

Respiration In Spiders

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Respiration, loosely the gaseous exchange of O₂ and CO₂ in spiders, is often misunderstood, even by arachnologists. Many arachnologists, including myself, came up through various entomology departments. Consequently, arthropod physiology courses concentrated on insects. The most significant difference in respiratory systems between insects and spiders is that almost all insects don't require their blood, or hemolymph, in order to respire, while spiders do.

Insect Respiration

The exchange of O₂ and CO₂ in insects is accomplished by an often complex system of air tubes, made up of trachea and the smaller tracheoles. The air tubes suffuse through the body in close contact with insect tissues. Hemolymph components are not needed to assist in gaseous exchange between the tissues and the air tubes. This point is driven home when you consider what happens with some insects, such as certain grasshopper species. When on the move, the blood is apparently being circulated around the body sufficiently, because the heart stops beating. The swishing around of the blood caused by movement is enough for the hemolymph to fulfill its function, which is largely distribution of nutrients, water, and the movement of wastes to the malpighian tubules for removal (roughly the insect equivalent of kidneys). The heart begins beating again when the insect stops moving.

This is not the case with spiders, but it seems logical to most exposed to insect physiology that they should be the same way, at least with those spiders having trachea.

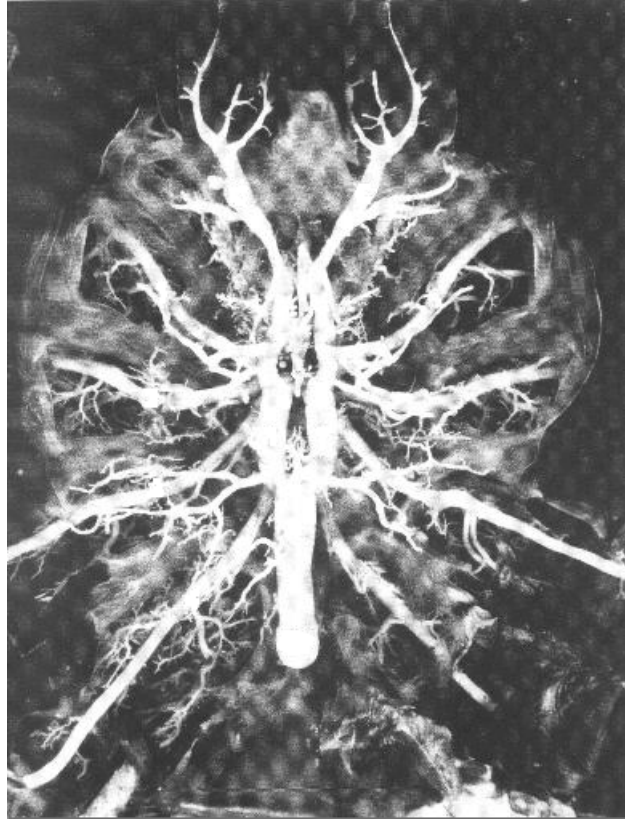
Spider Respiratory Systems

There are at least five different respiratory systems in spiders, depending on taxonomic group and whom you're talking to.

- 1) A single pair of booklungs, as with the cellar or daddylongleg spiders, Pholcidae.
- 2) Two pair of booklungs, suborder Mesothelae, and all or most of infraorder Mygalomorphae (including tarantulas).
- 3) A pair of booklungs and a pair of tubular trachea, as in the orbweavers and wolf spiders, and probably most species of spiders.
- 4) A pair of tubular trachea and a pair of sieve trachea (or two pair of tubular trachea if you're one of those who doesn't believe the difference between tubular and sieve trachea is enough to distinguish them from each other), as in the small spider family, Caponiidae.
- 5) One pair of sieve trachea only (or tubular trachea to some), as in the small spider family Symphytognathidae.

Spider Blood

Oxygen and carbon dioxide are carried in the spider hemolymph by the respiratory pigment protein, hemocyanin. Although similar to the iron-carrying hemoglobin of vertebrates, hemocyanin contains two copper atoms; this is what makes spider blood a faint blue in color. Hemocyanin is not as efficient as hemoglobin at binding gases, but it does the job for spiders.



As this illustration of a spider cephalothorax shows, the complex system of arteries going to the legs and head region can almost be considered a closed system. After Foelix, 1996.

