Antistea elegans (Blackwall, 1841) (Araneida, Agelenidae). *Ent.Ber.,Amst.* **23**: 143-145.
LEGENDRE, R. 1963: L'audition et l'émission de sons chez les aranéides. *Ann.Biol.* **2**: 371-390.
LEHTINEN, P. T. 1967: Classification of the cribellate spiders and some allied families, with notes on the evolution of the suborder Araneomorpha. *Ann.Zool. Fenn.* **4**: 199-468.
LOCKET, G. H. & MILLIDGE, A. F. 1951: *British Spiders* **1**: 1-310. Ray Society, London.
SIMON, E. 1893: *Histoire naturelle des araignées* **1**(2): 257-488. Paris.
SIMON, E. 1898: *Histoire naturelle des araignées* **2**(2): 193-380. Paris.

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Lungbook microstructure in *Tegenaria* sp.

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Summary

The lungbooks of spiders of the genus *Tegenaria* Latreille were examined with particular reference to anatomical methods for the maintenance of shape and respiratory function. Light and scanning electron microscopy were used to examine the lungbooks. Pillar cells were found in the blood spaces and three types of chitinous "hairs" were found and described. Short simple "interlamellar hairs" were found on the upward facing sides of the lamellae keeping the air space open; more complex hairs form looping networks at the free ends of the lamellae ("terminal lamellar hairs"); larger complex hairs arise from the atrial wall ("atrial hairs"). The complex looping hairs may function as mechanical buffers as well as in keeping the air spaces open.

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Introduction

The respiratory apparatus of arachnids consists of lungbooks and/or tracheae. *Tegenaria,* the spider genus used in this study, has two pairs of tracheal trunks and one pair of lungbooks. Each lungbook consists of ectodermal invaginations forming leaf-like lamellae, hence the term "lungbook". Air circulates between the lamellae and blood circulates inside them. Obviously for maximal gaseous exchange the air and blood spaces must be kept open by some means. This was therefore investigated.

Materials and Methods

Immature specimens were used and so not identified beyond the generic level. For examination under the light microscope, the opisthosoma was fixed for five hours in Carnoy fixative after the specimen had been anaesthetised with carbon dioxide and the dorsal cuticle removed under a physiological saline (Rathmeyer, 1965) to improve reagent penetration. The material was double-embedded in ester wax and agar (Wigglesworth, 1959) to minimise the problems of sectioning hard, brittle cuticle. Sections were cut at 8 μm and stained with one-step Mallory triple stain.

For examination with the Cambridge Stereoscan S4, lungbooks were dissected out of freshly killed

spiders under a binocular microscope, washed in 70% alcohol, dried and gold-coated according to standard procedure.

Results

Three types of hair can be distinguished in the air spaces of the lungbooks according to size, shape and position. Between the individual lamellae, the hairs take the form of simple, non-bifurcating structures with slight terminal swellings (Fig. 1). They occur only on the upward facing surface of the lamella (cf. Fig. 2) where they are present at high density – *ca* $0.36 \times 10^6/mm^2$. At the free edges of the lamellae, larger branching hairs are found which fuse into loops (Figs. 3, 5). The atrial wall has the largest hairs which also branch and fuse (Fig. 4). The bifurcating and fused hairs form complex irregular three-dimensional networks of a most unusual type.

The intralamellar blood spaces are lined with the hypodermis which secretes the cuticle and hairs of the lamellae. Sparsely distributed in the blood space are pillar cells bridging the gap, presumably keeping the blood space open.

Discussion

To function adequately it is obvious that the air and blood spaces in the lungbooks must be kept open and the hairs and pillar cells described above seem well designed for this purpose. The intralamellar blood space is maintained by the pillar cells analogous to those in the gills of decapod crustaceans. The interlamellar air space is maintained by short upright hairs with blunt ends which probably normally rest in contact with the opposing lamella. These hairs are carried only on the inward facing (dorsal) surface of the lamellae; if these were on both surfaces the hairs would tend to lock. This would be disadvantageous, particularly if the interlamellar volume can change through muscular action of the opisthosoma, providing a degree of forced ventilation. The ends of the lamellae are prevented from sticking together and their hairs prevented from interlocking with both

