1-1-1915

Notes on the morphology of the nervous system of the Carolina Locust, Dissosteira carolina L. [and] North American species of the Genus Sceliphron

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Theses Submitted for the Degree of Doctor of Philosophy.

Massachusetts Agricultural College,

Amherst, Mass.

1915.

NOTES ON THE MORPHOLOGY OF THE NERVOUS SYSTEM OF THE CAROLINA LOCUST, DISSOSTEIRA CAROLINA L.*

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INTRODUCTION

This insect belongs to the Orthopterous family Acrididae, or short horned grasshoppers, a generalized group of insects whose anatomy, both external and internal, does not show any great degree of specialization.

The Carolina locust is, moreover, a common insect, being generally distributed throughout North America, but it is not an important pest.

An attempt has been made to work out the nervous system simply from its morphological aspect in the hope that it may serve as a reference for dissection.

I take this opportunity of thanking Dr. H. T. Fernald and Dr. G. C. Crampton for their generous assistance during the course of this paper.

General

From a study of the embryonic stages of various insects it has been shown by investigators that the nervous system in its primitive stages consists of two narrow elongate cords which extend more or less parallel to each other from the posterior end of the abdomen to the neighborhood of the head region. Here they gradually diverge to form the circumœsophageal collar, pass one on either side of the stomadæum (or primitive mouth cavity), and meet in the rudimentary brain. These cords soon become broadened at intervals about the middle of each body segment and these broader portions gradually develop into the ganglia or nerve centres, while the narrower intermediate strips come to form the connectives between the ganglia. These parallel strips become gradually approximated along their entire length until the ganglia fuse transversely, while the connectives generally remain separate. So that in the earliest stages of the embryo there is a paired ganglion for every segment.

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*Contribution from the Entomological Laboratory of the Massachusetts Agricultural College, Amherst, Mass.

It has been shown that these paired ganglia are joined internally by transverse commissures, the remains of the cross commissures of the embryo.

It will be seen that so far the fusion of ganglia has been in a transverse direction, but in the later embryonic stages a longitudinal fusion takes place in the head region and in some cases at the posterior end of the abdomen.

The insect's head in its early embryonic stages is made up of six segments, and each of these primitive segments has its own paired ganglion. The first three paired ganglia later fuse longitudinally to form the brain proper, while the next three paired ganglia usually fuse to form the suboesophageal ganglion, and these two compound ganglia are connected by the circumoesophageal collar.

A process of cephalization, or longitudinal fusion in the direction of the head, may take place in the abdomen of the embryo, but usually there is a paired ganglion for almost every body segment.

Passing from the embryo to the insect proper we find that in the immature stages the nervous system is frequently of a primitive type, and usually varies considerably from its ultimate form in the adult of the same insect. This difference is especially marked in the case of holometabolous insects, where the adult is totally unlike the immature form, in that it has become much more specialized. This group of insects, which undergoes complete metamorphosis, has a pupal or resting stage during which the nervous system is broken down along with other internal structures and is built up again on a different plan to meet the new functions it will have to perform in the adult.

This new arrangement includes the process of cephalad fusion, or cephalization, and the amount of fusion of the ganglia varies considerably not only in the different orders and in different insects of the same order, but in the different sexes of the same insect, as Brandt (1875) and

Blanchard (1876) have shown in their investigations with the higher Hymenoptera.

As a rule the adults of the forms belonging to the more specialized orders, Diptera, Coleoptera and Hymenoptera, show the greatest amount of fusion, whereas in the lower, or more generalized, orders, comparatively little cephalization takes place; in the latter group of insects the metamorphosis is incomplete and the immature form is not unlike the final adult condition. There is therefore no breaking down and reconstruction of the nervous system in the more generalized insects, but only a gradual change to keep pace with the development of wings, reproductive organs, etc. throughout the stages from hatching to adult. So that the adults of some of these lower forms may still have a ganglion for almost every body segment and these ganglia may even show distinct traces of their original paired character.

As will be seen from a reference to fig. 1, the nervous system of the Carolina locust is that of the typical insect. The ganglia are well distributed throughout the length of the body, but there has been a concentration of ganglia in two places, the metathorax and the eighth abdominal segment. The ganglia of the first three segments of the abdomen have moved forward to fuse with the metathoracic ganglion, the ganglia of the fourth and fifth segments have each advanced one segment, but these first five abdominal ganglia still innervate their original segments by means of lengthened nerves. Further, the ganglia of the sixth, seventh and eighth segments have kept their original positions, while the ganglia of the last three segments have fused with that of the eighth segment.

The three thoracic ganglia are separate, though the meso- and metathoracic ganglia are closely approximated.

In the head region the brain and the suboesophageal ganglion are widely separated, but are composed of three fused primitive ganglia.

In some of the higher insects the thoracic ganglia have fused and have been joined by all the abdominal ganglia to form one large ganglionic centre in the thorax, from which nerves radiate to all parts of the body region.

The brain and suboesophageal ganglion are generally distinct, though sometimes they may form one mass with a central opening through which the oesophagus passes.

The suboesophageal ganglion may fuse with the first thoracic ganglion.

The nervous system of the Carolina locust falls under three main divisions, the brain or supra-oesophageal ganglion; the ventral system; and the visceral, stomatogastric, or sympathetic system.

The Brain

The brain (fig. 2) in this insect is situated in the mediodorsal portion of the head capsule just above the oesophagus, as its other name, supraoesophageal ganglion, indicates.

It is usually the largest ganglionic complex in an insect, and investigators have shown it to be composed of three fused ganglia, representing the paired ganglia of the first three primitive segments, or neuromeres, of the head.

The brain receives sensory impressions from the chief sense organs and the outlying parts of the body and sends back motor stimuli by means of the connectives and nerves.

In this insect the auditory organ in each pleuron of the first abdominal segment is innervated by the metathoracic ganglion, which thus assumes one of the functions of the brain in innervating a sense organ.

It has been shown by Binet (1894) that the brain coordinates the movements of the body, whereas the suboesophageal ganglion simply controls the muscular movements.

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For example, an insect deprived of its brain alone can still eat if food is placed in contact with its palpi, but if the suboesophageal ganglion is also removed it can make none of the movements of eating.

Again, since the brain controls the principal organs of perception, an insect deprived of its brain can neither perceive its food nor move towards it, even if the food be placed but a short distance from its palpi.

The relative size of the brain is no indication of the intelligence of the insect; this quality seems to be closely connected with the development of the so-called "mushroom bodies."

In the Carolina locust the brain is comparatively simple in its external features, being composed of three well defined parts, called the proto-, deuto-, and trito-cerebrum by Viallanes. These parts represent the three paired ganglia belonging respectively to the first second and third primitive segments of the head.

The protocerebrum is the largest division of the brain in this insect, being composed externally of the optic lobes (o.l.) and their ganglia (o.g.); the ocellar lobes (oc.l.), and a central area called the pars intercerebralis by V.Haller (1905).

The position of these parts can be seen in fig. 2.

The optic lobes send off nerves to the optic ganglia of the compound eyes through a narrow neck.

The three ocellar lobes form an inverted triangle enclosing the pars intercerebralis or median portion of the protocerebrum, and the two lateral ocellar lobes are separated by a median cleft. Each of these three lobes sends nerves to the corresponding ocellus (oc.).

The deutocerebrum is made up of the olfactory or antennal lobes, which send nerves (ant.) to the distal end of the antennae with branches to the muscles of each joint of the antennae.

The tritocerebrum is composed of the commissural lobes which are separated by a deep median cleft. These lobes give off the connectives to the subœsophageal ganglion, (sb.g.) the labral nerves, (lbr.) and the subœsophageal commissure (t.c.) also the frontal nerves (fr.) to the frontal ganglion. A more detailed description of these structures will be given under the discussion of the sympathetic system.

The labral nerves (lbr.) rise in the frontal portion of the tritocerebrum and descend to each side of the labrum, giving off a lateral branch to the muscles operating the labrum. The main nerve enters the labrum where it branches to the taste cups of the epipharynx and the internal labral muscles.

The Ventral System

In the insect under discussion the ventral nervous system consists of the subœsophageal ganglion, the three thoracic ganglia, and the five abdominal ganglia.

The Suboesophageal Ganglion

The suboesophageal ganglion lies below the oesophagus and under the centre of the tentorium. It is oviform, narrowing anteriorly where it receives the long connectives from the brain, and posteriorly where it sends the pair of connectives back to the prothoracic ganglion.

From its ventral surface it sends off three paired nerves, the mandibular, maxillary and labial, and one single nerve to the hypopharynx.

Dorsally a pair of nerves ~~are~~ is sent back to the prothorax, where ~~they~~ it innervates the upper neck muscles and the dorso-lateral prothoracic muscles.

The mandibular nerves (md.) arise ventro-laterally, and soon after their origin give off a branch to the articulating muscles of the mandibles, while the main nerves enter the mandibles to the internal muscles and tissues.

The hypopharyngeal nerve (~~hp~~ hyp.) arises posterior to the mandibular and goes to the sensory hairs and pits in the hypopharynx.

Immediately behind this are the maxillary nerves (mx.) controlling

the muscles of the gales, lacinia and palpus by means of branches. In the case of the palpus the nerve apparently extends to the sensory hairs at the tip.

The labial nerves (lb.) are given off behind the maxillary nerves and proceed to each side of the labium, with a branch to the tip of the palpus.

A pair of nerves arises close to the connectives and slightly dorsal to them and extends backward on each side to the prothorax, where it crosses the anterior prothoracic nerves and ends in the dorso-lateral muscles. On the way it sends a branch to the dorsal neck muscles.

