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Michael F. Whiting

Monte L. Bean Life Science Museum, Brigham Young University, Provo, Utah

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SCANNING ELECTRON MICROSCOPIC STUDY OF THE MALE GENITALIA
OF THE NORTH AMERICAN ALDERFLY GENUS *SIALIS*
(MEGALOPTERA: SIALIDAE)

Michael F. Whiting¹

ABSTRACT.—Scanning electron micrographs are presented for 14 species of the North American alderfly *Sialis*: *americana*, *arvalis*, *californica*, *contigua*, *cornuta*, *hamata*, *iola*, *joppa*, *mohri*, *nevadensis*, *occidens*, *rotunda*, *vagans*, and *velata*. Male genitalic characters are described for use in species identification.

Key words: *Sialis*, *Sialidae*, *Megaloptera*, *Neuroptera*, *SEM*, *alderflies*.

There are currently 24 biological species of *Sialis* recognized from North America (Ross 1937, Townsend 1939, Flint 1964, Whiting 1991). Ross (1937) was the first to illustrate and compare the genitalic characters among many species of alderflies. While both Canterbury (1978) and Evans (1971) have concentrated studies on the larvae of North American *Sialis*, since the work of Ross (1937) no serious study has compared the male genitalia among all the North American species. A clear understanding of genitalic characters is essential for proper species identification; consequently, there is a critical need to re-examine male genitalia within the genus *Sialis*.

During a study of the phylogenetic relationships among the North American species of *Sialis*, I used electron microscopy to evaluate minute genitalic characters with greater clarity. The purpose of this paper is to present the electron micrographs and brief descriptions of the species groups and the diagnostic genitalic characters for 14 species of *Sialis*. Because the micrographs better illustrate many of the structures used by Ross (1937) in his key to the North American species of *Sialis* and also show many new and important characters, this paper should be useful for species identification.

METHODS AND MATERIALS

Over 4000 specimens of North American adult *Sialis* were dissected and examined with

a light microscope to evaluate genitalic characters among many individuals from the 14 different species. From each species a male specimen was specially dissected for SEM study. Collection data for the specimens used in this study are as follows: *americana* (Rambur): WISCONSIN, Grant Co., Wyalusing State Park, 26 June 1957, A. L. Thorne; *arvalis* Ross: CALIFORNIA, Santa Clara Co., San Jose, Alum Rock Park, 19 April 1987, N. D. Penny; *californica* Banks: CALIFORNIA, Napa Co., Napa, 2 May 1948, H. P. Chandler; *contigua* Flint: VIRGINIA, Smyth Co., North Fork of Holston River, Route 42, near junction Route 633, 5 May 1981, B. C. Kondratieff; *cornuta* Ross: CANADA, Alberta, Konanaskis beaver ponds near Lusk Creek, 6 May 1969, T. G. Leischner; *hamata* Ross: UTAH, Wasatch Co., Bryants Fork Creek near Strawberry Reservoir, 6 June 1988, M. F. Whiting; *iola* Ross: VIRGINIA, Montgomery Co., Isaac Walton Park Pond, 11 May 1977, S. Mudre; *joppa* Ross: NEW HAMPSHIRE, Coos Co., Ellis River, Hwy. 16, Pinkham Notch, 7 June 1980, Baumann & Earnshaw; *mohri* Ross: MINNESOTA, St. Louis Co., Lake Jeanette, 22 June 1964, H. B. Mills; *nevadensis* Davis: CALIFORNIA, El Dorado Co., Blodgett Forest, 31 May 1969, D. Levin; *occidens* Ross: CALIFORNIA, Mariposa Co., Miami Ranger Station, 23 May 1942, S. H. Benedict; *rotunda* Banks: OREGON, Klamath Co., Wood River Spring, 12 June 1964, J. Schuh; *vagans* Ross: VIRGINIA, Brunswick Co., Greef Creek, U. S. 58 bridge,

¹Monte L. Bean Life Science Museum, Brigham Young University, Provo, Utah 84602. Present address: Department of Entomology, Comstock Hall, Cornell University, Ithaca, New York 14853-0999.