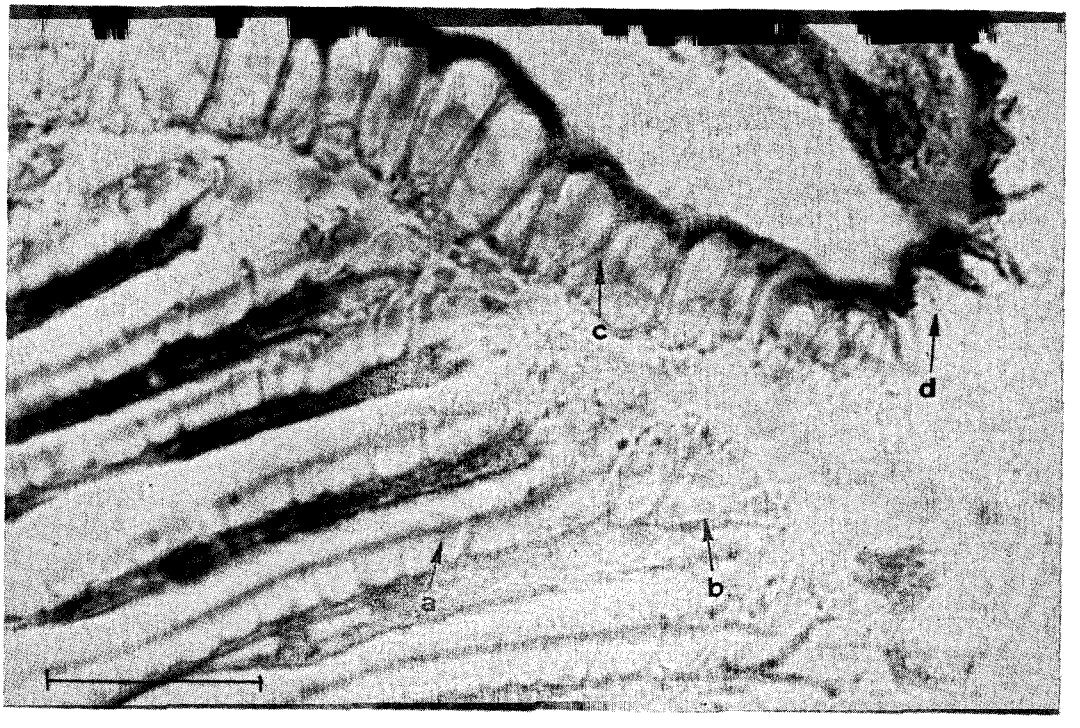

Fig. 5: Vertical longitudinal section (light microscopy) showing free edges of lungbook "leaves" projecting into the atrium. (a = interlamellar hairs, b = terminal lamellar hairs, c = atrial hairs, d = posterior edge of spiracle). Scale line = 20 μm.

themselves and the atrial hairs in a different way – by being fused together into a three-dimensional network. Fused cuticular hairs in arthropods are most unusual and raise an interesting morphogenetic problem. Normal cuticular hairs are secreted by trichogen cells – specialised cells of the hypodermis which, during ecdysis, produce a pseudopodium-like projection of cytoplasm which subsequently secretes a cuticular sheath which is the definitive hair. "Fused hairs" of the sort found would be formed if the projections of adjacent trichogen cells themselves fused before the cuticular sheath (i.e. the hair proper) was secreted. In an early description of these hairs, Schlottke (1938) produced evidence from light microscope studies that this is indeed what occurs.

Vyas (1974), working on scorpions, showed the presence of simple interlamellar "bristles", and also illustrated the branching and fusing terminal lamellar hairs without commenting on their unusual features and the possible relevance to maintaining an open air space. Moore (1976) described the "mesh" formed by the terminal lamellar hairs and the atrial hairs as air filters and dirt excluders without commenting on the problem of their formation. He also described the interlamellar hairs as "nail-headed spigots", a very apt adjective but an unfortunate use of a noun which has a very different connotation amongst spiders.

As well as maintaining the air space the fused hairs may act as mechanical buffers, cushioning any impacts received by the delicate lamellae. Arachnid cuticle is usually softer than that of insects and so physical deformation may be encountered quite often.

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References

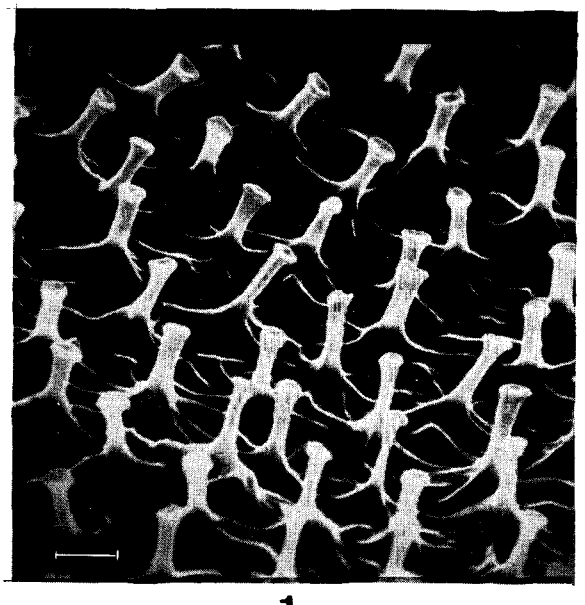
MOORE, S. J. 1976: Some spider organs as seen by the scanning electron microscope, with special reference to the book-lung. *Bull.Br.arachnol.Soc.* **3**(7): 177-187.