The Thoracic Ganglia

The thorax has a ganglion to each of the three segments. These ganglia are similar in external appearance, but their size increases in proportion to the number of nerves they send out. They are disc-shaped, broadly oval, each with a thick, firm central portion.

Each ganglion roughly resembles a double convex lens and the nerves are given off on three different planes, dorsal, lateral, and ventral.

Prothorax.

The prothoracic ganglion gives off four nerves, one anterior, two lateral, and one posterior.

The anterior nerve passes under the nerve from the suboesophageal ganglion and by means of branches innervates the ventral, ventro-lateral and lower neck muscles of the prothorax.

The first lateral nerve extends to the transverse muscles of the prothorax with branches to the coxal muscles of the leg.

The second lateral nerve (cr. l.) controls the internal leg muscles of the different joints, as far as the tarsal claws.

The posterior or auxiliary nerve goes backward to join the anterior or alary nerve (al_1) of the mesothorax.

Mesothorax.

The mesothoracic ganglion gives off five main nerves on each side.

The anterior nerve from this ganglion and the posterior nerve from the previous ganglion converge, run contiguous for a short distance and separate again.

The two arms extend laterally to the upper transverse alary muscles (al_2) and to the longitudinal dorsal muscles of the mesothorax. (dt_2)

Posterior to these a nerve goes to the lower transverse muscles, and ventral to these nerves we find the nerve which innervates the coxal muscles of the mesothoracic legs.

This is followed by the leg nerve proper (cr_2 N.) which is homologous with the prothoracic leg nerve.

Posterior to the leg nerve is the auxiliary nerve which joins the anterior metathoracic nerve.

Metathorax.

The metathoracic ganglion lies close behind the preceding ganglion. It is the largest of the three thoracic ganglia and is an important one in this insect, since it supplies nerves not only to its own segment, but in addition innervates the first three abdominal segments.

It is thus a compound ganglion made up of the ganglia of four primitive nerve segments, one thoracic and three abdominal, and the nerves from the three original ganglia of the abdomen have gradually lengthened out as their respective ganglia moved forward in the process of cephalization.

The following nerves go out from this ganglion:--

1. The alary nerve. (al_2) This is a lateral nerve from the dorsal surface of the ganglion to the wing muscles. It joins with the posterior nerve of the mesothoracic ganglion and the two together (as in the mesothoracic pair) innervate the depressor and elevator muscles of the wing. The anterior

branch extends to the depressor or outer layer of transverse muscles, while the posterior branch goes to the elevator or inner layer of transverse muscles with an offshoot to the dorsal longitudinal muscles of the metathorax.

2. Behind and below the alary nerve is a lateral nerve to the coxal and trochanteral muscles of the hind leg with branches to the ventral muscles of the metathorax.

3. The auditory and first abdominal nerve (as_1.). This nerve not only innervates the small ganglion in the auditory organ, but sends a branch behind the "ear" to the longitudinal dorsal muscles of the first abdominal segment, and to the muscles attached to the rim of the "ear."

4. The crural or leg nerve (cr_3.) goes to the hind leg with branches to the muscles in the different joints of the leg. It divides before entering the leg, and one branch proceeds to the tibial tendon at the distal end of the femur, while the main nerve innervates the femoral, tibial, and tarsal muscles.

5. The second abdominal nerve (as_2.) extends backwards to the longitudinal dorsal muscles of the second abdominal segment with branches to the dorso-ventral muscles and to the muscles attached to the arms of the furca.

6. The second ventral nerve (v_2.) goes to the ventral muscles of the second abdominal segment, giving off the first ventral nerve (v_1.) on the way.

7. The third abdominal nerve (as.3.) is homologous with the second.

8. The third ventral nerve (v_3.) is homologous with the second.

It will be seen that although the first three abdominal ganglia have fused with the metathoracic ganglion, ~~yet~~ they still send off the nerves characteristic of an abdominal ganglion in this insect, namely a long nerve to the dorsal and lateral muscles, a short ventral nerve to the ventral and muscles. A reference to the abdominal ganglia will illustrate this point.

The Abdominal Ganglia

There are five ganglia in the abdomen of Dissosteira carolina. These increase in size counting backward from the base of the abdomen, but they are all smaller than any of the thoracic ganglia.

The first four ganglia each send off two nerves on each side and these are homologous with the nerves of the first three abdominal ganglia which have fused with the metathoracic ganglion. The first two ganglia of the abdomen are really the ganglia of the fourth and fifth segments, but they have each moved forward one segment and are now situated in the third and fourth segment respectively. The next two ganglia belonging to the sixth and seventh segments have retained their original position and innervate the muscles of their own segments by means of two nerves homologous with those in the preceding five segments.

The fifth and last abdominal ganglion lies in the eighth segment, and supplies nerves to the muscles of the eighth, ninth and tenth segments which include the genital apparatus, but the homology of the nerves characteristic of the typical abdominal segment is not so clear as in the preceding segments, since the nerves extending to the last two segments have fused to form one main nerve with many branches.

Female

From the anterior portion of the ganglion a lateral nerve is given off on each side to the ventro-lateral, and dorso-longitudinal muscles of the eighth segment.

A strong nerve goes out from the posterior end of the ganglion, giving off several branches on its way to the end of the abdomen. Near its origin this nerve divides and the anterior branch innervates the muscles of the ninth segment.

The posterior branch subdivides and its several ramifications go to

the tenth and eleventh segments, where they innervate the various muscles of those segments, including those of the upper sheath of the ovipositor and the egg guide.

A ventral nerve goes to the muscles of the lower part of the ovipositor and the ventral muscles near the end of the abdomen.

Male

In the male there is a lateral nerve to the muscles of the eighth abdominal segment, homologous with that in the female.

The posterior part of the ganglion gives off a strong nerve which divides into two main branches near its origin. The outer of these branches subdivides into three nerves which go to the dorso-longitudinal muscles of the ninth, tenth and eleventh segments and the cerci.

The inner branch innervates the upper muscles of the male genital apparatus, and gives off two branches to the ventro-lateral muscles of the ninth and tenth segments.

From the under side of the ganglion a ventral nerve is given off to the lower muscles of the genital apparatus.

The Sympathetic Nervous System

This consists of an upper or stomatogastric system, and a lower or median system.

Stomatogastric System

The upper sympathetic system innervates the alimentary canal as far as the Malpighian tubes.

It originates in the brain as a paired system, the two nerves of which rise near the labral nerves, run parallel to them for a short distance and then curve in over the œsophagus, sending off small branches to the muscles of the latter. After giving off these branches they bend upward and meet in the frontal ganglion, which lies over the median dorsal line of the œsophagus.

The single recurrent nerve runs backward, passing under the brain between the two connectives, and appears to innervate the dorsal vessel.

In this insect, as in many Orthoptera, there is no dorsal or vagus system. Instead of this the paired sympathetic system is well developed in the shape of two nerves which start from the back of the deutocerebrum, give off the anterior sympathetic ganglia, and proceed in a posterior direction along each side of the oesophagus to a small stomachic ganglion situated anterior to the coecal pouches. On its way each nerve sends off branches to the longitudinal and circular muscle layers of the foregut.

Each of these stomachic ganglia produces five branches, laterally and posteriorly, some of which go to the muscles of the proventriculus, others to the coecal pouches or glands, and the longest appear to run back to the posterior coecal pouches, with extensions possibly to the Malpighian tubes.

Median System

The lower or median system consists of a small median nerve (me), of which the first traces in this insect were found between the meso- and meta-thoracic ganglia, at which point two lateral nerves are given off and appear to go to the mesothoracic spiracles.

Posterior to the metathoracic ganglion is another pair of lateral nerves, which were traced to within a very short distance of the spiracle of the auditory organ.

The median nerve was observed to extend posteriorly between the connectives as far as the third abdominal ganglion. Here it enters a small triangular ganglion and branches out into two lateral nerves which run towards the spiracles of the fourth abdominal segment.

No further traces of the median system were observed in the specimens examined, but it is possible that the salivary glands and the dorsal vessel may be innervated either by the stomatogastric or the median system.

General Workers

The first important worker on the nervous system of insects was Newport who investigated the nervous system of Sphinx ligustri.

He traced the growth of the nervous system from the newly hatched larva, showing its development throughout the larval stages, and at frequent intervals during the pupal state, to its final condition in the adult. These experiments were accompanied by descriptions and a series of figures.

Leydig (1864) in addition to his work on the brain investigated the component parts of a ganglion. He found that the nerve cells which give off fibres originate from a central network of fine fibrillae to which he gave the name of punktsubstanz or "fibrillar substance."

The work of Brandt (1875) and Blanchard (1876) on the variations in arrangement of the abdominal ganglia in different insects is of much interest.

Lienard (1880) worked out the transverse commissure below the brain in a number of different insects.

This commissure was first discovered by Lyonnet (1762) in Cossus ligniperda, and found by subsequent investigators in other insects.

Workers on the Brain, especially the Mushroom Bodies

It is not proposed to go into the histology of the brain or its internal structure, but mention may be made of the so-called "mushroom bodies," which appear to play an important part in the intelligence of insects.

They were first discovered by Dujardin (1850) in Orthoptera and Hymenoptera, but he did not recognize their stalked character and called them "lobes with convolutions."

Leydig (1864) found them in Ants, Bees, and Wasps and named them "stalked bodies," but did not grasp the significance of the cup shaped bodies or calyces which the stalks support. He recognized the olfactory lobes and central body with which the "mushroom bodies" were later shown to be connected.

Dietl (1876) was the first to use sections in the study of the brain. This method enabled him to recognize the true shape of these bodies of which he

gave an accurate description, calling them Pilzhutformiger Korper or "mushroom bodies."