Spider Trachea

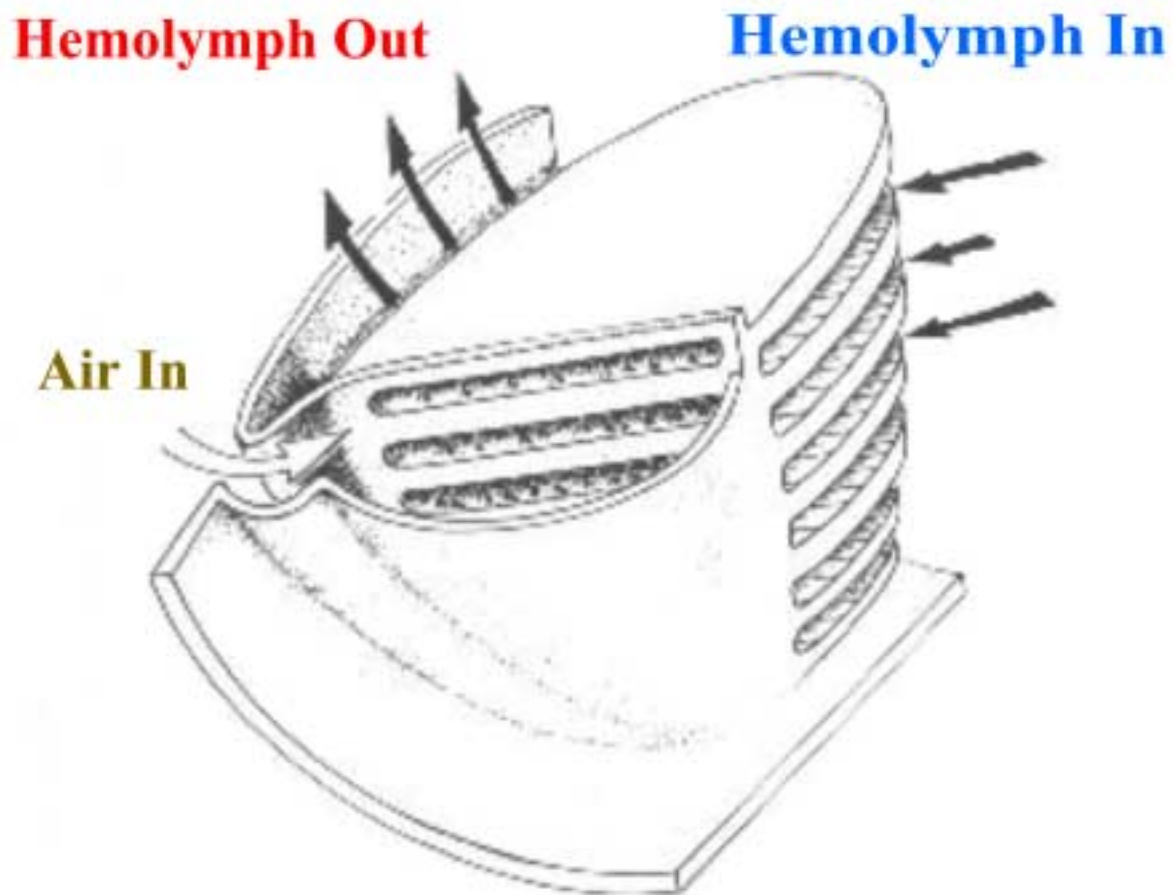
The tracheal air tubes permeate throughout the body (or parts of it, depending on species) and open near the tissues, although not in close enough contact to deliver O_2 and remove CO_2 by themselves as they do in insects. Instead, hemocyanin pigments need to pick up O_2 from the air tube ends and deliver it, also passing the CO_2 back to the air tube endings. Tubular trachea have a single (rarely two) openings (called a spiracle, or stigma), most often found on ventral side of the abdomen, near the spinnerets.

Booklungs

Lung or booklung slits (in some species, lung slits come equipped with variable openings that can widen or decrease in size with O_2 requirements) open at the anterior portion of the ventral abdomen. A chamber (the atrium) at the opening expands internally leading to the many leaf-like air pockets of the booklung. The booklung is little more than stacked air pockets with an extremely thin cuticle that allows gas exchange by simple diffusion to take place as blood is directed through it. Peg-like structures cover much of the surface of the booklungs on the hemolymph side to prevent collapse.

Tarantula Respiration

Since tarantulas are large and much easier to study, many physiologists interested in spider respiration end up using them. The geographic location of the specimens they use are rarely mentioned, except most are probably from the US. Almost routinely, these physiologists are unconcerned with tarantula taxonomy. Only rarely do they attempt to find a competent spider taxonomist. More often, they trust anyone who tells them they can identify the species they are working with. This disregard for taxonomy is practiced by even the most famous of the physiologists, including R. F. Foelix, the author of the only current but at best semi-complete spider biology book.



A booklung showing the leaf-like alternating air pockets with venous hemolymph flowing in one direction between the pockets. The cellular layer separating the air pockets from the hemolymph is so thin, gas exchange by simple diffusion is possible. After Foelix, 1996.

