Studies in the Genus Pepsis: (Hymenoptera: Psammocharidae)

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Thesis for degree Doctor of Philosophy, Massachusetts Agricultural College

Kenneth A. Salman
PART I

STUDIES IN THE GENUS PEPYSIS

(Hymenoptera: Psammocharidae)

Kenneth A. Salman

A section of a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at the Massachusetts Agricultural College, Amherst, Mass.

1930
Part one of this thesis is concerned with the morphology and taxonomy of a genus of Spider Wasps and is divided into three separate studies. The first, which has been published in the "Transactions of the American Entomological Society", deals with the morphology of a single species. The second is a consideration of the general features of the genus and includes a discussion of the value of the data accumulated in the first study as a basis for investigations in the taxonomy of the genus. The third study is one concerned with the taxonomy of the species of the genus inhabiting a certain limited area.

The limited scope of the studies, dealing as they do with but a single genus of insects, may make the problems dealt with seem insignificant to the layman. To the student of taxonomy, however, the genus *Pepsis* presents many difficult problems. The large number of described species, the inadequacy of the characters used in the descriptions and classifications of authors, the enormous variation within a single species and the scarcity of material for study have all combined as factors in creating a situation that can best be described as chaotic. The author first became interested in this genus of large and beautiful insects in 1926 and since that time has attempted to solve some of the problems presented by the group.
An analysis of the situation shows that there have been well over four hundred specific designations made in this genus since its erection in 1804 by Fabricius. Many of the species have been described entirely on the basis of color and color patterns. Often the descriptions are so brief and general as to make it impossible to determine just which form, or species, is referred to in the description.

Lucas, who was able to study type specimens and thus had an intimate knowledge of many of the species, published a monograph of the genus (1895) that was a monumental work and contributed towards the clarification of the taxonomic puzzle. Up to the present time his paper has remained as the basic work on the genus. It has been used freely and referred to often by the present author and must be considered, because of its importance, by any worker in the group. Even in that paper, however, it is evident that the classification he used was not a natural one and the student of the group often will find it extremely difficult to use some of his keys and descriptions as aids in the identification of specimens. It is evident that many of the characters he used, and which have been used by taxonomists since 1895, are inadequate and that variation, which appears to reach an extreme in species of this genus, was not given sufficient consideration. Although Lucas introduced morphological characters and gave this type of character a much greater value than had any previous worker,
a study of a number of specimens of different species will soon convince the modern student of taxonomy that there are more morphological characters available than were utilized by him. This is particularly true of the males.

The ultimate goal of these studies is a revision of the taxonomy of the genus and the logic of the attack of the problem is shown by the results as reported in this thesis. As the studies of previous authors apparently had led to no clear conception as to the status of the various species in the genus, the first work was to test and evaluate the characters that had been used by them to separate the species. This done, the next step was to attempt to discover new characters or new utilizations of previously known characters. This could best be accomplished by the analysis of the morphology of a single species and accordingly *Pepsis elegans* Lep. was studied in detail. Its morphological features are described in the first study of the thesis. Following this, it appeared logical to disregard existing descriptions and classifications and to separate the specimens available for study into what may be termed "natural species" on the basis of characters which apparently were of importance as indicating true differences. As these investigations progressed, an unconscious and conscious evaluation of each character was made and its limits of variation within a species was determined. The results of
this work are given in the second study of the thesis under the subheading "Specific Characters". Notes on general subjects, that had been omitted by previous writers or have appeared recently, are included in that study.

The next step in completing the problem appeared to be a tying up of the "natural" with the "described" species. This process is the routine work of the taxonomist and consists of a judgment on the validity and status of the described species, the description of new species and the construction of keys for the differentiation of species. As the genus contains such a large number of described species and, as the specimens available for study were chiefly from North America, the author has limited himself in his third study to the area of North America, north of Mexico.

