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Do Static Electric Forces Contribute to the Stickiness of a Spider's Cribellar Prey Capture Threads?

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ABSTRACT Cribellar thread is the most primitive type of prey capture thread produced by spiders. Its dry surface is formed of thousands of fine fibrils that catch on the setose surfaces of insects and, by an unknown mechanism, also hold smooth surfaces. Static electric attraction has been suggested as the force by which these smooth surfaces are held. However, when the stickiness of cribellar threads produced by *Hyptiotes cavatus* and *Uloborus glomosus* (family Uloboridae) was measured with contact plates that had similar textures but very different dielectric values, no support was found for this hypothesis. Differences in stickiness values were small and showed no relationship to the dielectric indexes of the surfaces used to measure stickiness.

The most primitive type of prey capture threads produced by spiders are dry, composite threads, known as cribellar threads (Fig. 1; Shear, '94). These threads were present in the first aerial webs constructed by spiders and are produced by members of 22 spider families, including the primitive orb-weaving spider family Uloboridae (Coddington and Levi, '91; Opell, '79). Cribellar threads are formed of elements that provide strength and impart stickiness (Eberhard, '88; Eberhard and Pereira, '93; Friedrich and Langer, '69; Kullmann, '75; Opell, '89, '90, '93, '94a, '95; Peters, '83, '84, '86, '92; Peters and Kovoor, '88). The support elements include one or two pairs of larger, supporting axial fibers and, in most members of the family Uloboridae, a network of 30–56 smaller paracribellar fibers that form a superstructure around the axial fibers (Peters and Kovoor, '80). The stickiness of a cribellar thread resides in a cloud of thousands of very thin, looped cribellar fibrils that are deposited around the axial fibers and paracribellar fibers to form the thread's outer sheath (Fig. 1). These cribellar fibrils are spun from spigots on a spinning plate termed the cribellum. An increase in the number of cribellar spigots results in the production of stickier cribellar threads that contain a greater number of fibrils (Opell, '94a,b, '95). However, the mechanism by which cribellar threads hold surfaces is not fully understood.

The stickiness of these cribellar threads appears to result from two types of nonadhesive force. Insect surfaces with stout setae and spines are held by cribellar fibrils snagging on these irregularities, whereas smooth surfaces and those with fine setae that do not catch on cribellar fibrils are held by an uncharacterized force (Opell, '93, '94c). Several authors have noted that cribellar thread also sticks to smooth surfaces, such as steel, glass, and graphite (Eberhard, '80; Kullmann, '75; Peters, '86), and Peters ('84, '86) has suggested that this may be the result of electrostatic attraction.

The purpose of this study was to test this hypothesis by comparing the strength with which cribellar threads hold surfaces that have similar textures but greatly different dielectric (permittivity) properties. If static electric forces contribute to the stickiness of cribellar threads, then highly conductive surfaces should drain off this charge more rapidly and, consequently, register less stickiness than surfaces that are poor conductors. Cribellar threads produced by the two spider species used in this study held the nonsnagging surface of a beetle elytra with mean forces of 92 and 117 μN/mm of thread contact (Opell, '94c). The technique used to measure stickiness has a sensitivity of about 2 μN/mm of thread contact. Therefore, even if conductive surfaces do not completely neutralize these putative static electric forces, it should still be possible to detect a significant reduction in the stickiness they register.

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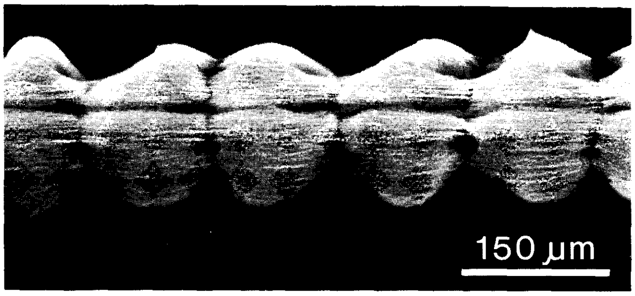


Fig. 1. A cribellar thread produced by an adult female *Hyptiotes cavatus.*

MATERIALS AND METHODS

Three nonconductive contact plates were used to measure cribellar thread stickiness. These were made of teflon (polytetrafluroethylene), paraffin, and calcite (the outer surface of a chicken egg shell cleaned thoroughly with acetone), materials that have dielectric constants of 2.0, 2.3, and 8.5, respectively (Linde, '94). To produce conductive surfaces with similar textures, I coated the surfaces of teflon and paraffin contact plates with 50 Å of carbon using a vacuum evaporator and then with 204 Å of gold using a sputter-coater.