25 April 1982, B. C. Kondratieff; *velata* Ross: MINNESOTA, Louis Co., Eaglenest Lake, 1 June 1959, W. V. Balduff.

For specimens preserved on pins, the last four segments of the abdomen were removed and placed in a warm solution of 10% KOH (potassium hydroxide) for 20 minutes until the abdominal cuticle was softened and the genitalia became clearly visible. Specimens preserved in alcohol did not require treatment with the KOH solution. The abdomens were placed in an ultrasonic cleaning unit for 15 seconds to dislodge any foreign material from their surfaces. They were then removed from the cleaning unit and further dissected as needed to expose the genitalia. The abdomens were serially dehydrated in a series of ethanol concentrations (70%, 80%, 90%, 100% for 15 minutes each) and then placed in a solution of acetone over calcium sulfate crystals (2 hours). They were next critical-point-dried, mounted on aluminum stubs, and gold-plated in a Polaron DC sputter coater in preparation for SEM examination at 10 kv.

GENITALIC STRUCTURES

SEM analysis illustrates with greater clarity the genitalic structures useful for species identification within the *Sialis*. Ross (1937) used purely descriptive names for *Sialis* genitalia. Since a definite homology for the genitalia of alderflies with those of other insect groups has not yet been proposed, and since all other species descriptions of *Sialis* have relied upon these same names (Townsend 1939, Flint 1964, Whiting 1991), for the sake of consistency this paper will use Ross's descriptive names.

The male genitalia of *Sialis* consist of three major parts: the lateral, genital, and terminal plates. The lateral plates are a pair of ovoid plates just posterior to sternum 9 (Fig. 1c). These plates are contiguous mesally in most species and covered with dense setae. In some species these plates are modified into large arms bearing coarse setae (Fig. 9). The genital plate is a single sclerotized plate found posterior to the lateral plates and anterior to the terminal plates (Fig. 1b). In many species this plate is divided into two major arms that vary in size and length among species. Basally, the genital plate is either fused to the basal portion of the terminal plate (Infumata

species group) or attached to a membranous wall. Because the shape of the genital plate is highly species specific, it is the most diagnostic character for determining species identity. However, because it is also the smallest genitalic structure and is usually concealed beneath the terminal and lateral plates, it is often the most difficult structure to observe. The terminal plate is a single plate on the caudal end of the abdomen circling the borders of the anus (Fig. 1a). The dorsal margin of this plate is reduced while the ventral margin is often cleft, bilobed, or modified into single or double arms. Every species and species group of *Sialis* has a unique combination of modifications of these genitalic structures, making species identification rather simple and straightforward.