The types of twelve described species and of one variety are to be found in the United States. The types of eleven of these species have been examined by the author. The type of P. angustimarginata Viereck, which is deposited in the collection of the University of Kansas, and the type of P. marginata var. sericata Cresson, have not been seen. In addition, the type pf P. nephele Lucas, which was loaned to the author through the kindness of Dr. Tsabo-Patay of the National Museum of Hungary, has been examined.
It is a sincere pleasure to express my indebtedness to those who have aided in these studies. Dr. H. Bischoff of the Berlin Museum has been very helpful in supplying details concerning the type specimens of many of the species described by Robert Lucas. Dr. Robert Benson of the British Museum of Natural History has performed a similar service in examining type specimens in the collections of that museum. To E.T. Cresson Jr., of the Philadelphia Academy of Natural Sciences, Herbert F. Schwarz of the American Museum of Natural History, Nathan Banks of the Museum of Comparative Zoology, Elizabeth McCracken of Stanford University, E.P. VanDuzee of the California Academy of Sciences, W.C. Hilton of Pomona College, Carl Duncan, Mrs. C.C. Gowdey and Joseph Bequaert, as well as the authorities in charge of the entomological collections of the Mississippi A. & M. College, University of North Carolina and the University of Kansas, the author wishes to acknowledge his appreciation of the opportunities they have given him to examine their collections of specimens. A particular expression of gratitude is due the members of the Department of Entomology of the Massachusetts Agricultural College, Doctors H.T. Fernald, G.C. Crampton and C.P. Alexander, who have been constant sources of aid and encouragement.
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STUDY I.

THE EXTERNAL MORPHOLOGY OF *PEPSIS ELEGANS* LEPELETIER

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LV, 119-193, 1929.
THE EXTERNAL MORPHOLOGY OF PEPsis ELEGANS

LEPELETIER

Introduction

One of the most evident facts in the study of many of the systematic groups of insects is the lack of uniformity in the nomenclature used by the workers to describe the various morphological features of the insects concerned. This was especially noticeable when an attempt was made by the writer to complete a systematic revision of the genus Pepsis and the desirability of a detailed, purely morphological study of some one species of the genus was realized. It is hoped that, by the study which follows, the nomenclature will be clarified and the morphological status of the various structures, which have been misnamed heretofore, will be determined. It is also hoped that morphological characters of specific value will be found which can be substituted for the color characters that have been used to a great extent by previous workers, for morphological characters are considered to be the more desirable.

The paucity of material available for study led to the selection of the species Pepsis elegans Lepeletier of which a greater amount of material was available than was the case with other species. This is somewhat unfortunate for P. elegans has not been
considered as recognizable by a number of systematists working on the group, because of a seeming discrepancy between the descriptions of most specimens which are to be referred to this species and the original description of the male, in which it is stated of the abdomen "...Segmentorum secundii, tertii, quinti, sextique margo posticus linea ferruginea tenui ferrugineo pubescentie terminatus..." (Lepeletier, 1845, p. 439). Smith (1855, p. 201) took the view that "...the red margin of the abdominal segments of the male, as described by St. Fargeau, is attributable to the iridescence of the pile, and is most observable in sunlight.", which view has been accepted by most of the recent workers who consider P. elegans to be a valid species. The writer has accepted Smith's view and the following morphological study is based on specimens which can be referred to P. elegans according to that view.

General Appearance and Color

Considering the relatively large size of most of the species of the genus, P. elegans is a medium to small-sized species. The general color of the entire body is black, but its surface is covered with a short, dense pubescence or pile which, in certain lights, gives it a purplish color. Long hairs, although present, are not conspicuous in a general survey except in the case of male specimens in which there occurs a so-called
ventral hair brush (discussed later) on the ventral surface of the abdomen. From the second segment on, the antennae are of a yellow or reddish-orange color. They are usually held porrect in male specimens and are loosely coiled in female specimens. The legs are very long in proportion to the size of the body and are of the same color as the body. The wings are large and, when at rest, extend along the dorsum beyond the tip of the abdomen. They are blackish in color, usually showing a violet or purplish over color or shimmer when seen in certain lights.

Head and its Appendages

The head of the male is slightly more than half the size of that of the female and its features are less rugedly and strongly developed than are those of the female. The head, when viewed from in front, is roughly circular in shape, but it is flattened dorsally at the vertex and is prolonged ventrally by the mouth-part structures. The sutures which limit the various sclerites concerned in the formation of the head capsule in other insects are, for the most part, greatly altered or missing in P. elegans because of the modifications which have taken place. Accordingly, some of the terms used in this paper are connotative of areas of the head capsule rather than of definite sclerites.