Flogel (1878) examined these bodies in the brain of insects from all the different orders and showed that the development of these structures is closely correlated with the growth of intelligence. For instance they reach their highest development in the Hymenoptera (Bees, Wasps etc.) and gradually descend the scale until they are mere rudiments in the Hemiptera.

Packard (1880) described and figured them by means of sections in the Rocky Mountain Locust and the best idea of their structure in that insect may be gained by referring to his work.

Bellonci (1882-86) found them in the brain of the Cockroach and a Fly, and called them "fungiformo corpo." He showed that they are connected by fibres with the protocerebrum. He also studied the relations between the optic ganglia and the brain.

Viallanes (1884-99) worked out the development of the "mushroom bodies" in the brains of insects from several different orders. He demonstrated that the olfactory or antennal lobes, and the optic ganglia are connected with these bodies by fibres which enter the cups of the mushroom bodies, where there are masses of cells.

Villanes considered that the mushroom bodies are connected with the intelligence, since in Bees and Wasps, which are usually regarded as the most intelligent insects, they obtain their greatest development.

The work of Viallanes on the brain of different insects showed a great advance on any previous investigations. He divided the brain of the adult insect into the proto-, deuto-, and trito-cerebrum without reference to embryology, but he found later that these three divisions corresponded to the three primitive neuromeres or nerve segments of the brain.

Binet (1894) worked on the "mushroom bodies," but he is better known

for his physiological experiments on the brains of insects. These experiments were an improvement on those of Faivre along the same lines, and demonstrated that an insect may live for months without a brain, if the suboesophageal ganglion remains uninjured.

Kenyon (1896) investigated the brain of the honey bee, and explained the internal structure of the mushroom bodies in that insect. He confirmed the observations of Viallanes, showing that the cup cells are particularly well developed, and that the bodies are connected by fibres with every part of the brain.

Jonescu (1909) worked on the mushroom bodies of the honey bee and found the nerve cells in the cups to be differentiated into three groups, a median group of larger cells surrounded by two lateral groups in which the cells are smaller. He showed that these groups of cells send down fibres into the stalks, as well as fibrous tracts into the protocerebrum.

Miss Thompson (1913) investigated the brains of three genera of Ants and considers that the complex development of the mushroom bodies in these insects is further evidence that these bodies are "the chief motor and psychic centers of the brain," a "view held by investigators of the ant brain." She finds four groups of cells in the cups, and that the arrangement of the cell groups in the ants is homologous with that found by Jonescu in the honey bee. The fibre tracts arising from the cell groups vary in the different castes of the ants, the queen having more tracts than the worker or male. Miss Thompson points out that this difference in the number of fibre tracts is not due to size, since the mushroom bodies of the worker are larger than those of the queen in two of the genera, and about equal in the third. This therefore seems to indicate, she says, that the queen has the most complex and highest type of brain.

From all these observations it would appear that the development of the mushroom bodies is closely correlated to the intelligence in insects.

Their function has been compared to that of the cerebrum in Vertebrates

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Explanation of Plates

Fig. 1. Ventral view of Dissosteira carolina ♀ showing ventral nervous system and its connections.

Fig. 2. Frontal aspect of head of ♀ Lower right half shows labrum, and lower left half gives maxilla and labium.

Fig. 3. Sagittal view of head of ♂

Fig. 4. Ventral view of fifth abdominal ganglion of ♂

Fig. 5. Sagittal view of fifth abdominal ganglion of ♂

Fig. 6. Ventral view of fifth abdominal ganglion of ♀

Fig. 7. Sagittal view of fifth abdominal ganglion of ♀

Fig. 8. Part of alimentary canal showing the stomachic ganglion.

Lettering of Figures

Subscripts denote the number of the segments, except under al, where 1 and 2 refer to the meso- and meta-thorax respectively.

ag. Abdominal ganglia.

al. Nerves to the muscles of the tegmina and hind wings.

ant. Antennal nerve.

as. Nerves to the dorso ventral and dorsal muscles of the abdominal segments.

br. Brain

c. Cercal nerve.

cr. Nerves to the muscles of pro-, meso-, and meta-thoracic legs.

dt. Nerves to the dorsal muscles of the three thoracic segments.

f.g. Frontal ganglion.

fr. Frontal nerve.

g.a. Nerves to genital apparatus of male.

hyp. Nerve to hypopharynx.

lb. Labial nerve.

lbr. Labral nerve.

m. Nerve to maxilla.

md. Mandibular nerve.

me. Median nerve.

oc. Ocellar nerves.

oc.l. Ocellar lobe.

o.g. Optic ganglion.

o.l. Olfactory lobe.

ov. Nerves to sheath of ovipositor.

p.s.g. Posterior sympathetic ganglion.

sb.g. Suboesophageal ganglion.

st.g. Stomachic ganglion.

tg. Thoracic ganglion.

tr.c. Transverse or suboesophageal commissure.

v. Nerves to ventral muscles of the abdominal segments.

Part of a Thesis for the Degree of
Doctor of Philosophy

NORTH AMERICAN SPECIES
of the
GENUS SCELIPHRON

BY

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Amherst, June, 1915

Introduction

This paper has been prepared by the writer in the Entomological laboratory of the Massachusetts Agricultural College, Amherst as a part of a thesis for the Degree of Doctor of Philosophy. He here desires to express his debt of gratitude to Dr. H. T. Fernald for his valuable suggestions and kindly interest at all time during the progress of the work and for his trouble in securing material from many public and private collections in the United States; to Dr. G. C. Crampton for his ready help in the anatomical portion of the paper; and to Mr. Daniel G. Tower whose preliminary notes on these insects were at the disposal of the writer, and were of no small assistance. The writer is also under great obligations for opportunities to study material from the U. S. National Museum, the American Entomological Society at Philadelphia, the Brooklyn Museum, and the New Hampshire State College, which had been loaned to Professor Fernald through the kindness of those in charge of these collections, and also from Professor Herbert Osborn, Dr. J. C. Bradley and many others, which were obtained in a similar way.

General Characters

The insects of the genus Sceliphron of the sub-family Sceliphroninae found in North America are of medium to small size, varying from half an inch to an inch even within the same species. The wings are large in proportion to the somewhat slender body and the legs are long, especially the hinder pair. The surface of the body is almost completely covered with punctures varying in size and proximity to each other and with hairs differing in length and density on various parts of the body. It will be noticed that the nature of the punctation bears a close relation to the size and distribution of the hairs, in that each puncture usually has its corresponding hair, though some of these are rubbed off in older specimens. In other words the punctures mark the places of attachment of the hairs to the chitinous integument of the insect's body.

Some of these punctures are so small as to be visible only under a high powered lens and the corresponding hairs are very fine and usually decumbent. Such hairs may be seen on the dorsal segments of the abdomen and the terms "fine sericeous" or "sparsely sericeous" are applied to such areas. Similar minute but somewhat denser hairs are found on the legs and are called "sericeous" or"densely sericeous." These last are dark or whitish according to the species, while the "coarse sericeous" hairs found on portions of the fore- and hind-tibiae are always dark.

There are two regions in which the hairs are seen to lie flat down on the integument and are so closely set as to hide the ground color of the body, and give it a soft, satiny appearance when viewed from certain angles. The hairs in these regions are called "pubescent." One region is found along the sides of the clypeus and the frons where the hairs are silvery, and more developed in males than in females. The other region consists of two somewhat circular areas on the third and fourth ventral segments of the abdomen of Sceliphron cyaneum females, and the hairs in this instance vary from dark to pale brown when seen from different angles.

From the above description it may be noticed that the terms "sericeous" and "pubescent" apply to fine decumbent or semi-decumbent hairs and the chief point of distinction seems to be in their density and length, since the sericeous hairs are shorter and only partly disguise the color of the integument, while the longer pubescence may completely hide the underlying chitin.

The remaining portion of the vestiture of the body in these insects is composed of erect or nearly erect, more or less coarse hairs which are attached to distinct punctures of varying sizes and density of arrangement. In connection with this part of the vestiture the writer has used the terms "hairs" or "erect hairs" coupling with them various epithets to denote gradations in density and coarseness. The coarsest hairs are found on the clypens, the genae, the "end" and "sides" of the propodeum, the sternum of the mesothorax, and the coxae. The hairs on the "dorsum" of the propodeum,

the thoracic pleuva, the prothoracic lobes, the dorsal surface of the petiole and the undersides of the trochanters and femora are perhaps not quite so dense and coarse as those in the first class, but the gradations are so slight that no marked line of distinction can be drawn. The smallest erect hairs occur on the dorsal portion of the sixth or terminal segment of the female abdomen and along the sides of the ventral portions of the abdominal segments in males and females.

Certain areas of the integument are marked by more or less parallel grooves known as "striations", other parts by fine irregular raised lines enclosing shallow punctured areas and giving a condition known as "rugose".

These insects do not show any startling color markings or bands, the body being more or less evenly colored with shades of metallic blue, black, or green, sometimes with purple or violet reflections. As mentioned above, the actual body color is sometimes obscured by the closely set vestiture of fine pubescence.

The wings may be dark brown to pale ~~[illegible]~~ fuliginous even in the same species, or they may be hyaline with fuscous tips and in most cases ~~they~~ may show violet to bluish reflections in certain lights.

External Anatomy (See next page)

~~Analytical Keys~~

~~A very good working table of the families of the Sphegoidea is given by Ashmead[1] and should be consulted by those interested.~~

~~The following table of the subfamilies of the Specidae has~~

~~1. Canadian Entomologist XXXI, p. 152.~~

External Anatomy

Head

The head is medium to large, broader than high, and seen from above is transversely elongate. The compound eyes are large, somewhat oval bodies, extending from the sides of the vertex almost to the base of the mandibles.