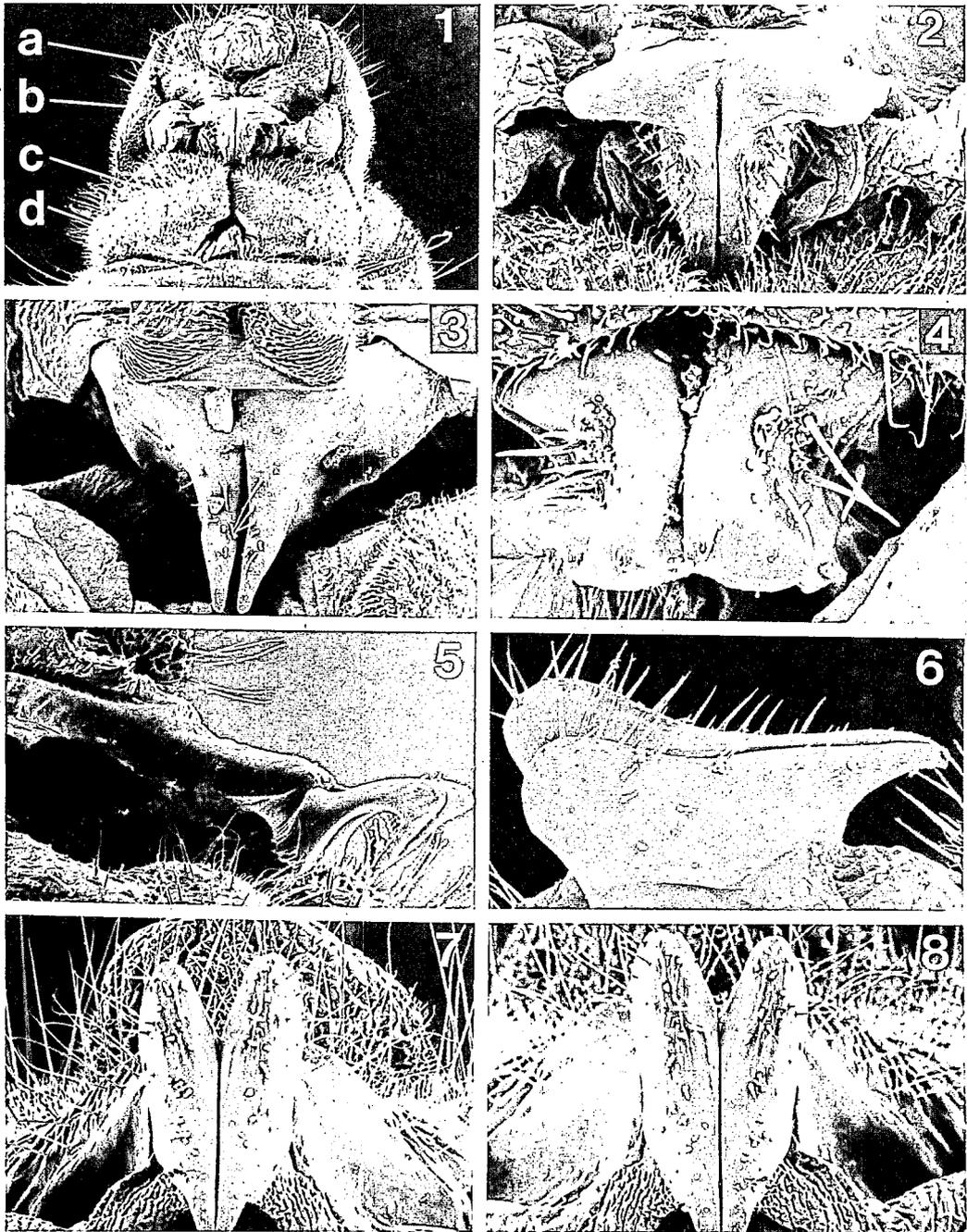
CALIFORNICA GROUP

The California species group consists of three eastern species (*driesbachi* Flint, *iola* Ross, and *joppa* Ross) and six western species (*arvalis* Ross, *bilobata* Whiting, *californica* Banks, *cornuta* Ross, *hamata* Ross, and *occidens* Ross). This group is characterized by a conspicuous bulbous evagination on tergum 9, reduced sternum 9, and a greatly reduced genital plate clothed sparsely with setae.

Sialis californica Banks.—From a lateral aspect (Fig. 6), the genital plate is saddle-shaped and lobed behind the point of basal attachment. The size of this lobe appears to vary in different populations, with a tendency to gradually decrease as the distributions become more northern. From the dorsal aspect, the arms of the genital plate are contiguous mesally and moderately covered with setae (Fig. 8).

Sialis occidens Ross.—The basal portion of the genital plate projects above the apex of the terminal plate (Fig. 1). The genital plates are superficially shaped like *S. californica* except that the basal portions are flanged laterad and devoid of any setae (Fig. 2) and the genital plate is not lobed behind the point of articulation with the basal membrane.

Sialis hamata Ross.—The ventral margin of the terminal plate bears a dark, elongate sclerotization that projects from the base of the terminal plate and hinges basally to the genital plate (Fig. 5). The length of this neck is reduced in northern populations. The genital



Figs. 1-8. Male genitalia of *Sialis* spp.: 1, *occidens* Ross, a. terminal plate, b. genital plate, c. lateral plate, d. sternum 9 (ventral); 2, *occidens* Ross, genital plate (ventral); 3, *cornuta* Ross, genital plate (ventral); 4, *arvalis* Ross, genital plate (ventral); 5 and 7, *hamata* Ross, genital plate (anterolateral and ventral); 6 and 8, *californica* Banks, genital plate (lateral and ventral).

plate is lobed ventrally and apically recurved, giving a distinct barbed-hook appearance. That the caudal aspect of the genital plate in *S. hamata* (Fig. 7) is identical in shape with the dorsal aspect of the genital plate in *S. californica* (Fig. 8) suggests that these may be sister species.

Sialis cornuta Ross.—The terminal plate has the apical margins cleft, and each cleft lobe is produced into swollen bulbs that diverge laterally (Fig. 3). The genital plate is broad and convex and mesally bears a pair of straight, stocky arms (Fig. 3).