Head capsule.--(Pl. I, figs. 1 & 2). The
epicranium (Ep) and frons (f) occupy the greater portion of the frontal aspect of the head and extend cephalad of the occipital suture (os) to the fronto-clypeal suture (fc). These two sclerites are considered together, for there is some question as to the exact location and identification of the lateral arms of the epicranial suture, which ordinarily form the lateral limits of the frons. If we are to accept the idea of the migration of the lateral arms of the epicranial suture advanced by Stickney (1923) in his study of the head capsule of Coleoptera, as occurring in the same manner in Hymenoptera, it is probable that the small triangular sclerite, which has been called the frons in this paper, is all that remains of this sclerite. The lateral arms of the epicranial suture now may be represented by the sutures laterad of the frons. The thickenings which occur on the ental surface of the head capsule in this region would bear out the above conclusion, but, in the absence of any study which would show such a migration in a graded series of forms, this is not to be considered certain, though probable.

The three ocelli (o) are found near the dorsal surface of the head on a flattened portion of the vertex. They are equidistant, one from another, and form the points of an isosceles triangle. The anterior ocellus is slightly larger than the two posterior ocelli and
is situated on the median line at the dorsal terminus of the epicranial suture (es). The epicranial suture is incomplete in that it does not extend posteriorly to join the occipital suture, but ends at the anterior ocellus. It forms a median longitudinal furrow passing forward from the anterior ocellus between the antennal sockets (a) to a point ventrad of them where it divides into two lateral arms (probably to be considered as the true lateral arms of the epicranial suture) which join the fronto-clypeal suture. One antennifer (an) is found in each antennal socket as a heavily chitinized projection from the ventral outer margin of the socket.

The frontal pits (fp), which lie on the fronto-clypeal suture, are well defined and deep depressions that outwardly mark the positions of the anterior arms of the tentorium. The fronto-clypeal suture (fc) is clearly defined for the most part, but its lateral prolongations near the frontal pits are indistinct. As determined by a study of the thickenings found on the ental surface in this region, the lateral prolongations of this suture follow a course dorsad to the frontal pits, then extend obliquely ventrad to the dorsal lateral angles of the clypeus.

The clypeus (C) is broadly convex, with its apical margin arcuately concave and its distal lateral angles broadly rounded. The compound eyes (E) are large
protuberant, and reniform in shape, the inner margin being the concave one. They form important features of the frontal aspect of the head and extend from points on a line drawn transversely to the dorso-ventral axis of the head through the hind ocelli, nearly to the lateral ventral margins of the head near the points of articulation of the mandibles.

The genae (G) are the general areas forming the "cheeks" or sides of the head capsule. They extend anteriorly to the clypeus as small, narrow strips ventrad of the compound eyes. The genae, together with the postgenae (Pg), are strongly rounded, the two pairs of sclerites together forming a large portion of the latero-posterior area of the head capsule. There is no evidence of definite sutures dividing these areas into genae and postgenae and it is probable that these two pairs of sclerites have become fused.

The occipital suture (os) is present on the posterior surface of the epicranium as a semicircular, carina-like ridge extending around and above the occiput (oc), thus separating the occiput from the vertex (v) or general dorsal region of the epicranium. The occiput surrounds the foramen (fo) and fuses with the postgenae somewhere ventrad of the foramen. It is somewhat watchglass shaped, being concave in its central portion, and completely encircles the foramen as a raised rim to which are attached the occipital processes (Pl. II, figs. 12 & 14, op) of the prothorax.
The gular area, which is found at the ventral terminus of the *gular suture* (gs) and is sometimes called the *precyla* (gb) or gular bar, is seen as a small, mesal, triangular plate in the trophicava (discussed later), beneath, but fused with the raised carina-like margin of the postgenae.

The **trophicava**¹ (tc) is a broad semicircular depression or cavity in the ventral margin of the postgenae into which the basal portions of the maxillae and the labium are inserted.