Seen from in front they occupy together an area about equal to that which lies between them, while on a side view each eye covers about twice the area of the cheek which lies behind it. They are narrowest at the top where they are bluntly rounded, and gradually expand towards the bottom where they are broadly truncate with a slight emargination to receive the lateral extensions of the clypeus. The eyes may be nearer each other at the vertex than at the clypeus, as in females, or the reverse, as is the case in males of the species dealt with in this paper.

Clypeus. The clypeus is roughly a trapeziform plate lying below the antennae and occupying the lower central portion of the front of the head with its lower angles extending laterally under the compound eyes to form part of the articulation of the mandibles. On either side of the clypeus is a narrow downward extension of the frons bounded externally by the inner margin of the eye, internally by the lateral clypeal suture, and ending below in the lower of two foveae. A second or upper fovea is also present about half way to the top of the clypeus from this point close to the suture between clypeus and frons, but apparently in the latter plate. The lower

margin of the clypeus is normally tridentate, but the relative size and shape of the teeth varies in species and individuals. These variations will be noted under the descriptions of species. The lower margin of the clypeus is marked by a transverse to quite emarginate suture below the base of the antennae, and the lateral clypeal sutures may be continued upward as faint lines meeting between the antennal pits thus forming a small triangular area above the truncated apex of the clypeus, or these lines may end at the suture which is then distinctly emarginate and its ends curve upwards on each side almost to the base of the antennae. The central area of the clypeus is convex, with a more or less distinct median ridge, and is covered with rather long erect black hairs and closely set coarse punctures, and may be partially clothed with a silvery pubescence.

Frons. The frons lies between the clypeus and the ocelli but extends downwards on each side between the clypeus and the compound eyes and upwards on each side of the ocellar area as far as the ocellocular line. This is a line from the top of the compound eye to the lateral ocellus on each side. The sides of the frons extending along the inner margin of the compound eyes are somewhat sunken below the rest of the facial area and are closely punctate.

The frons as a whole is usually covered with coarse erect black hairs, and the sides are more or less clothed with fine silvery pubescence which is seen to the best advantage

from behind. A short median ~~incised~~ raised line runs from between the antennae to within a short distance of the median ocellus.

Ocelli. The three ocelli lie near the top of the head forming a triangle with the median ocellus, the largest of the three, below. The base of the triangle, or postocellar line, is always greater than the distance between the median and either lateral ocellus, and always less than the ocellocular line. The exact proportions vary with the species. The surface between the ocelli, or intraocellar area, is slightly raised and each of the ocelli has a slight depression at its outer base.

Vertex. Behind the ocelli is a shallow oblong depression, and posterior to this there may be a raised oval area, which might be regarded as the vertex proper, but in this paper the vertex is that part of the head bounded anteriorly by a line through the lateral ocelli, posteriorly by the occipital ridge and laterally by the genae and tops of eyes.

Occiput. The occiput is the narrow circular strip at the back of the head surrounding the occipital foramen, but is of no systematic importance.

Genae. The cheeks or genae are paired sclerites at the back of the head between the compound eyes and the occiput, and extend from the vertex to the base of the mandibles. They are narrowest at the top and gradually widen ventrally where they curve in on each side to meet between the occiput and the gular cavity, and extend laterally outwards under the eyes to meet the clypeal extensions.

The mouth parts with the exception of the mandibles do not appear to be of systematic importance but mention may be made of the labrum which is a narrow oblong strip attached under the lower edge of the clypeus. In pinned specimens it is usually hidden behind the closed mandibles, but if these are opened the labrum can be seen as a flap lying over the top of the other mouth parts.

Mandibles. The mandibles of females are long, rather curved, bluntly rounded at the tip, and may or may not have a tooth on the inner side according to the species. In males they are shorter and taper to a point.

The extension of the lower angle of the clypeus meets a corresponding extension of the genae and the two together furnish articulations for the mandible in the following manner. On the under part of the clypeal extension is a condyle which fits into a socket on the upper side of the mandible, while the genal piece has a facet to receive the condyle on the lower side of the mandible. There is also a median basal projection on the outer side of the mandible, serving as an attachment for muscles. This projection fits into an emargination on the lower margins of the clypeal and genal extensions when the mandible is closed, but swings inwards leaving the emargination empty when the mandibles are open.

Antennae. The antennae are situated in the middle of the frontal areaand articulate in two oval sockets facing obliquely outwards, thus giving the antennae a wide range. They are of medium length

consisting of 12 segments in the female and 13 in the male.

The proximal segment, or scape, is divided into a small basal portion, the bulb, which articulates with the head in an oval socket, and a larger part the scape proper. The latter is to all appearances a separate segment from the bulb, but the two parts are generally regarded as one segment. The true scape is somewhat oval and enlarges suddenly after its junction with the bulb, forming the thickest part of the antenna. The second segment, or pedicel is small, rounded proximally where it articulates with the scape and truncate distally where it joins the first segment of the filament. The remaining segments are known as the flagellum or filament and are more or less cylindrical. All the segments of the flagellum, except the last, are narrower at their proximal ends, the first being noticeably so formed. The first three segments are about the same length and either the first or second may be the longest according to the species. The remaining segments gradually decrease in length to the penultimate, which is the shortest. The last segment is slightly longer again and tapers distally to a more or less truncate end.
The antennae are dark in color, the scape and pedicel being either dark blue or dark green with strong hairs on the inner side, while the flagellum is dull black, but the covering of fine recumbent hairs may give it a greyish appearance.

Thorax

Prothorax. The prothorax falls naturally into two parts, a some-

what narrow anterior portion articulating with the head and known as the neck, and a broader part behind, which articulates with the mesothorax and is usually termed the collar. Seen from above the neck is flatly convex, narrow in front and widening posteriorly to fuse with the collar, and the angle of inclination of the dorsal surfaces to each other varies, being sometimes acute and sometimes a right angle. The anterior dorsal of the neck is slightly reflexed and is usually hidden within the occipital foramen into which the neck fits.

The ventral surface of the neck is shorter than the dorsal and is composed of two plates closely approximate along a median suture and together forming the episternum of Snodgrass. The anterior portions of these plates are narrow and concave and fit closely under the convex extension of the prothorax to form with it a short cylinder which fits into the occipital foramen, and gives the head freer movement. These plates widen posteriorly into two lobes whose posterior margins are convex and unite with the concave ventral surface of the collar to form articulations for the coxae. The small triangular sternum lies between the bases of the coxae and adds support to their articulations.

The dorsal surface of the collar is somewhat flat anteriorly, but slopes upwards ~~and~~ sometimes almost vertically to a rounded crest at the back which is divided by a median furrow into two lobes. The anterior dorsal surface may be slightly arched and almost horizontal so that it forms nearly a right

angle with the posterior surface, the lobes being rounded and not prominent, or it may form an acute angle with the posterior surface, in which case the lobes are rather sharp, with their crests higher than the mesonotum.

The posterior region of the collar is somewhat vertical and extends over the anterior margin of the mesonotum which has a broad median projection under it.

Between the lateral edge of the episternum and the anterior lateral margin of the collar is a very narrow plate called the epimeron which has been partly telescoped under the collar. This narrow strip appears to be the continuation of the anterior margin of the neck. The epimeron suddenly grows wider ventrally and extends to the base of the coxa on each side. The collar extends ventrally as far as the epimeron and its lower posterior margin projects over a portion of the mesothorax in the form of a semicircular lobe, called the prothoracic lobe by Fernald. This lobe touches the side of the mesonotum above and covers a depression on the mesopleuron at the bottom of which lies a spiracle.

Mesothorax. The mesonotum is a broad, rather sellate plate with its anterior margin articulating with the posterior margin of the collar and at the sides with the prothoracic lobe. Its lateral margins are somewhat emarginate to receive the tegulae and slightly reflexed while its broadly truncate posterior margin is closely applied to the scutellum. Lying between the

lateral margin and the median line on each side is a shallow groove starting from the posterior margin and extending forwards for about one third the length of the mesonotum.

Near the anterior end of each groove there is a curved incised line extending forwards for the middle third of the segment. These curved lines may be the parapsidal grooves. A short straight line can be seen lying along the anterior third of the median depression of the mesonotum. The scutellum is a rather narrow plate lying behind the mesonotum. It is distinctly raised in the middle and usually marked by a faint median depression. It has a lateral forward extension on each side as far as the base of the fore wings and tegulae broken by two deep cavities, a smaller one on each side of the raised central portion and a larger cavity from which the fore wings have been evaginated. These two cavities are separated by a sharp ridge. The mesopleuron is a large plate occupying the side of the mesothorax and extending obliquely from behind the prothoracic lobe to the base of the mesocoxa where it ends in an elevation evidently serving to prevent further dorsal flexure of the leg. The mesopleuron is bounded dorsally by part of the mesonotum, and by the overhanging edge of the scutellum, but its ventral limits are not defined. Its anterior margin shows a deep depression under the prothoracic lobe bearing a spiracle which is protected by the lobe, but its posterior boundaries are rather vague.

This plate is divided by morphologists into three parts, the pre-episternum, the episternum and the epimeron. The episternal groove is a shallow lateral depression marked by scattered ridges and separating the pre-episternum from the episternum. The epimeron has no definite limits, but lies in the broad depression extending obliquely down the sides of the body and marked by distinct foveae. This depression is known as the metapleural groove.

