crab spider (Thomisidae), note hair instead of cheliceral teeth; Below: A sheetweb weaver (Linyphiidae) with strong cheliceral teeth.

Venom

All spiders, except the hackled orbweavers (Uloboridae) and certain species of the primitive segmented trapdoor spiders (Liphistiidae), have venom. It seems logical to many that spider venom should contain not only toxins to incapacitate the prey but, conveniently, also all the digestive enzymes needed to break down the tissues. This is not the case. The venom of many spiders studied does contain a connective tissue enzyme, which does make sense, since loosening the connected organs seems like a valuable adaptation. However, spider venom has none of the required enzymes needed to break down proteins, carbohydrates, fatty acids or other materials. Spider venom plays an insignificant role in digestion.

Digestive Enzymes

Digestion in insects has been fairly thoroughly investigated. Oddly enough, many insects feeding on plant fluids digest much of their food externally. Many of these insects with piercing-sucking mouthparts (a beak, as in a female mosquito, except for plant fluids and not blood) inject an enzyme that breaks down plant pectins, aiding in beak penetration. They also inject an enzyme to break down carbohydrates. Although insects like aphids that feed on the phloem fluids (plant food vessels) don't have protein enzymes (they don't need them because the phloem fluid contains free amino acids, or protein pieces already broken down) other plant feeders do have protein and fat enzymes to help digest the food outside of the body.

Most insects digest their food internally. The foregut is largely used as a food storage organ, but enzymes secreted in the midgut can regurgitate forward, letting some digestion take place in the foregut. In grasshoppers, mass regurgitation results in the bulk of the food digestion to occur in the foregut.

In most insects, the foregut is lined with cuticle that prevents the movement of most or all substances between the foregut and the body cavity (coelom, usually called hemocoel = open blood cavity in arthropods).

Nearly all the digestion action in insects takes place in the midgut. Enzymes are secreted in anterior regions of the midgut and the broken down products of digestion are absorbed into the body cavity largely in the midgut, and in a blind sac-like structure called the caeca. The caeca (singular caecum) are important in insects, but were adapted by spiders into incredibly useful and efficient organs.

Absorption also occurs to a lesser extent in the insect hindgut, which also functions in water and salt balance.

Absorption in the spider gut pretty much follows the insect design, but spiders must break down the food into what is essentially liquid before it can get past the mouth and into the foregut. This is a very useful adaptation. Many plant-eating insects with chewing mouthparts ingest a lot of material they can't use. Lignin, cellulose, and other plant materials can't be digested by many plant eaters and must be eliminated in the feces. Insect predators with chewing mouthparts masticate their prey, and in doing so, take in a lot of exoskeleton material they cannot digest, forcing them to process and eliminate unusable portions.

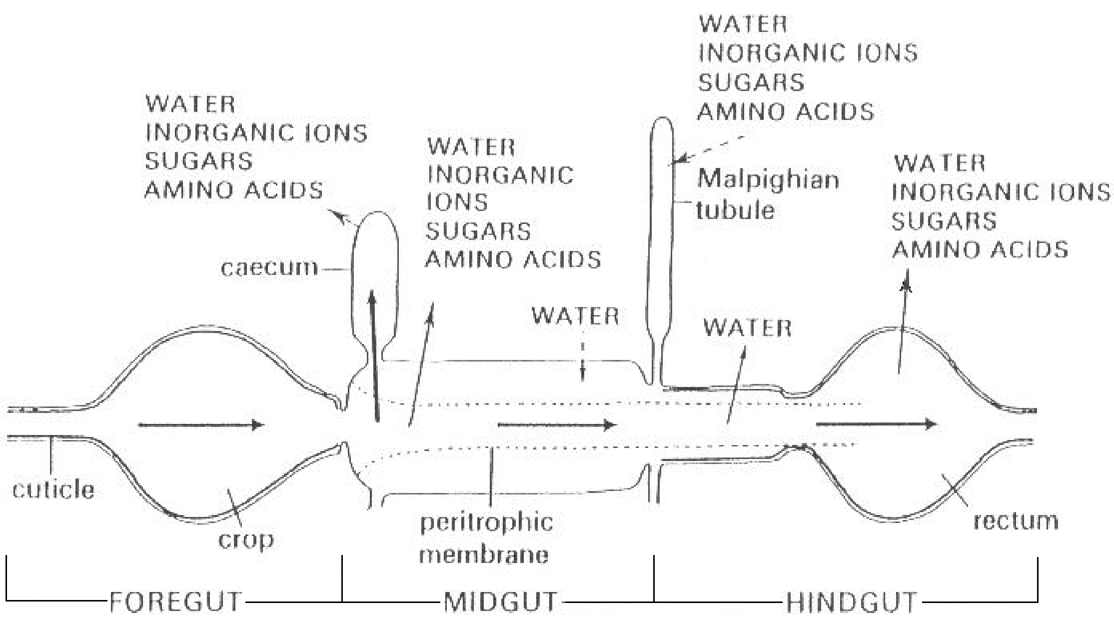
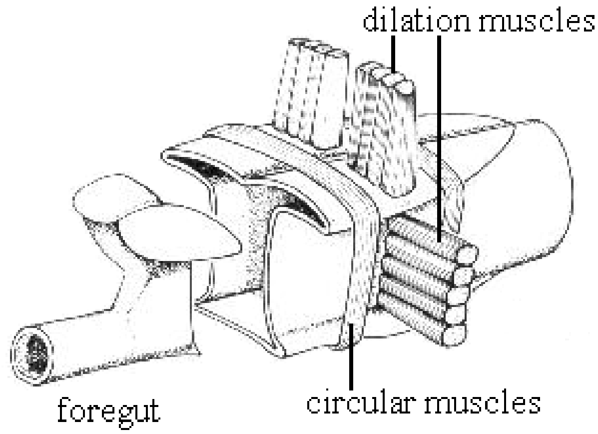