**Tentorium.--(Pl. I, fig. 3.)** The endoskeleton of the head is known as the tentorium. In *P. elegans* the three pairs of apodemes, which are known respectively as the **posterior arms** (pa), the **dorsal arms** (dt) and **anterior arms** (at) are clearly defined. The body of the tentorium (bt), however, is not as clearly demarked and seems to include only that portion of the endoskeleton which is immediately cephalad of the foramen and which is formed by the fusion of the anterior and posterior pairs of apodemes. Figure 3 is a lateral view of a longitudinal section of the head along its median

¹The term "trophicava" has been used in place of MacGillivray’s term "maxacava" as being more accurately descriptive of facts, for the trophi are inserted in the cavity. MacGillivray’s term would indicate that the maxillae alone were concerned.
axis and shows only one half of the endoskeletal structure.

The posterior arms arise from slight invaginations laterad of the base of the rim surrounding the foramen and the pair forms a free arch over and cephalad of the foraminial aperture. (Only one arm is shown in the figure, the plane of section cutting the arch in the center.) The attachments of the anterior arms are marked on the frontal aspect of the head by the frontal pits (Pl. I, fig. I, fp). Each anterior arm extends backward as a long bar from the ental surface of the head capsule at the base of each frontal pit, to the body of the tentorium. The dorsal arms are somewhat modified in that they do not extend from the body of the tentorium as distinct structures, but one arises from the middle portion of the dorsal surface of each anterior arm and soon becomes so thin and so slightly chitinized as to appear tendon-like and indistinct.

Antennae.—(Pl. I, figs. 8, 9, 10.) The antenna of the female is composed of twelve segments while that of the male has thirteen. The first, or basal segment, is known as the scape (sc). The second is known as the pedicel (pd) and the remainder of the segments are known collectively as the flagellum (fl). The scape, the pedicel and occasionally the base of the first flagellar segment are of a dark brown color while the remainder of the antenna varies in color from a light yellow to a
reddish-orange, the darker color being found more commonly in male specimens. The female ordinarily holds the antennae with the flagellum loosely coiled while the flagellum of the male is usually porrect. The scape is modified proximally to form a bulb while the pedicel is a small, ring-like segment and the flagellar segments are nearly cylindrical and sub-equal in length. In the female the scape is the thickest segment of the antenna while in the male, it is narrow and short, being as short as any of the flagellar segments.

In the female the sensory cells of the antenna are not grouped as they are in the male although there appears to be a somewhat regular band of sensory cells along the inner ventral surface of many of the flagellar segments. This band is usually rather poorly defined. In the male there is a definite grouping of the sensory cells into proximal and distal elongately triangular areas (Pl. I, fig. 10) which usually occur on segments four to ten inclusive, although a sensory area may also occur on the other segments of the flagellum. The sensory areas are roughly triangular in outline, are somewhat depressed, and vary in size on the different segments. The surface of each area lacks the minute hairs which are to be found on the other portions of the antennal surface and the sensory cells appear as small, brownish spots on the surface. The cells appear to be of the "sense peg"
type, but no attempt has been made in this study to investigate their structure.

**Labrum.**—(Pl. I, fig. 1, la.) This is attached to the inner surface of the clypeus by membrane and usually is not exserted. It is rounded in outline and the somewhat truncate apical portion is deflexed posteriorly. A fringe of strong, black spines flanked on each side by longer slender ones, is found along the margin of the plate, and, in the female, a few short spines are scattered over the acical portion of the deflexed surface. A membranous structure known as the *epipharynx* (Pl. I, fig. 1, epi) is attached to the posterior surface of the labrum. It is rectangular and somewhat larger than the labrum and extends into the oral cavity as a purse-like fold. The oral aperture is found just caudad of the epipharynx.

**Mandibles.**—These are conspicuous and well developed. They are placed just behind the epipharynx, one on each side of the mouth opening. Each (Pl. I, fig. 4) is curved and tapers gradually to a blunt apex. A strong, blunt tooth (t) is borne on the inner margin about a third of the distance from the apex of the mandible. Four groups of long setae are found on each mandible, the most noticeable of which, consisting of six setae, occurs in a groove just basad of the tooth on the inner face. Two other groups are found on the
ventral face of the mandible and a fourth group occurs near the middle of the lateral face.