Sialis arvalis Ross.—The genital plate is hinged to the apical margins of the terminal plate and is attached ventrally to a clear, sac-like membrane. The genital plate is strongly flanged basally and is apically produced into a pair of short fingers (Fig. 4). The terminal plate bears a pair of large lobes apically (not visible in Fig. 4).

Sialis joppa Ross.—The genital plate is broad but slightly constricted on the lateral margins. Apically, the genital plate is produced into a pair of short fingers (Fig. 15). Lateral to the genital plate and posterior to the terminal plates are a pair of clear, membranous extrusions.

Sialis iola Ross.—The genital plate is elongate, rectangular, and apically produced into a pair of short fingers. The terminal plate has the apex narrow and tapering to a blunt point (not visible in Fig. 16).

AEQUALIS GROUP

The Aequalis group consists of two western species (*nevadensis* Davis and *rotunda* Banks) and three eastern species (*aequalis* Banks, *contigua* Flint, and *vagans* Ross). This group is characterized by a large, relatively unspecialized genital plate devoid of setae and a large, flaplike sternum 9. Tergum 9 rarely bears a bulbous evagination.

Sialis rotunda Ross.—The genital plate is subdivided into two concave halves that serve as receptacles for the apical portion of the lateral plates (Fig. 9). Two stocky genital hooks arise from the median evaginated ridge on the genital plate. These hooks run parallel and are moderately recurved ventrad (Fig. 10). The terminal plate is quadrate and only slightly cleft (Fig. 9). The lateral plates are produced into a pair of blunt arms

covered with dense setae on the dorsal margins (Fig. 9).

Sialis nevadensis Davis.—This species bears a very large, subrectangular genital plate that is slightly convex. The genital plate bears a small pair of short fingerlike projections on its upper surface (Fig. 13). Beneath each finger is a membranous region which appears white under light microscopy.

Sialis vagans Ross.—The genital plate is large and subrectangular from a lateral aspect (Fig. 11). Extruded mesally is a single arm that becomes strongly bulbous apically (Fig. 12). Two small, pointed fingers are produced on the apical portion of this bulb.

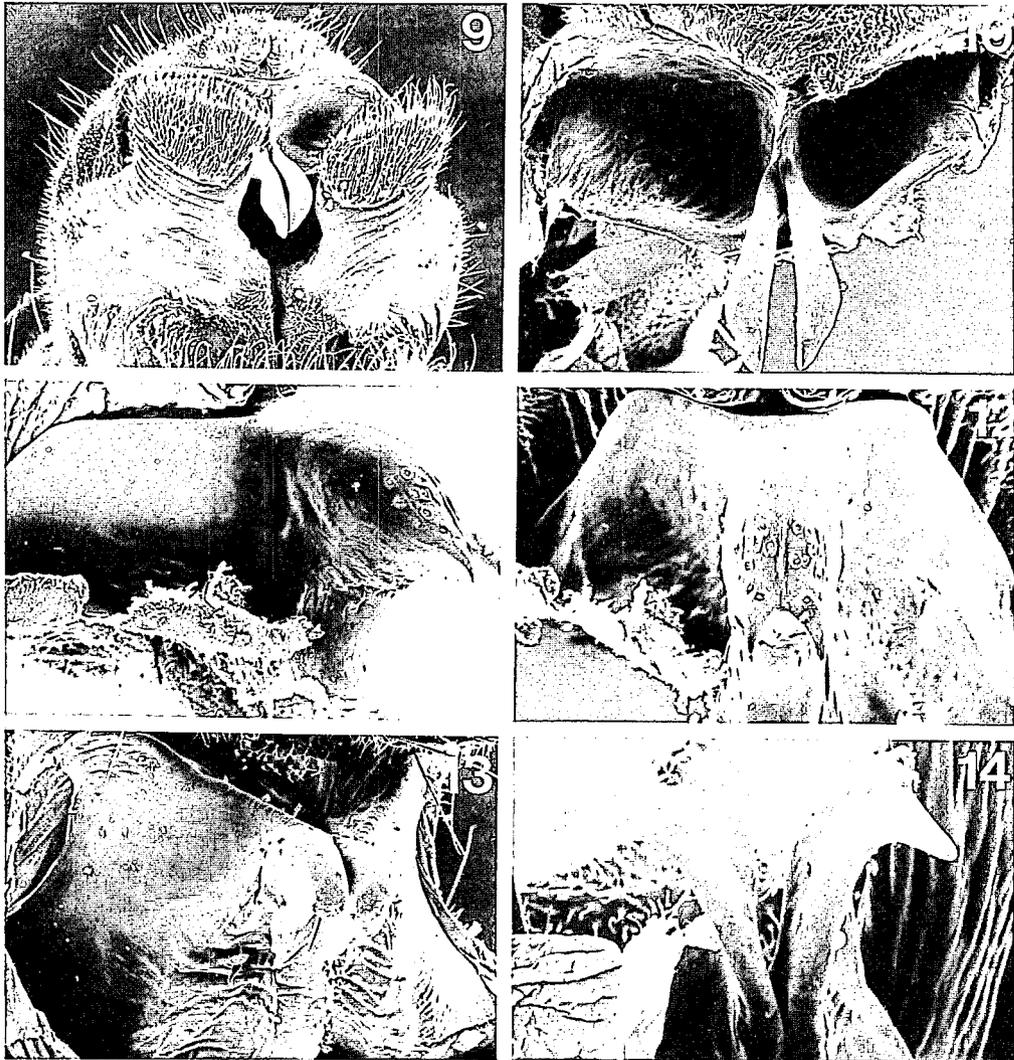
Sialis contigua Flint.—Basally, the genital plate is similar in size and shape to *S. vagans*. However, the median arm is narrower and the apical fingers are longer and diverge laterally from the medial point of attachment (Fig. 14). The terminal plate is U-shaped with the arms of the U closely appressed.