This study measured the stickiness of threads produced by mature female spiders of the family Uloboridae. These spiders produce threads whose cribellar fibrils form a regular series of torus-shaped puffs with uniform widths (Fig. 1). All thread samples were collected from webs made by spiders housed individually in closed plastic boxes kept in an environmental chamber and were, therefore, free of dust and pollen. I examined each thread with a dissecting microscope to ensure that only undamaged threads were used in this study. Stickiness measurements were made with 48 hr of thread production. Enough threads were collected from a single web or from two consecutive webs produced by a spider to allow stickiness measurements to be made with two or three different surfaces. Using teflon and gold-coated teflon contact plates, I measured the stickiness of cribellar threads produced by 14 *Hyptiotes cavatus* (Hentz, 1847). Using wax, gold-coated wax, and calcite contact plates, I measured the stickiness of cribellar threads produced by 20 *Uloborus glomosus* (Walckenaer, 1841).

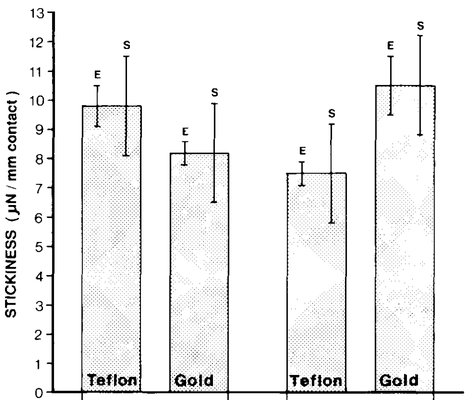
In previous studies that measured the stickiness of these two species' cribellar threads with contact plates made from a beetle elytra, a fly wing, a fly notum, and fine sandpaper, the threads of *H. cavatus* consistently registered greater stickiness than did those of *U. glomosus* (Opell, '94b,c). However, when these surfaces are ranked according to the strength with which they were held by each species' cribellar threads, the order is the same for both species. This indicates that the same forces are responsible for the stickiness of the two species' cribellar threads.

Cribellar thread samples were collected and their stickiness measured using the instrument and procedures described by Opell ('93, '94a–c). I collected threads from a web on a microscope slide with raised, adhesive supports spaced at 4.8 mm intervals. This slide was then mounted in an adjustable holder, permitting a thread to be oriented perpendicular to a small, rectangular contact plate made of one of the five surfaces described above and having a width of 2 mm (measured to the nearest 20 µm under a dissecting microscope). This contact plate was glued to the protruding tip of a glass needle strain gauge that was mounted in a horizontal plexiglass frame and attached to a mechanical advancement mechanism. The contact plate was pressed against the cribellar thread at a speed of 13.5 mm per min until it exerted a force of 19.61 µN/mm of thread contact. The contact plate was then immediately withdrawn at a speed of 14.0 mm per min until the plate pulled free of the thread. As the strain gauge moved, its needle passed over a scale that was calibrated using 5 mg balance riders. From the position of this needle immediately before the contact plate pulls free from the thread, I determined the force necessary to pull the plate from the thread and calculated the stickiness of the cribellar thread, expressed as micronewtons of force per millimeter of thread contact.

Four stickiness measurements were made of each spider's cribellar thread with each contact plate, and the mean stickiness value obtained with a plate was used as that individual's value. Immediately after measuring the stickiness of an individual's thread, I recorded relative humidity (RH). All measurements were taken at 23°–25°C and 54–57% RH. Humidity and temperature were controlled, as they have the potential to affect the rate at which static charges dissipate. As RH increases, electric charge should dissipate more rapidly and, if this charge contributes to the stickiness of cribellar thread, diminish the thread's stickiness. The glass needles used with contact plates had the following sensitivities: teflon 1.72 µN/mm, gold-coated teflon 1.72 µN/mm, paraffin 1.84 µN/mm, gold-coated paraffin 2.57 µN/mm, calcite 2.82 µN/mm.