A few popular scientific names, by turns comical and sad to those with a little knowledge about the subject, most often appear in these papers. The first is *Dugesiella*, most often seen as *Dugesiella hentzi*. Genus *Dugesiella* disappeared into the *Aphonopelma* long ago, and even if they were referring to *Aphonopelma hentzi* (Girard), it can't be taken as a reliable identification. When a physiologist refers to *D. hentzi*, or *A. hentzi*, this only means that somebody got an *Aphonopelma* species that someone else thought probably came from Texas.

A bad, but still used by physiologists name is *Eurypelma californicum*. The *Eurypelma* dissolved into other genera quite some time ago, and *Aphonopelma californicum* is a bad species. They may have been referring to *Aphonopelma eutylenum*, but not necessarily. When you hear any of these names, all it means is that someone thought the specimens may have come from California.

Some "scientific" names are really embarrassing. In the 1970s, some did research on what they called *Eurypelma helluo*. They perhaps mistook the specimen (or correctly identified it?) as the wolf spider, *Lycosa helluo* Walckenaer (now *Hogna helluo* (Walckenaer)) and changed the genus name to make it more tarantula-like. God only knows what those people were studying.

With any kind of luck, the physiologists were at least studying spiders, possibly even tarantulas, and they came up with some interesting discoveries.

In tarantulas tested, they found that the 1st pair (anterior) of booklungs handled the blood coming from the prosoma (cephalothorax), while the 2nd pair of booklungs serviced the blood from the abdomen before returning it to the heart.

In insects, the heart most often is a simple tube that sucks blood up from the abdomen, shunts it through the aorta, and dumps it roughly in the vicinity of the head region in the insect's body.

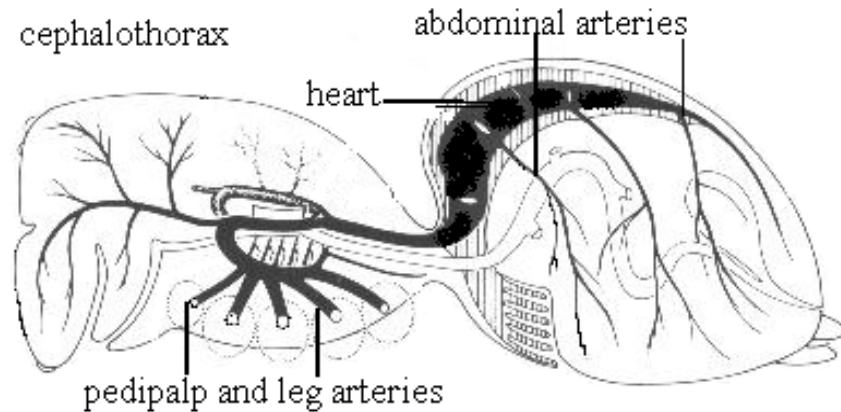
With spiders, the arrangement is different. After the blood passes into the aorta then through the pedicel and into the cephalothorax region, the fluid is divided into what can almost be considered a closed arterial system. It branches and is directed to specific regions of the head and legs. The blood returns to the booklungs and then the heart via an open blood bath, venous system. Other arteries called the lateral abdominal arteries stem from the heart on either side and branch down and through the abdomen. On the posterior end of the heart, an abdominal artery extends down toward the spinnerets.

When the spider heart contracts (systole), blood is pushed not just forward through the aorta and into the cephalothorax, but sideways through the lateral arteries, and backward, through and down the abdominal artery. This system makes it possible for a different blood pressure to occur in the cephalothorax and the abdomen. Under conditions of excessive activity, the blood pressure in the cephalothorax becomes much higher than in the abdomen. A point is quickly reached where the hemolymph pressure is so high in the cephalothorax, that blood can't be pushed from the abdomen through the aorta and into the cephalothorax. When this happens for a sufficient amount of time, the spider suddenly stops.

Many of us have seen this behavior in our tarantulas. When tarantulas are given a chance to escape, some rocket off with great speed away from their captors. If the tarantula doesn't reach a place it "feels" is safe fast enough, it may run out of time and suddenly freeze, allowing the keeper to catch and scoop up the naughty escapee. Most likely, it stops because the blood has ceased moving into the cephalothorax.

Physiologically, there are potentially two major reasons for the "tarantula freeze." The muscles being frantically used in the escape attempt are housed in the cephalothorax, causing many to believe the muscles simply ran out of O₂ and quit. Maybe, but wouldn't there be some stumbling, cramping, or some other sign of weakening muscles? This doesn't appear to happen.

A major oxygen requiring organ in the tarantula cephalothorax is the spider's huge brain. Could it be that the muscles might be able to go a bit farther, but the spider's brain was deprived of O₂ for just a tad too long? The simple explanation may be that these manic, careening potential escapees just plain pass out.



A generalized spider circulatory system. When the heart contracts, blood moves not only forward into the aorta and through the pedicel into the cephalothorax, but sideways, through the abdominal arteries then down, and backwards through a rear artery on the posterior of the heart, toward the spinnerets. After Foelix, 1996.

References

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