RATHMEYER, W. 1965: Neuromuscular transmission in a spider and the effect of calcium. *Comp.Biochem. Physiol.* **14**: 673-687.

SCHLOTTKE, E. 1938: Die Häutung der Spinnenlungen und die Dabei zu Beobachtende Grössenänderung der Zellkerne. *Z.Morph.Ökol.Tiere* **34**: 207-220.

VYAS, A. B. 1974: Scanning electron microscopy of book-lungs of the scorpion *Heterometrus fulvipes*. *Ent. News* **85**: 88-91.

WIGGLESWORTH, V. B. 1959: A simple method for cutting sections in the 0.5 to 1μ range, and for sections of chitin. *Q.Jl microsc.Sci.* **100**: 315-320.



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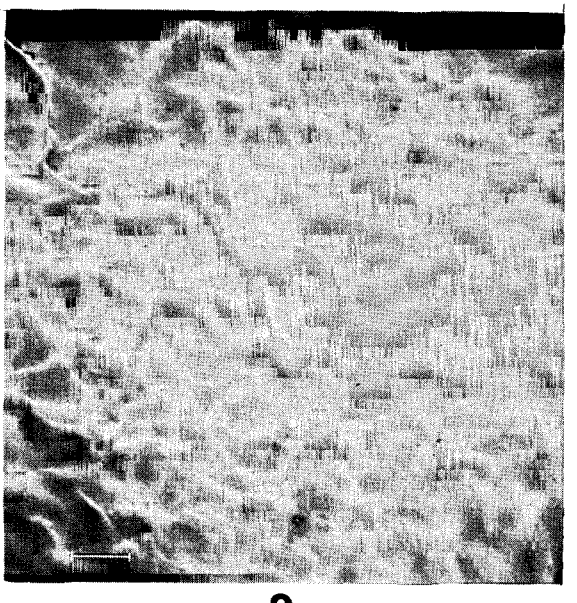

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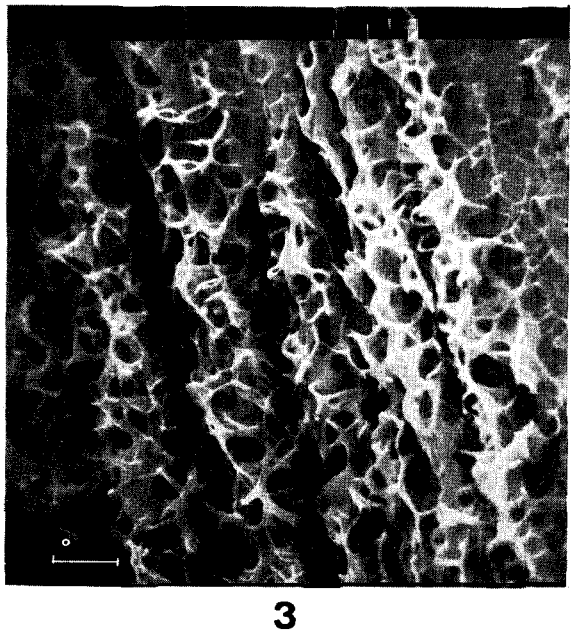

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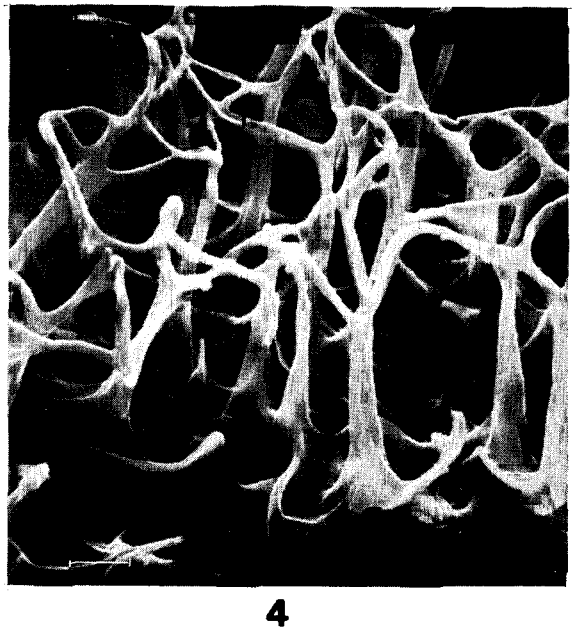

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Figs. 1-4: Scanning electron micrographs. **1** Interlamellar hairs; **2** Plain surface of lamella on opposite side of air space to interlamellar hairs; **3** Terminal lamellar hairs on parallel lamellae; **4** Atrial hairs. Scale lines: 1, 2, 4 = 2 μm; 3 = 10 μm.