INFUMATA GROUP

The Infumata species group comprises eight species: *conca* Banks, *hasta* Ross, *infumata* Newman, *itasca* Ross, *mohri* Ross, *nina* Townsend, *spangleri* Flint, and *velata* Ross. All of these species are eastern or mid-western except *velata*, which occurs throughout North America. This group is characterized by a shield-shaped genital plate bearing a long pair of whiplike arms. The genital plate is completely fused to the basal portion of the terminal plate and is devoid of setae. The lateral plates are elongate, sternum 9 is moderately large, and tergum 9 lacks a bulbous evagination.

Sialis velata Ross.—The genital arms are long and curve 90 degrees before attaching to the genital plate. These arms fuse together before reaching the genital plate (Fig. 17) and bear a median lobe that is nearly one-half the length of the arms. The terminal plate, quadrate and slightly cleft, is basally fused to the genital plate.

Sialis mohri Ross.—The genital arms are long but stockier than *S. velata*. The median lobe of the genital arms is absent (Fig. 18). The terminal plate bears a pair of long, heavily sclerotized arms that converge medially (not visible in Fig. 18).



Figs. 9–14. Male genitalia of *Sialis* spp.: 9, *rotunda* Banks, lateral, genital, and terminal plates (ventral); 10, *rotunda* Banks, genital plate (ventral); 11 and 12, *vagans* Ross, genital plate (lateral and ventral); 13, *nevadensis* Davis, genital plate (lateral oblique); 14, *contigua* Flint, genital plate (ventral).