Each mandible articulates on two ball and socket joints, one anterior and the other posterior. The mandibular portion of the anterior articulation \((ah)\) consists of a shallow socket at the anterior terminus of the basal margin of the lateral surface. A slight ball-like protuberance of the extreme lateral and basal angle of the clypeus fits into the mandibular socket and completes the joint. The posterior articulation \((ph)\) is well developed, the mandibular portion consisting of a condyle at the posterior terminus of the basal margin of the lateral surface which fits into a socket or depression in the latero-ventral margin of the postgena. Each mandible is moved by two muscles. The inner and larger, which is called the \textit{flexor} \((fx)\), is attached to the basal margin of the inner surface of the mandible. The smaller muscle, which is called the \textit{extensor} \((ex)\), is attached on the inner surface of the basal margin of the lateral surface of the mandible just cephalad of the posterior articulation. The muscles allow only transverse movement, the flexor closing and the extensor opening the mandibles. When not in use the tip of one mandible extends over and covers the tip of the other. There seems to be no special arrangement as to which mandible is the outer for, in the specimens examined, the right
seemed to cover the left about as often as the left covered the right.

Maxillae.—These occur just behind the mandibles, one on each side just in front of the labium, which is the posterior mouthpart structure. When the labium and the maxillae are not being used in feeding (i.e., when they are not extended) they are folded under the head in a protected position. When they are extended, however, they form a tube-like structure.

In each maxilla (Pl. I, fig. 5) the cardo (ca) is heavily chitinized and is modified basally to form two knob-like projections, the shorter of which fits into a socket on the ental surface of the postgena. Evidences of a point of attachment for a lorum are to be seen under the inner margin of the cardo, but a lorum connecting the cardines of the maxillae is not demonstrable. The main portion of the plate known as the stipes, (sti₁) is elongately triangular and bears, on its outer margin, a six-segmented maxillary palpus (mxp) at the base of which is a membranous, inconspicuous palpifer. (Another view is that the maxillary palpus consists of but five segments, the one here considered to be the basal palpal segment being called the palpifer). The inner margin of the main surface of the stipes is raised and ridge-like and a secondary inner extension of the stipes (sti₂) occurs as an irregularly chitinized area at a level different
from that of the main portion of the stipes. The galea (ga) and lacinia (lc) are attached to this extension. The lacinia is small, membranous and pad-like while the galea is rather heavily chitinized and consists of what appear to be two closely appressed and fused plates which may be all that remains of an ancestral condition in which a distinct endogalea and exogalea were present. A short, chitinized bar, which is called the interlorum (Pl. I, fig. 6, il), extends to the hypopharynx (hyp) from near the point of meeting of the bases of the lacinia and the galea and the inner extension of the stipes. The interlorum is also attached to the flexor muscle of the mandible near the base of the mandible by a broad, flat, chitinized band which seems to be a secondary prolongation of the interlorum.

Labium.—(Pl. I, fig. 2.) The submentum (sm), which is the small basal plate on the posterior surface of the labium, is peltate in form and fits between the cardines and stipites of the maxillae. The mentum (mn) occurs just distad of the submentum as a large, strongly rounded, heavily chitinized plate, the basal lateral portions of which are elongated and bent over in such a manner as to extend anteriorly to meet the hypopharynx, which is situated on the anterior surface of the labium. The distal margin of the mentum is cut away on each side in such a manner as to furnish cavities in which
occur the membranous palpigers, to each of which is attached a four-segmented labial palpus (lp). The mentum of the labium is protected on each side by the stipes of a maxilla when the mouthparts are extended. The glossa (gl), which is a large pad-like structure, occurs distad of the mentum and, together with the paraglossae (pgl), one of which occurs on each side of the glossa, is joined to the mentum by membrane. The distal portion of the glossa is bilobed and covered with short, plush-like hairs on its anterior surface while the posterior surface lacks this covering. The middle portion of the anterior surface of the glossa is crossed by numerous transverse striations which may have some function in the process of "lapping up" the food of the adult. The posterior surface of the glossa lacks these striations, but bears longitudinal striations instead. Two areas, more heavily chitinized than the remainder of the glossa, occur on the dorsal surface near the base. The functions of these areas are not known. The paraglossae are membranous. Each bears a few short hairs near the tip and, on the posterior surface near the base, a pad-like pubescent area occurs. A small, membranous, papilla-like protuberance, which is the distal portion of the hypopharynx (Pl. I, fig. 7, hyp), occurs on the median line of the anterior surface of the labium just basad
of the proximal portion of the glossa. The identity of the hypopharynx is determined by the presence of the opening of the salivary duct just behind the distal papilla-like protuberance.