There is no apparent suture or line separating the mesopleuron from the sternum or ventral plate. The latter is a large plate occupying the ventral surface between the fore and middle coxae and marked by a distinct median suture with a shallow ~~depression around it~~ pit near each end. About halfway between this suture and the upward curve of the mesopleuron is a short line sometimes appearing distinctly incised with a shallow depression around it.

The episternal groove is continued ventrally on each side and curves forward to meet behind the bases of the pro-coxae. This groove divides the meso-sternum into the prepectus, or small portion anterior to the episternal groove, and the meso-sternum proper, which extends to the bases of the meso-coxae, whose articulations it bears.

Metathorax. The postscutellum is a narrow plate lying behind the scutellum to which it is somewhat closely applied and in front of the propodeum from which it is separated by a deep fissure. Its lateral extensions are from two to three times as broad as the middle portion, and have a deep cavity from which the hind wings arise, and a much shallower cavity on each side of the central portion of the plate. The posterior margins of

these lateral pieces are somewhat flanged and extend over the anterior margin of the propodeum and the dorsal edges of the metapleura. Outside the cavity of the hind wings on each side is a small oval protuberance, sometimes called the metapleural lobe.

The metapleuron is a somewhat indefinite plate with its dorsal portion lying obliquely under the hind wings and its ventral extending horizontally under the side of the propodeum. It is broad dorsally where its limits are well defined, but gradually narrows ventrally when its boundaries become rather indefinite, being more distinct in one species than the other.

The hind legs are both at the ventral posterior end of the metathorax with the small metasternal area lying between the coxal cavities.

Abdomen

The median segment or propodeum lies between the post-scutellum and the base of the petiole, and is bounded laterally by the metapleura. It is really the first segment of the abdomen which has become closely connected with the thorax, and it was regarded by early writers as part of the metathorax. Behind the propodeum is a very slender cylindrical petiole which suddenly enlarges near its posterior end to the size of the abdomen. The petiole and its enlarged posterior portion form the second abdominal segment proper but for our purpose it can be regarded as the first segment of the abdomen.

The propodeum therefore lies between the metathorax and the petiole and is fused with the former except for a dorsal fissure separating it from the postscutellum.

Its dorsal surface or dorsum extends from behind the postscutellum to the point where the body begins to slope ventrally towards the base of the petiole. This point is marked by a more or less distinct fovea or pit. The shape of the dorsum varies with the species, since its posterior margin may be evenly rounded, or its sides may converge to a point. Its surface may be more or less striated, and a median groove may be present or absent. On each side of the dorsum is a spiracle belonging to the propodeum; this lies in the anterior half of the segment in the line of the depression which marks the limits of the dorsum. The portion of the propodeum behind the dorsum is termed the end by Fernald. It extends posteriorly as far as the petiole and its hinder margin is strongly reflexed to prevent too great dorsal flexure of the petiole. The end is bounded laterally by a faint depression extending forward on each side from the base of the metacoxa to the stigma or spiracle. This is known as the stigmatal groove. Between this groove and the metapleuron is the remaining portion of the median segment, known as the side.

The somewhat slender petiole is usually narrower basally than distally. It varies in length usually with the size of the specimen, and has a slight downward curve. At the base of the dorsal side of the petiole is a small elevator muscle called the

funiculus. As mentioned above, the petiole is a slender cylinder for the greater part of its length, but enlarges dorsally near its hinder end to join the second segment of the abdomen. The sternal portion of the cylinder extends continuously to the sternum of the second abdominal segment with which it is connected by a membranous strip. The dorsal portion of the cylinder is shorter thus giving the petiole proper the appearance of being cut off obliquely and the intervening space between its posterior edge and the anterior dorsal edge of the second abdominal segment is covered over by a roundly convex plate. This plate may be regarded as the true notum and is hinged to the petiole proper along its anterior dorsal edge by a thinly chitinized strip, thus allowing considerable flexion along that region. The notum sends down a flap on each side which extends below the edge of the sternum but is connected with it on the inner side by a membrane, so that the lower portion of the flap is free on each side. The posterior margin of the notum widens out to fit over the anterior margin of the second abdominal segment, and between the two plates is a thinly chitinized strip similar to those found between any two other abdominal segments.

The modification of the petiole may be interpreted as follows. The cylindrical portion is possibly the result of the gradual curling up of the sternum and pleuron on each side and the ultimate dorsal fusion of the pleura to form a solid tube. During this process the notum appears to have been

gradually pushed backwards until it finally came to occupy its present position as a convex plate fitting over the distal end of the cylinder. The above is only a brief suggestion as to the process through which the petiole may have passed in order to reach its present highly specialized condition, but this subject is of sufficient interest to be worked up from a morphological standpoint.

The portion of the abdomen behind the petiole is of normal size widening suddenly to a somewhat ovate form. In females the tip of the abdomen is dorso-ventrally flattened to a blunt point, while in males the tip is more or less truncate and curved under. In females six segments are visible dorsally and ventrally, while males show seven on top and eight below. The spiracles are on the anterior dorso-lateral portion of the segments and occur on all the segments in females and males, but usually only those on the first two segments are visible in pinned specimens. The third and fourth ventral segments of the female may or may not have pubescent spots on their ventral surfaces and the posterior margin of the third ventral segment may be sinuous or almost straight, according to the species. In males the fourth and fifth segments are finely pubescent along their posterior margins and the third and sixth may be slightly pubescent also. These segments are flattened or even concave giving the abdomen a compressed appearance ventrally. The genitalia are usually withdrawn inside the posterior segments so as to be almost completely hidden. In conjunction with other characters they may be used in separating males, but they

have not been so employed in this paper. The sixth or terminal segment of females is modified to protect the genitalia, and at the same time to allow them free play. The ventral portion of the terminal segment is longer than the dorsal and its tip is somewhat squarely truncate. It has a flap on each side which fold together dorsally, while the triangular dorsal portion fits over the basal part of the segment.

Wings

The wings are of medium size and may be either hyaline and fuscous at the tips, or evenly colored in varying shades of brown showing blue violet in certain lights. In this paper the nomenclature of veins and cells given by Cresson and used by Fernald in his North American Digger Wasps has been followed, ~~and Comstock's System of Nomenclature is also included.~~ It is not proposed to give a general description of the wings but the characters of systematic importance will be mentioned in the table for separation and under the descriptions of the species. A reference to the figures at the end of this paper will furnish all the necessary details.

Legs

The legs are long and slender especially the hind pair, and in addition to the hairs and spines mentioned below, all the segments are clothed with a fine to coarse sericeous hairs, dark or whitish according to the species.

All the coxae are clothed with somewhat long hairs but have no spines; the fore- and middle-coxae are both smaller than the hinder pair, which articulate closer together than either of the other two pairs. The trochanters are all smaller than their corresponding coxae and have scattered hairs mostly on the inside. The femora in the three pairs of legs are all stouter than the tibiae with which they articulate but while the fore and middle femora are distinctly longer than the corresponding tibiae, the hind femur and hind tibia are about equal in length. The femora have no spines but are covered with rather long hairs on the inside. Round the tip of each tibia is a circle of small spines two of which are usually longer than the others, and each tibia usually has a row of small recumbent spines all its sides. The fore and hind tibia has a densely sericeous area, the former in a small strip on the inside near its distal end, and the latter in a narrow strip along its outer side. The fore tibia has a large somewhat modified spine with a chitinous blade and some fine hairs on its inner surface. This spine runs parallel to the first tarsal segment which has a similar modification on its outer side. This structure forms a cleaning apparatus. The middle and hind tibiae each have two strong spines of unequal length, but only the hind tibia has a cleaning apparatus which is a little different to that on the fore-tibia as will be seen from a comparison of the figures. The tarsus in each leg consists

of five segments the first of which is much longer than any of the others and is called the metatarsus. All the tarsal segments are covered with closely set spines, those at the distal ends being longer than the others.

The last tarsal segment is provided with a pair of strong curved claws, between which is well developed pulvillus. On the inner side of the claws near their bases there are usually two or three fine [redacted] hairs one longer and stiffer than the others, while about the middle of the inside of the claw there may be a small tooth. These teeth occur only on the claws of the fore- and middle legs in these insects.

Sensory Areas on the Antennae of these Species

In the females of both cyaneum and zimmermanni all the segments of the filament have somewhat irregularly oblong apparently bare regions lying along their inner sides when the antennae are held curled forward. These areas appear slightly depressed and usually darker than the remaining parts of the segments owing to the absence of the fine recumbent hairs with which the other portions are covered. When the antennae are cleared and mounted the above areas are seen to be covered with pits and hairs of various sizes probably of a sensory nature. The structures on the male antennae appear to be more complicated since in addition to depressed regions along the inner basal portion of each filamentous segment they have somewhat oval to oblong, bare, brown to blackish areas on the distal

end of these segments. These areas when cleared are seen to be covered with small pits and hairs closely packed and are a distinct contrast to the larger and more scattered pits on the inner basal portions of the segments. These brownish areas occur, as far as could be determined, only on the seventh, and eighth segments in cyaneum and on the seventh, eighth and ninth and occasionally sixth segments in zimmermanni, and vary in size and shape. In both species there are also minute slightly raised areas near the basal end of all the segments of the filament, but the nature of these is undetermined. They are seen on the upper part of the inside of the segments when the antennae project forward.

Analytical Keys

A very good working table of the families of the Sphegoidea is given by Ashmead[1] and should be consulted by those interested. The following table of the subfamilies of the Sphecidae has

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1. Canadian Entomologist XXXI. p. 152

been taken from those given by Ashmead[2] and by Fernald[3] with slight variations in connection with the subfamily Sceliphrominae.

