PECKHAMIA 19.1, 30 August 2008 ISSN 1944-8120

This is a PDF version of PECKHAMIA 1(3): 41-44, September 1977. Pagination of the original document has been retained. Author's notes (19.1): The original Fig. 2 has been replaced with a color photograph of the same spider, taken at the same time in 1977. A line drawing of *Lyssomanes viridis* from page 51 of PECKHAMIA 1(3), by D. E. Hill, has also been included here.

SOME OBSERVATIONS ON THE PHYSIOLOGY OF LIVING *LYSSOMANES VIRIDIS* WHICH SHOULD APPLY TO THE ARANEAE IN GENERAL. D. E. Hill

Recently I examined the structure of the cryofractured book lung of *Phidippus audax* with a scanning electron microscope. Each book lung is essentially a stack of flattened air-sacs, or *lamellae*, which project anteriorly into the lateral hemolymph space of the anterior opisthosoma. Each lamella is roughly triangular in shape. Hemolymph flows across each lamella from the medial to the lateral side (Fig. 1). Air enters the lamellae from the third, posterior side, after passing through a network of irregular cuticular struts (air filter) which lines the atrium of the book lung. The thin walls of each lamella are joined by rigid struts near the medial side, and the intra-lamellar air space cannot be expanded or compressed in this region. Toward the posterior and lateral sides, however, the two walls of each lamella are not joined. Here the inner surface of the ventral (or ventro-lateral) wall is covered with buttressed studs, while the opposing dorsal (dorso-medial) wall is completely smooth. Thus a large portion of each lamella is capable of considerable expansion, and the residual (minimal) air volume is dictated by the height of these studs (about 3 μm). S. J. Moore (1976) describes a similar structure for some other

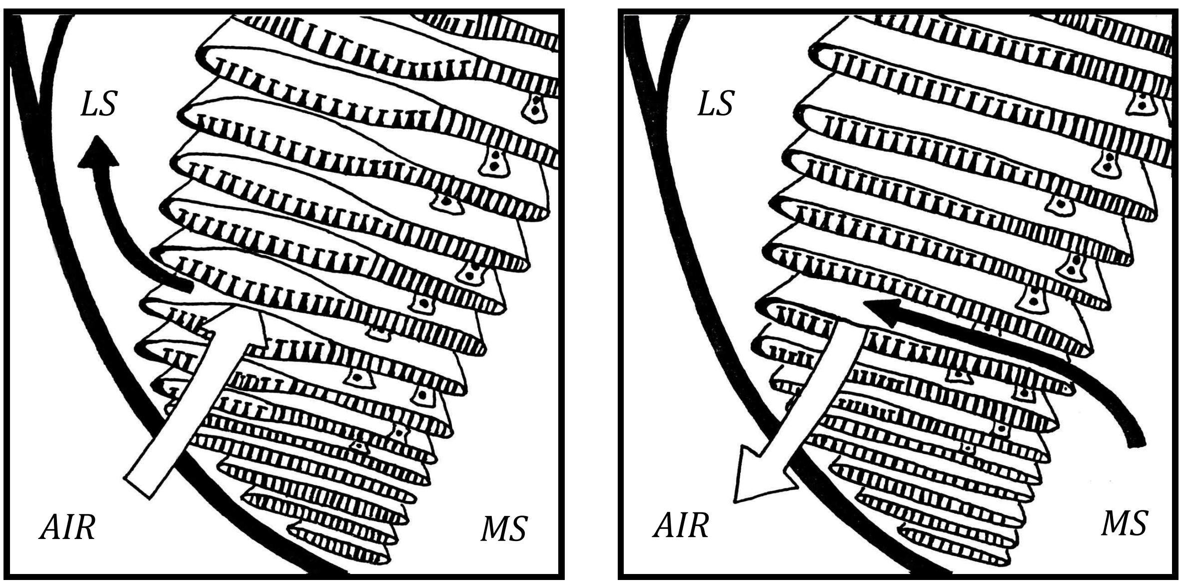

Fig. 1. The hemolymph bellows hypothesis for book lung ventilation: Schematic transverse sections of the left book lung, as seen from the rear. Hemolymph of the medial sinus (MS) flows between the lamellae (flattened air-sacs) of the book lung to the lateral sinus (LS), then ascends dorso-medially to the heart via the pulmonary vein. Left: The lamellae are inflated with air as hemolymph is pulled out of the inter-lamellar spaces by the contracting heart. Right: With relaxation of the heart, hemolymph enters the book lung from the medial sinus to compress the lamellae.

spiders (*Araneus*, *Argiope*, *Argyroneta* and *Tegenaria*). This distinctive structure demands a functional explanation.