Diagram of a generalized insect gut.



The spider sucking stomach.

Spiders avoid this energy expensive process by making sure potential waste products don't get ingested initially, leaving everything they do take in as more or less a concentrated energy drink.

We know that spiders regurgitate all required enzymes from the mouth and onto the prey (in those that tear up the prey) or into the prey (for the rest). With tarantulas and others that shred the prey, these enzymes are poured onto the prey bolus, then "licked" back into the foregut.

The widow spiders and many crab spiders force enzymes into the hole they made in the prey, then suck it back into the mouth. They repeat this action who knows how many times before completing the meal.

Exactly where the digestive enzymes are produced that are regurgitated on the spider's prey can be somewhat of a mystery to many reading about it. Most writers simply say enzymes are exuded from the intestinal tract and leave it at that. Others point to glands located in the maxillae and rostrum of the mouthparts, but stop short of claiming the fluids exuded do any more than soften food material. If anyone has more evidence on the rostrum and maxillary glands, I'd appreciate the citations. Barring that, the following is the most likely scenario.

A type of cell called secretory cells are found in the midgut and midgut caeca. Digestive enzymes are secreted from these cells and apparently make their way through the sucking stomach, past the foregut, and onto the prey. A back and forth repetition of enzymes flowing forward, then digested food and enzymes flowing back into the spider continues until the spider is satiated or "decides" the prey item is used up.

The initial filtering of inappropriately large particles is done by a plentiful amount of hair surrounding the mouth. Further filtering is completed by the palate plate located in the pharynx. The palate plate is composed of platelets arranged like roofing shingles in this flattened region. The larger particles are removed by the platelets. Later, an intestinal discharge of fluid cleans them off the platelets and to the outside regions of the mouth, where the spider removes them with its pedipalps.

Sucking Stomach

Two more structures involving ingestion and storage found in spiders deserve mention here, the first being the sucking stomach. The foregut begins (or ends) just in front of the sucking stomach, while the midgut begins just behind it. Dilation muscles are attached dorsally and laterally onto the sucking stomach. A series of muscles circling the sucking stomach and serve like rubber bands contracting to shrink the size of the stomach. Dilator muscles contract to expand the stomach’s volume. When acting in coordinated unison, the structure becomes an efficient pump, capable of handling a relatively high volume of liquid in a short period of time.

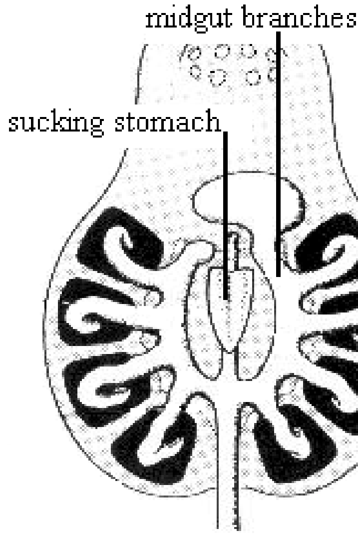
Midgut Caeca

The caeca in some insects are simple organs, not highly developed or capable of storing a great deal of food. In other insects, it can be a massive organ system, accumulating a lot of food material.