Analytical Key to Subfamilies

1. Second cubital cell receiving only the first recurrent vein; the second recurrent vein received by the third cubital cell, or at least beyond the second transverse cubital. (Both recurrent veins are received by the first cubital cell in a few extra-limital forms. .....2.

Second cubital cell receiving both recurrent veins, or the second recurrent vein is interstitial with the second transverse cubitus, although sometimes the first recurrent is interstitial with the first transverse cubitus, or then received by the first cubital cells.....3.

2. Antennae inserted on the middle of the face; claws with one to six teeth beneath tibiae strongly spinous, or at least never with weak or feeble spines; tarsal comb in female present (except in Isodontia).....Chlorioninae (Sphecinae Authors)

Antennae inserted far anterior to the middle of the face; claws simple, without teeth, or at most with a single small tooth near the middle; tibiae smooth, not spinous; tarsal comb in female never present.....Podiinae

3. Claws simple, without a tooth beneath; tibiae more or less spinous; tarsal comb in female present; abdomen most frequently very elongate, the petiole composed of two segments rarely only of one segment; cubital vein of hind wings usually originating beyond the

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2. Idem p. 348
3. Digger Wasps of North America. Proc. U.S.Nat.Mus. XXXI, p.308.

transverse median vein.

Sphecinae (Ammophilinae Authors)

Claws simple with a single tooth beneath, although sometimes very minute; hind pair with or without a tooth; tarsal comb in female absent; abdomen always with one-segmented petiole; cubital vein of hind wings intertitial or nearly so.....4.

4. Antennae inserted on the middle of the face; metathorax with a large V-shaped area above; mesopleura not longer than the height of the thorax.....Sceliphroninae.

Antennae inserted far anterior to the middle of the face, on or just above an imaginary line drawn from base of eyes; metathorax without a large V-shaped are above; mesopleura much longer than the height of the thorax.....Podiinae.

Key to Genera of Subfamily Sceliphroninae.

Second cubital cell receiving both recurrent veins.

Species black and yellow, not metallic; clypens flat, at apex bidentate; transverse median vein in front wings not interstitial with basal vein but uniting with the median vein a little before the origin of the basal nervure; petiole of abdomen about twice as long as the median segment.....Pelopaeus, Latr.

Species metallic blue or violaceous; clypens normally 3-dentate anteriorly, transverse median vein in front wings interstitial with the basal vein; petiole of Abdomen not longer than median segment..Sceliphron, Klug

Table of Species

1. Females.....2

   Males.....3

2. Abdomen with pubescent spot on third and fourth ventral segments; body hairs almost entirely dark.....cyaneum Kl. (p.26).

   Abdomen without pubescent spot on third and fourth ventral segments; whitish hairs on dorsum of median segment..zimmermanni Dahlb (p.

3. Body dark blue black or blue green hairs almost entirely dark.....cyaneum Kl.

   Body paler, hairs almost entirely whitish, wings fuligi-nous to hyaline with fuscous tips.....zimmermanni Dahlb.

Genus Sceliphron Klug

Sceliphron Klug, Neuschrift Ges. Naturf. Freunde, Berlin III.1801, 561

Chalybion Dahl., Hym. Eur. I. 1843, 21.

Chalybion Patton, Proc. Bost. Soc. Nat. Hist. XX. 1880, 378 (desig.Patton).

Genotype - Chalybion caeruleum (= cyaneum Dahlb. desig. Patton)

Body metallic blue black or blue green, sometimes with violet reflections. Clypeus normally tridentate, but teeth vary in size and shape. Metapleural sutures indistinct. Claws of posterior tarsi unarmed. Petiole of abdomen somewhat variable in length, but never as long as median segment.

The genus Sceliphron was established in 1801 by Klug who included five species under it viz: spirifex, madraspatanum, lunatum, cyaneum and fuscum. In 1802 Latreille[1] established the genus Pelopaeus

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1. Hist. Nat. Crust. et Ins.III. 334

giving Sphex spirifex L. and S. lunata F. as examples, and in Vol. XIII of the same work (1805) besides describing these species under Pelopaeus, mentioned that Klug had called the genus Sceliphron. In 1843 Dahlbom[2] established the genus Chalybion, separating it from Pelopaeus on a color basis with violaceum F., zimmermanni n. sp., and cyaneum L. as species, and at the same time included spirifex, lunatum and several other species under Pelopaeus. Two years later in his tabulation of species on p. 432 of the same work he mentioned Pelopaeus as a genus with Chalybion and Pelopaeus as sub-genera, since no additional characters could be found to justify separation. Chalybion remained under Pelopaeus until 1880 when Patton[3] gave distinctive characters in addition to color, sufficient in his opinion to establish Chalybion and Pelopaeus as separate genera, and with this the writer agrees.

It will be noticed that the species removed from Sceliphron by Latreille are black and yellow while cyaneum remaining is blue, and fuscum apparently unknown to modern workers. Accordingly the separation of Pelopaeus from Sceliphron leaves cyaneum as its type in accordance with recommendations k. and n. of the International Rules of Nomenclature. Patton's designation of cyaneum as the type of Chalybion would therefore make this genus a synonym of Sceliphron as restricted by the removal of the species placed under Pelopaeus by Latreille.

Pelopaeus californicus Saussure is regarded by the writer as conspecific with cyaneum, since he has examined a number of specimens from California, all of which are similar to cyaneum and he does

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2. Hym. Eur. I. 1843, 21.
3. Proc. Bost. Soc. Nat. Hist. XX 1880 378.

not consider the shorter petiole of sufficient importance to justify separation. In this the writer agrees with Patton.

Descriptions

Sceliphron cyaneum Klug.

It has been found advisable to give only the more important references on this species.

Sceliphron cyaneum Klug, Neuschrift Ges. naturf. Freunde, Berlin III. 1801, 561.

Pelopaeus cyaneus Lepeletier, Encycl. Method. Ins. X. 1825-33.

Chalybion cyaneum Dahlbom, Hym. Eur. I. 1843, 21.

Pelopaeus (Chalybion) cyaneus Dahlbom, Hym I. 1845, 432.

Pelopaeus caeruleus Lepeletier, His. Nat. Ins. Hym. III. 1845, 320.

Pelopaeus caeruleus, Jones, Naturalist in Bermuda. 1859, 113.

Pelopaeus (Chalybion) caeruleus Saussure, Reised. Novara. Zool. II. 1867, 26.

Pelopaeus (Chalybion) californicus Saussure, Reise d. Novara. Zool. II. 1867, 26.

Pelopeus californicus Saussure - Patton, Proc. Bost. Soc. Nat. Hist. XX, 1880, 379.

Chalybion caeruleum Patton, Proc. Bost. Soc. Nat. Hist. XX, 1880, 378.

Pelopaeus caeruleus Provancher, Natural. Canad. XIII, 1882, 12.

Pelopaeus caeruleus Provancher, Faun. Entom. Candd. Hym. 1883, 613.

Chalybion caeruleum Cameron, Biol. Centr.Amer. Hym. II, 1888, 25.

Chalybion (Pelopaeus) californicum Saussure, Cameron Biol. Centr. Amer. II, 1888, 25.

Chalybion caeruleum Schwarz, Proc.Ent.Soc.Wash.I. 1890, 254.

Pelopaeus caeruleus Peckhams Wis. Geol. and Nat.Hist.Surv.Bull.2, 1898,176, pl.II. fig.5; Pl.X, figs. 1-3.

Types. There is a specimen (seen by Fernald in 1913) in the Berlin Museum bearing a label cyaneus from North America and stated by the authorities there to be in Klug's handwriting. It is a small male undoubtedly of this species. No specimens in that collection were found which appear to have been labeled by Dahlbom. At Lund are eighteen specimens, the first marked "Chalybion caeruleum, Sphex Lin. Pelopaeus Pelet. ♂ ♀ New York." This specimen is a male and it is to be inferred that Dahlbom at the time of labelling this specimen was confusing it with Chlorion caeruleum. This confusion has already been discussed by Fernald (Ent. News XV. 1904, 117).

The types of californicus Sauss. have not been seen, but are presumably at Geneva.

The following description has been made from fifteen females and the same number of males selected from a large number of specimens and covering as wide a distribution as possible.

Metallic blue black or blue green, sometimes with purple reflections especially on legs and abdomen; head and body except abdomen thickly pilose, pubescence silvery on sides of frons, dark on third and fourth ventral segments of famale abdomen; remainder of body covered with fine dark sericeous hairs more or less concealed by pilosity except on legs and abdomen. Wings varying from pale to dark fuliginous.