In this regard, I have been able to observe regular movement of the book lung lamellae directly, through the transparent lateral wall of the opisthosoma of *Lyssomanes viridis* (Fig. 2). An unrestrained adult female, resting on a near-vertical surface after feeding, was observed under a binocular microscope at a magnification of 144 X. The spider was carefully tilted until I was able to look directly across the surface of the lamellae (This near-lateral view is about 15 degrees above the lateral view, and both lighting and the fortuitous placement of leg IV by the spider are critical). In this position, the rapid movement, up and down, of the series of lamellae in unison is evident. Each upward movement of the lamellae coincides with the pulsatile flow of hemolymph through the readily visible pulmonary vein, as the heart contracts at a rate varying from 150 to 210 cycles/minute. After completing this observation, I discovered that V. Willem (1918) had observed the same synchrony of heartbeat and lamellar movement in *Pholcus phalangioides*. I have subsequently repeated this observation with a local pholcid. In *Lyssomanes*, the visible movement is greatest for the dorsal lamellae, nearest to the pulmonary vein. The ability of the heart to move the lamellae in this manner suggests that the suction force applied to the thin lamellar walls with each heart beat should be able to lift these walls apart, much as one would inflate a bellows, thereby inflating the lamellae. Stewart and Martin (1974) recorded the requisite decline of pressure in the pulmonary vein of a spider with each contraction of the heart. At this size scale the

Fig. 2. Adult female *Lyssomanes viridis* (Walckenaer 1837) collected by D. B. Richman in April of this year in magnolia, Martin County, Florida. These spiders typically lurk in rudimentary retreats on the underside of magnolia leaves. The actual length of this livid green spider is 7 mm. The scales of the optic quadrangle are bright red and white. The narrow front of the prosoma (corresponding to the extreme posterior position of the ALE), the relatively long legs, and the extreme flexibility of the tarso-metatarsal joint are all unusual for a salticid.

pull of the contracting heart appears to be conveyed as an impulse through the viscous hemolymph. Fluid pressure within the medial sinus (Fig. 1) should immediately force a distention of the inter-lamellar spaces, and a deflation of the lamellae, prior to the next contraction of the heart. A less regular movement of the lamellae was also observed in 15 day embryos of *L. viridis*.

This characterization of the book lung as a passive *hemolymph bellows*, driven indirectly by the heart beat, may be generally applicable to the Araneae, if not the Arachnida. The book lung, rather than merely representing a curiously primitive and inefficient way of increasing the surface area available for gaseous diffusion (which it does), is, in my opinion, a very successful device for utilizing the flow of hemolymph to power ventilation of the respiratory surface. This use of hydraulics to achieve physical movement is a general feature of the Arachnida.

Several other observations of interest are also possible with *Lyssomanes*. Occasionally one can observe the opening and closing of the spiracle, as well as a certain amount of movement of the posterior wall of the vestibule or atrium of the book lung. This may be associated with an irregular rhythm of tidal flushing of the book lung. The heartbeat is readily observed, although the rapid movement of hemolymph through the appendages is more difficult to see and requires the combination of concentrated effort with appropriate trans-illumination. Movement of the pigmented eye tubes of the AME is easily observed from above, as well as directly through the lenses.

With an individual that has fed recently, one can observe peristaltic waves of the midgut where it passes through the pedicel, between the book lungs. The constant churning of fluid, particles, and droplets within the extensive midgut diverticula of the opisthosoma is also readily observed, definitely indicating the presence of contractile elements in these structures. While the spider is feeding, almost-violent pulsations of diverticula in the space lateral to the AME may be synchronized with movements of the sucking stomach. The dynamic qualities of digestion are apparent.

Perhaps one of the most impressive observations which one can draw from looking at transparent spiders, including *Lyssomanes*, is the extreme translucidity of internal structures. This includes both nerves and muscle, as well as the individual cells of the digestive diverticula containing darker droplets. One is greatly impressed by the important distinction between the fixed artifacts of a histological preparation and the dynamics of a living, fluid structure.

REFERENCES:

MOORE, S. J. 1976. Some spider organs as seen by the scanning electron microscope, with special reference to the book lung. Bull. Br. Arachnol. Soc. 3: 177-187.

STEWART, D. M. & A. W. MARTIN. 1974. Blood pressure in the tarantula, *Dugesiella hentzi*. J. comp. Physiol. 88: 141-172.

WILLEM, V. 1918. Observations sur la circulation sanguine et la respiration pulmonaire chez les Araignees. Arch. neerl. Physiol. 1: 226-256.