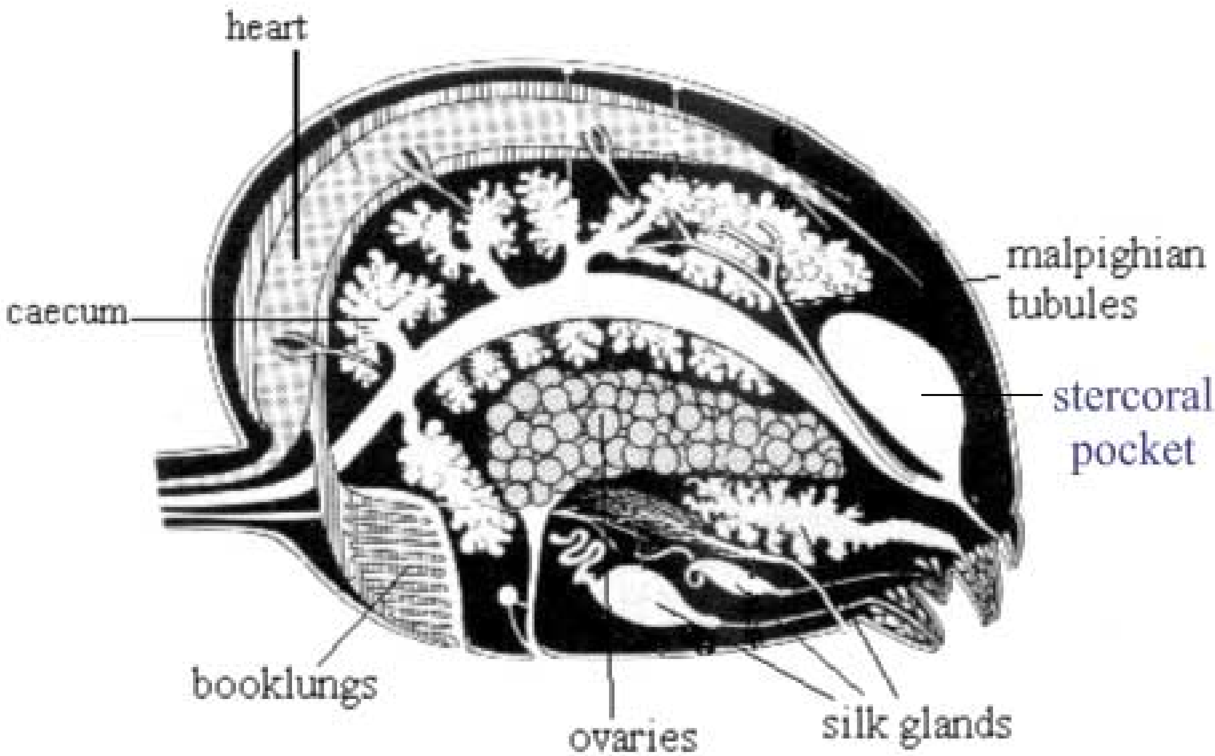
In most spiders, the caeca are well developed and invasive. In the cephalothorax, the caeca often branch down into the coxa of the legs, sometimes even extending between the eyes of certain jumping spiders. The caeca can proliferate to greater degrees, surrounding other organ systems like the ovaries and silk glands, supplying them with needed nutrients. In well fed spiders, the bulk of the abdomen or even the bulk of the spider itself consists of caecal fluids. This is the main reason many spider species can go for long periods of time without food.

In most spider species, the abdomen is capable of expanding or shrinking because the abdominal cuticle contains only pliable endocuticle, not the hardened exocuticle typical of the cephalothorax. Most of us have seen how a tarantula’s abdomen can balloon or shrink depending upon how much the spider is eating. With most other arthropods, at least as adults, the abdomen contains exocuticle and is not potentially able to shrink or expand. If they stumble on a windfall of food, they can’t take advantage of it as spiders can.

The methods spiders use for digestion and food storage is one of the major structural components making spiders so different from all the other arthropods.



Spider cephalothorax. Note caeca branches extending into the legs and toward the head.



Spider abdomen. Note the extensive branching of the caeca.