Female. Head across the eyes broader than thorax across the tegulae; clypeus sloping abruptly at sides down to depressed areas

of frons, somewhat flat in centre with surface closely punctured and covered with dark erect hairs and finer dark sericeous hairs; these are best seen from the side and vary in density with individuals; anterior margin of clypeus black, extending laterally under the eyes, armed near the middle with three blunt teeth, (the median tooth generally the smallest), and a small lateral process on each side varying in size but never as large as the central teeth; a row of strong black hairs projects forwards over the teeth; posterior margin concave, bending round at the sides to join the clypeal sutures which form the lateral boundaries of the clypeus; central portion of clypeus with a median line appearing as an irregular shiny strip; surface of frons channelled on each side of the antennal elevation and clypeus; these depressions together with the antennal region are closely punctate, the punctures being somewhat confluent and smaller than those on the clypeus with correspondingly smaller hairs; there is also a fine silvery pubescence on the sides on the frons seen best from behind; antennal region divided by a distinct median elevated line extending from between the antennae to within a short distance of the median ocellus; intra- and circum-ocellar areas finely punctured and with small erect black hairs; surface of vertex rather sparsely punctured with a few long black hairs on a slightly raised area behind the ocelli; occiput covered with fine punctures and shorter black hairs, sometimes densely sericeous; genae clothed with long erect black pilosity interspersed with fine sericeous

hairs thickest along the hinder margins of the eyes and the lower portions of the genae and giving these parts a coppery reflection when seen from behind; inner margins of compound eyes more concave than those of males and more convergent posteriorly than anteriorly; antennae - scape and pedicel blue black or blue green, generally metallic with a few black hairs mainly on inner side and surface covered with very fine dark hairs; flagellum or filament dull sooty black or greyish black owing to the presence of minute recumbent hairs; first segment of the filament usually slightly the longest, the remaining segments very gradually decreasing in length until the last which is usually a little longer than either the penultimate or ante-penultimate; last segment tapers distally but is somewhat squarely truncate at its distal end; mandibles long, narrow, curved, without teeth, rather bluntly pointed; sometimes worn down so as to be roundly truncate at tip, black or blue black for basal half, gradually shading to pale brown at distal end, with a groove along upper and lower margins, sometimes with fine hairs, and a strong groove at external basal end with a few stout black hairs; there is also a row of short hairs on the inner face but these are usually hidden when the mandibles are closed.

Thorax. Neck may be slightly rugose with sparse punctures and small hairs; collar narrower than remainder of thorax, sides almost vertical, laterally compressed with a central depression ending dorsally in a deep fovea; the anterior dorsal surface may form an acute angle with the posterior surface making the lobes somewhat sharp, or it may slope gradually upwards making these more

rounded; median dorsal groove may be transversely striated; dorsal surface, sides and episterna strongly punctured and covered with erect black hairs interspersed with a fine brownish vestiture; prothoracic lobe with small scattered punctures and hairs, posterior edge fringed with short delicate pale brown hairs; mesonotum with a distinct median depression for its anterior half, surface strongly and closely punctate and covered with somewhat erect black hairs; scutellum also with median groove, but not so closely punctured as mesonotum, postero-lateral margins of lateral depressions fringed with fine pale brown to silvery hairs; postscutellum finely punctured in centre, lateral extensions fringed posteriorly with small light brown to whitish hairs; mesopleura and mesosternum covered with strong punctures and coarse black hairs interspersed with minute coppery hairs; metapleura and metapleural grooves somewhat sparsely punctate; the latter sometimes almost bare and shiny; median segment—dorsal shield bounded by a linear U-shaped depression and broadly rounded at posterior margin where there is a small but deep fovea; this depression may be transversely marked by ridges on each side both anterior and posterior to the spiracle, but these raised lines usually end where the sides begin to curve round posteriorly; dorsum with a distinct median depression, rather faint anteriorly where the shield has a gradual upward slope, surface of shield usually with no markings other than rather small often confluent punctures, but may be rugose, hairs medium sized; sides and end

usually with more distinct punctures small at sides of shield, coarser at posterior end pilosity to correspond; petiole stouter at distal end before suddenly enlarging to size of abdomen, punctures fine, hairs slender and rather scattered, finely sericeous mainly in upper distal surface. Abdomen of medium size somewhat ovate shining, arched dorsally, flatter ventrally, pointed behind, almost the whole dorsal and ventral surfaces covered with minute dark recumbent hairs giving the abdomen a dirty appearance in certain lights without obscuring the body color; first three dorsal segments without coarse punctures or stout hairs, last three with small punctures and scattered hairs, a row of fine punctures along the hinder margins of the first two of these segments, but the corresponding hairs very rarely complete; sixth or terminal dorsal segment with a group of small punctures and hairs on each side nearest the anterior margin, but central portion bare except for minute hairs; sixth or terminal ventral segment with a narrow punctate strip on each dorsal flap sparsely covered with small hairs of varying sizes, ventral surface covered with fine hairs except for a bare median strip; fifth ventral with a few scattered punctures and hairs; fourth with a black or brown pubescent area on the middle of the posterior part of the segment and a few hairs on each side (Fig. 4); third bears a smaller similarly colored pubescent area and a deeply sinuate double row of hairs extending across the segment behind the pubescent area, but if the abdomen is at all telescoped these cannot always be seen; posterior margin of third segment sinuate;

second segment with a V-shaped double row of hairs; in all of the above cases the hairs may be missing but the punctures can still be seen.

Wings vary from pale to dark fuliginous with violet to purple reflections except at tips which are dull and sometimes darker than the basal portion of the wing; forewing has no distinctive characters apart from those shown in the figures; tegulae blue green or blue black, sometimes with purple lights, shining, paler at margins, finely sericeous for basal half, hairs dark; hind wings, angle between median and transverse median usually greater than a right angle; discoidal leaves cubital slightly exterior to junction of median cubital and transverse median.

Legs colored with various shades of blue, black or green sometimes with metallic purple reflections; coxae and trochanters blue black or greenish black, sometimes dull purple in old specimens, strongly punctured especially on ventral side, with long black hairs and fine brown sericeous vestiture; femora and tibiae colored much the same as the preceding segments, femora with rather long black hairs on ventral side and minute brown hairs over the whole surface, fore- and hind-tibiae finely sericeous, with a coarser brown cericeous area along inner surface; tarsi may be dark to purplish or the sericeous hairs may give them a brownish appearance; claws dark brown for basal half, paler at tips; spines on legs black to brown.

Male - Differs from female as follows:

Body usually more hairy; eyes more approximate below than above; clypeal teeth small and rather pointed, no side processes; frons less sunken at sides of clypeus; mandibles of medium size, pointed at tip; antennae with thirteen segments; second segment of flagellum longer than first; dorsal lobes of collar usually somewhat more acute; abdomen more compressed ventrally especially the last few segments, tip curved under; seventh or last dorsal segment evenly rounded, covered with short black hairs chiefly at sides, hinder margin bearing a pair of genital palpi one on each side, sixth, fifth, fourth and third dorsal segments with one sometimes two rows of small punctures near hinder margins but corresponding hairs often absent; eighth or terminal ventral segment usually drawn in so that only the lobed distal portion projects beyond the hinder margin of the seventh ventral and covers the anal opening; this lobe is here termed the hypopygium, but has been given various names by different authors; it is covered with short erect hairs seen best in profile; seventh ventral segment bare, sixth finely sericeous; fifth and fourth finely sericeous in centre, punctate at sides; third with anterior margin sericeous and a sinuous row of punctures anterior to it; second with a deeply sinuous row of punctures and hairs.

Length Females 15-23 mm; males 12-18 mm.

Distribution This species is widely distributed throughout North America and the writer has examined specimens from Southern Canada, the Eastern United States from Maine south along the east coast to Florida, then west through the Gulf States to Southern

California as far north as San José, then east again through Nevada, Utah and north to the Great Lakes. This insect also occurs in South-eastern Montana but, as far as the writer knows, does not extend over the Rocky Mountains to the northern Pacific coast region. He has also seen specimens from the central Gulf Coast of Mexico.

This species therefore, as known to the writer, seems to be entirely an Austral form occurring mainly in the Upper and Lower Austral with occasional specimens in the Transitional.

Habits. The members of the sub-family Sceliphroninae are collectively known as Mud-daubers, and this beautiful species is called the Blue Mud-dauber. The females can be noticed during the early summer months flying in and out of barns, outhouses, porches or any sheltered place, and if followed up may be seen at work on their small earthern nests which are usually placed fairly high up near the roof.

The writer has had little opportunity of studying the habits of these insects, so that he cannot do better than give a short summary of the interesting observations made by Mr. and Mrs. Peckham[a] on the habits of this species, then known as Pelopaeus caeruleus. These observations were made over a period covering a number of years and are of great interest and importance, especially those on the methods employed by the wasps in capturing and stinging their prey.

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a. Instincts and habits of the Solitary Wasps by G.W. and E.G. Peckham. Wis. Geol. and Nat.Hist.Survey.Bull. No.2. Sci. Ser. No. 1. 1898, p. 176.

On appearing in the early summer the female selects a spot for her nest which is always built of damp earth and soon hardens to the required firmness. She digs the mud with her mandibles "forcing her head down into the soil and raising her body into a nearly vertical position." She carries the mud to the building site in her mandibles and moulds it while still soft into the required shape "using her mouth, mandibles and feet." The authors found that it took from thirty-two to forty loads to complete a cell, each load making about half a ring in the larger parts or a whole ring near the bottom of the cell. The completed nest usually consists of six or more cells on the average placed against each other to form a mass which is then daubed over with small pieces of mud so that the contour of the rings is hidden. The great majority of the cells are placed in a vertical position with their openings on top. The cells are provisioned with spiders, a few large ones or many small ones being crammed into one cell, and the "legs of the spiders bent in all directions without regard either to their comfort or their life." The spiders are caught and held by the mandibles and forelegs, then stung first by the wasp in flight apparently at random, and a second time after alighting nearby the place of capture. This second sting is usually given on the under side of the cephalothorax. The authors came to the conclusion that the wasp uses her sting "rather to overcome any resistance that she may encounter than to paralyze the spider and thus keep it fresh. To her it is a matter of indifference whether the spiders

are killed or paralyzed and either result may follow."
Mr. and Mrs. Peckham made an examination of a large number of recently provisioned cells of various species of Pelopaeus and found most of the spiders dead while the others, although reduced to a state of quiescence, were alive and would respond to stimulation by a quivering of the tips of the legs, but as a rule did not live very long.

Sceliphron Zimmermanni (Dahlbom)

Chalybion Zimmermanni Dahlbom Hym. Eur. I. 1843, 22.