RESULTS

Figures 2 and 3 present the mean stickiness values obtained with five different contact plates. To control for changes in the surfaces of these contact plates that might have resulted from repeated use, the mean stickiness values of threads produced by the first seven *H. cavatus* and the first ten *U. glomosus* examined are presented separately from those of threads produced by spiders that were subsequently examined. In each comparison, the stickiness of a species' thread was measured at the same RH (Figs. 2, 3).



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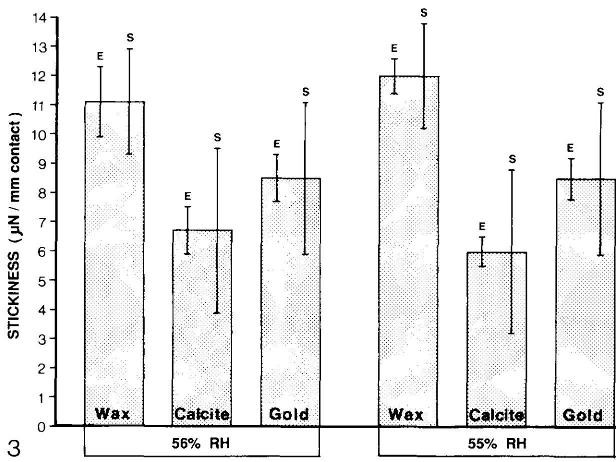

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Fig. 2. Comparison of the stickiness of cribellar threads produced by *Hyptiotes cavatus,* as measured with teflon and gold-coated teflon surfaces. Columns on the left report the first set of measurements and those on the right the second set; n = 7 for each replicate.

Fig. 3. Comparison of the stickiness of cribellar thread produced by *Uloborus glomosus,* as measured with paraffin, calcite, and gold-coated paraffin surfaces. Columns on the left report the first set of measurements and those on the right the second set; n = 10 for each replicate. Error bars represent ± 1 standard error of the mean (E) and ± the sensitivity limits of the measurement technique (S).

Differences between the mean stickiness values obtained with the five surfaces were small. Consequently, the sensitivities of the glass needles used to measure stickiness, rather than the variances of the stickiness values themselves, set the limits for comparing means. In only one of eight possible pair-wise comparisons does the difference in mean stickiness values exceed the overlaps in measurement sensitivity. Thus, statistical comparison of mean stickiness values is inappropriate.

Even if the small differences in mean stickiness values are considered meaningful and the issue of measurement sensitivity is ignored, these results are not consistent with the operation of a static electric mechanism. One comparison shows that a teflon plate is held less strongly than a gold-coated teflon plate, whereas a replicate comparison shows that it is held more strongly (Fig. 2). Replicate measurements taken with paraffin, calcite, and gold-coated paraffin are more consistent, indicating that repeated use of these contact plates does not affect the stickiness they register (Fig. 3).

The results of this latter comparison are also inconsistent with a static electric model. If the greatest stickiness is registered by a plate with the lowest dielectric constant, then paraffin should register the greatest stickiness, calcite slightly less, and gold-coated paraffin much less. However, the gold-coated plate registered slightly more stickiness than the calcite plate and slightly less stickiness than the paraffin plate (Fig. 3).

DISCUSSION

This study does not support the hypothesis that electrostatic forces contribute to the stickiness of cribellar threads. The stickiness values obtained with surfaces that had greatly different dielectric properties were so similar that limits of measurement sensitivity made it impossible to distinguish between them. This study was conducted concurrently with a comparison of the stickiness registered by the cribellar threads of *H. cavatus* and *U. glomosus,* as measured with different insect surfaces, including those that do not appear to snag cribellar fibrils (Opell, '94c). As that study found large difference in the stickiness measured with different surfaces, the failure of this study to detect differences in stickiness cannot be attributed to faulty methodology.

This earlier study found that cribellar threads produced by *H. cavatus* held a beetle elytra with a force of 117 µN/mm (Opell, '94c). It is difficult to explain why the artificial surfaces used in this study registered so little stickiness compared to the beetle elytra. The paraffin contact plate should be chemically similar to the epicuticle of the elytra. This difference may indicate that cribellar fibrils interact with molecules specific to the surfaces of insects, although the nature of these interactions remains unclear. Alternatively, the fibrils of cribellar threads may be hygroscopic and adhere by thin moisture films more readily to natural insect surfaces than to the artificial surfaces used in this study.

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