AMERICANA GROUP

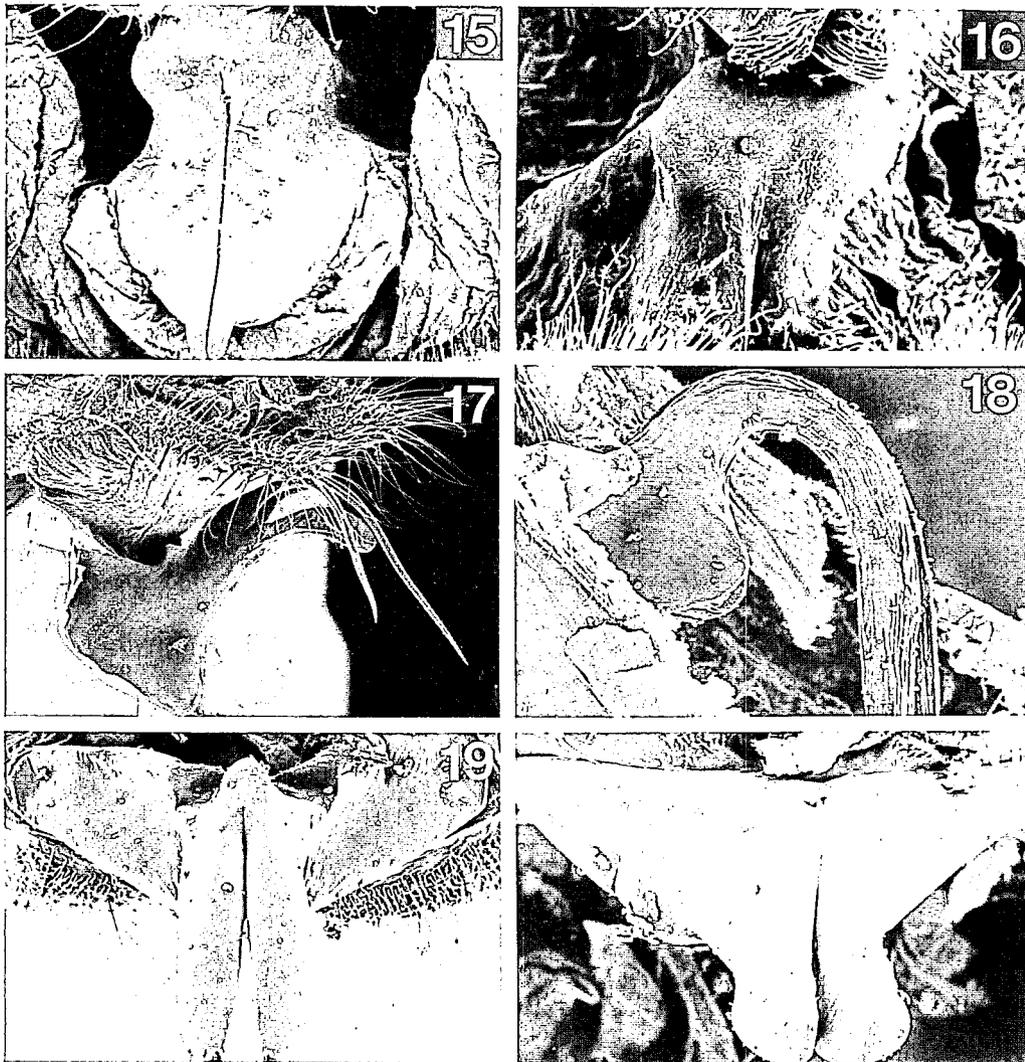
The Americana species group consists of two eastern species: *americana* (Rambur) and *glabella* Ross. This group is distinguished by the large, unspecialized genital plate, moderately large sternum 9, and the unique, light red coloration of the body. The genital plate lacks setae, and sternum 9 lacks a bulbous evagination.

Sialis americana Rambur.—The genital plate is triangular and mesally bears a pair of long, broad arms (Figs. 19, 20). These arms

run nearly parallel but diverge slightly laterally. The genital plate and arms do not bear setae.

DISCUSSION

The higher magnification and greater depth of field available make SEM a valuable tool for investigating evolutionary and taxonomic relationships within the *Sialis*. SEM analysis of North American *Sialis* has revealed that the genital structures are clearly diagnostic for all



Figs. 15–20. Male genitalia of *Sialis* spp.: 15, *joppa* Ross, genital plate (ventral); 16, *iola* Ross, upper half of genital plate (ventral); 17, *velata* Ross, genital and terminal plate (lateral oblique); 18, *mohri* Ross (lateral); 19 and 20, *americana* (Rambur) genital plate (ventral and dorsal).

14 species studied and that these structures are the key to understanding evolutionary relationships within the Sialidae.

All species identifications of adult Sialidae in North America have relied upon the key published by Ross (1937). After working with this key for several years, I have found that some couplets are ambiguous because they rely on characters that are either obscure or artificial. Compounding this problem are sketchy drawings that only partially reflect the actual structure. SEM analysis and light

microscopy have revealed that there are characteristics better suited for species identification than those used in the key of Ross. Some of these characters are illustrated and outlined above. Therefore, use of these micrographs in conjunction with Ross's key will aid in more accurate identification of *Sialis* species.

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