Pelopaeus (Chalybion) Zimmermanni Dahlbom Hym. Eur. I. 1845, 433.

Pelopaeus (Chalybion) aztecus, Saussure Reise d Novara Zool. II P.I. 1867 Hym 26.

Pelopaeus (Chalybion) zimmermanni, Saussure Reise d. Novara Zool.II. P.I. 1867 Hym 26.

Pelopaeus texanus Cresson, Trans. Amer. Ent. Soc. IV. 1872. 210.

Chalybion Zimmermanni Patton Proc. Bost. Soc. Nat. Hist. XX. 1880, 379.

Chalybion texanum Patton, idem.

Chalybion aztecum Patton, idem.

Chalybion zimmermanni Cameron, Biol. Centr. Amer. P. 71. 1888 Hym II. 25.

Chalybion aztecum Cameron, idem.

Types. Dahlbom evidently described zimmermanni from at least two specimens since he records both male and female. In the Berlin Museum there is a specimen labelled with this name, but so far as could be ascertained by Fernald who examined it in 1913, the only difference from cyaneum was that the dorsum of the propodeum was

slightly cross striate which, as has been shown, is not distinctive. At Lund there are several specimens the first a male being labelled "Zimmerm N. Amerika" on the upper label and "Zimmermanni Dlbm. sp. ign." on the second. On the dorsum of the propodeum of this specimen are traces of transverse ridges, the thoracic hairs are white and wings quite fuliginous. Another specimen is labelled "E Sud Carolina a Zimmermann". The writer is inclined to regard the first named specimen from Lund as representing at least one of the original specimens used by Dahlbom and the one at Berlin as not zimmermanni at all.

The types of aztecus Sauss. have not been seen but are probably in the Saussure collection at Geneva.

Texanus Cress. was described from two specimens called female and male. No females with clear wings are known and a re-examination of material at Philadelphia by Mr. Cresson shows that he designated one of them as female by error. Two specimens labelled "type" in the U. S. Museum are in reality paratypes.

This species has been redescribed from seven females and fourteen males from the localities mentioned in the habitat.

Female. Medium sized, dark blue or blue green, coarser pilosity everywhere dark except on dorsum of median segment where it is whitish, finer hairs silvery to whitish; no pubescent spots on third and fourth ventral segments of abdomen; mandibles unidentate; wings fuliginous.

Head similar to that of cyaneum in general shape; clypeus usually somewhat flat at sides, arched in centre, with median ridge,

surface distinctly punctured, pilosity only moderately dense, silvery pubescence on sides, anterior margin black with narrow extensions under the eyes, three rather pointed teeth, no lateral processes, posterior margin broadly truncate and slightly emarginate; frons not so deeply sunken as in cyaneum, distinctly punctured, moderately covered with erect black hairs; a fine silvery pubescence clothing nearly all the sunken area of the frons; ocelli with distinct grooves at outer bases; vertex sparsely punctured, erect hairs rather few, finer hairs whitish; genae distinctly punctate, moderately dense hairs interspersed with fine sericeous vestiture; inner margin of compound eyes distinctly concave near upper end, gradually convergent towards clypeus for lower half, eyes usually more approximate below than above; antennae - scape black with metallic blue green reflections, a number of rather short hairs mostly on inner surface, finer sericeous hairs vary from silvery to pale brown, pedicel with a few small hairs on inner surface; flagellum dull black with a dense covering of fine recumbent hairs giving it a black to greyish appearance according to the light; first segment of flagellum distinctly narrower proximally and shorter than second, remaining segments only very slightly narrower proximally last segment not cut off truncately as in cyaneum but tapering to a blunt point; mandibles of medium length with one rather wide tooth on inner margin not reaching to the tip; a row of four or five stout hairs on outer side and about twice that number on inside.

Thorax. Anterior surface of collar with a steep upward slope to the somewhat acute crests; and distinctly rugose at anterior end, dorsal lobes small and separated by a shallow depression; punctures small and scattered, pilosity finer and smaller than in cyaneum, sericeous hairs pale to whitish; median depression on sides of collar not ending abruptly in a fovea but continued above to the groove between neck and collar; prothoracic lobe with a fringe of pale brown hairs; median depression on mesonotum faint or absent; depressions at posterior sides of mesonotum not as strongly marked as in cyaneum; scutellum may have a slight median depression; posterior margin of lateral pits fringed with silvery white hairs; postscutellum with small punctures, posterior margin with a few white or pale hairs; median segment - anterior margin of dorsum flanged, posterior margin more pointed than in cyaneum, whole surface of shield transversely striated or rugose and without median depression, hairs rather delicate, whiter at sides along the outline of dorsum.than in the centre; posterior end of dorsum sloping more gradually to hinder margin than in cyaneum, surface with irregular striations, punctures confluent, numerous dark hairs; stigmatal groove not well marked, sides of dorsum strongly punctate behind, smaller punctures anteriorly; mesopleura and mesosternum with deep punctures and long black hairs; metapleura distinctly punctate except along metapleural groove which is somewhat bare and shiny, lateral oblique depression shallower than in cyaneum; petiole slightly shorter and

more slender than that of cyaneum, punctures and hairs scattered, chiefly on basal half, finely sericeous mostly on upper half of distal end.

Abdomen medium to small, rather ovate, paler blue than in cyaneum, shining, with minute white recumbent hairs scattered evenly over the dorsal surface, first three dorsal segments without dark hairs, fourth and fifth with a few scattered punctures and dark hairs; sixth or terminal segment with hairs near posterior margin, bare along median line, dorsal segment may almost cover ventral; tip of abdomen a little more slender than in cyaneum; ventral segments - dorsal flaps of terminal segment (where visible) with dark hairs along the sides, thinner or almost absent along the median line; fifth to third segments with a double sinuate row of fine punctures, but hairs only scattered; third and fourth without the pubescent areas present in cyaneum; second with a V-shaped double row of punctures with apex pointing forwards, but corresponding hairs not complete.

Wings similar to those of cyaneum but without such a range of brown shades in the few specimens available; forewings as in figures; tegulae with white sericeous hairs; hind wings - angle between median and transverse median about a right angle; discoidal leaves cubital slightly more exterior to junction of median, cubital, and transverse median than is the case in cyaneum.

Legs. Segments with same general features as in cyaneum, somewhat paler blue; coxae, trochanters, and femora covered with fine white recumbent hairs; fore- and hind-tibiae with a dense pale

brown sericeous area especially noticeable on hind-tibiae; fine hairs white on other parts of tibiae; tarsi with rather pale sericeous hairs.

Male. Differs from female as follows:

Body color paler blue; vestiture of body denser and hairs everywhere white except on face and genae and some of the ventral segments of abdomen; the approximation of the eyes across the clypeus is more noticeable than in female giving the face a narrower appearance below than above; middle tooth of clypeus more prominent than laterals, which are small and rudimentary; mandibles without tooth, of medium length, stout at base, tapering to a point; wings varying from somewhat dark fuliginous to hyaline with fuscous tips; abdomen more compressed ventrally and curved under at tip, similar to that of cyaneum male in general features except that the fine sericeous hairs are whitish.

Length. Females 16 - 20 mm. Males 12 - 19 mm.

Habitat. Dahlbom mentioned that "Zimmermann caught this elegant species in South Carolina, North America" and it has been reported from Michoacan; Cordova; Atoyac in Vera Cruz; Ventanas; Valladolid in Yucatan; and Teapa in Tabasco. Specimens have been examined from Elkin, N. C.; "Loui"; Texas - Dallas Co.; Cypress Mills; Austin; Comal Co; Brownsville; from "Mex"; Alta Mira, Tampico, Mexico; San Antonio, Nicaragua; and ~~"Patapa"~~ Teapa? These localities seem to show that it is mainly a lower Austral form with occasional specimens from the Tropical Zone and a possible occurrence in the Southern part of the upper Austral. No records of the habits of this species as such have been found by the writer.

Explanation of Plates

The following figures were drawn by the author in most cases with the aid of a camera lucida, and are only intended to be diagrammatic.

Fig. 1. Dorsal view of thorax of Sceliphron cyaneum

Fig. 2. Lateral view of Sceliphron cyaneum

a , prothorax

a_1, neck

a_2, collar

ac, anterior coxa

b , mesothorax

b_1, mesonotum

b_2, scutellum

b_3, mesothoracic episternum (including pre-episternum and episternum)

b_4, episternal groove

b_5, mesothoracic epimeron

c , metathorax

c_1, postscutellum

c_2, metapleuron (including metepisternum and metepimeron).

c_3 metathoracic epimeron

c_4 metapleural lobe

d , median segment or propodeum

d_1, dorsum

d_2, end

d_3, sides

d_4, stigma or spiracle

d_5, fovea

d_6, stigmatal groove

f , funiculus

fw, forewing

hw, hindwing

l , lobe

mc, mesocoxa

p , petiole

pc, posterior coxa

s , stigma or spiracle

st, sting

t , tegula

1 - 6 abdominal plates.

Fig. 3. Ventral aspect of abdomen of Sceliphron cyaneum female showing the pubescent spots on the third and fourth segments. Lettering as above.

Fig. 4. Frontal view of head of Sceliphron cyaneum female.

Fig. 5. The wings of Sceliphron cyaneum with the cells named according to the usual nomenclature.

Fig. 6. The same wings with the veins named according to the usual nomenclature.

Fig. 7. Fore tibial comb spine of Sceliphron cyaneum.

Fig. 8. Hind tibial comb spine of Sceliphron cyaneum.

Fig. 9. Antennae of Sceliphron cyaneum female.