Thorax and its Appendages

The thorax (Pl. II, figs. 11 and 12) is of the peculiar humped-back shape typical of the members of the family Tsammocharidae. Snodgrass (1910), in his paper on the thorax of Hymenoptera, has worked out the homologies of the various sclerites and Crampton (1914 and 1926) has made important contributions to the knowledge of the homologies of the sclerites found in the neck region and in the tergum.

Prothorax.—The pronotum (Pn) is a relatively broad, transverse plate. Its front margin covers the points of attachment between the head and the internal occipital processes (Pl. II, fig. 12, op) or cephaligers of the latero-cervicals (L) and its hind margin is arcuately concave and overlaps the front margin and prephragma of the prescutum (Pr). The anterior lateral corners are bluntly pointed and the posterior angles are broadly rounded and form lobes which cover the mesothoracic spiracles lying just underneath on the anterior margins of the mesepisterna (Ep$_2$). The latero-
cervicals form the greater part of the broad, flat, antero-ventral surface of the prothorax. Each latero-cervical extends anteriorly to form a portion of a collar-like transverse band from the inner surface of which projects a chitinized tooth called the occipital process (op) on which the head articulates. A hook-like projection, which is called the coxal process (cp1), is found on the ental surface of each latero-cervical near the lateral posterior angle of the sclerite and this projection forms a part of the apparatus for the attachment of the coxa (C1) of the fore leg. The prosternum (S1) is seen as a small, transverse, triangular plate attached to and basad of the hind margins of the latero-cervicals. The furcisternum (fs1), which is caudad and dorsad of the sternum and which forms the broad, rounded lobe between the front coxae, is the base to which the sternal apophyses of the endoskeleton of the prothorax are attached.

Mesothorax.—The tergum of the mesothorax is divided into a prescutum (Pr), scutum (Sct), scutellum (Scl), and parascutellum (Psc). The prescutum is the large, arched, anterior plate of the segment which is considered to be fused posteriorly with the scutum.
The lateral portions of the scutum are separated from the prescutum by the so-called parapsidal grooves (pf), the areas so marked off being known as the parapsides although they are portions of the scutum. The parapsides are deeply excavated and the tegulae (tg) and fore wings are attached to them. The scutellum is a transverse sclerite which forms the broadly rounded, nearly triangular, elevated, median area caudad of the scutum. Laterad of the scutellum are the parascutella (Psc) which are deeply excavated and are separated from the scutellum by a secondary carina-like ridge. In some species of the genus _Pentia_ a secondary transverse suture, which is the external evidence of the attachment of the entodorsum (called the ventral V-shaped ridge of the notum by Snodgrass) at this point, is visible just caudad of the scuto-scutellar suture. This gives the appearance of there being a distinct sclerite lying between the scutum and scutellum. In _P. oceana_, however, this suture is not present as a distinct line. The post-scutellum (Pl. II, figs. 14 and 15, png) or postnotum of the mesothorax is not visible on the surface of the thorax and will be discussed later in connection with the endoskeleton of the thorax.
The lateral and sternal sclerites of the mesothorax are fused and modified so as to make their identification rather difficult. The mesepimeron (Epm) is considered by Snodgrass to border the postero-dorsal margin of the episternum. In P. elecans the line of division between the episternum and epimeron is not clear, but study suggests that the narrow, somewhat pitted band, which lies along the postero-dorsal margin of the mesepisternum, is the mesepimeron. The mesepisternal and mesosternal sclerites are continuous, there being no complete suture dividing these sclerites. The mesepisternum (Eps₂) is divided into two portions by a secondary furrow called the median episternal groove (mpg). The dorsal portion of the mesepisternum borders the front coxal cavities and is, in turn, bordered on its postero-dorsal margin by the mesepimeron. The ventral portion of the mesepisternum is fused to the sternum (S₂), no definite line of demarkation being present between the two sclerites. There is a median longitudinal groove on the sternum which is the external evidence of the line of attachment of the apophyses of the mesothoracic endoskeleton. The pleuro-sternal plate (mesepisternum plus sternum
and furcisternum) is modified posteriorly to form the coxal process (cp) which projects into the mesothoracic coxal cavity from its anterior margin. The coxa (Cx) of the mesothoracic leg articulates on this projection. Mesad of the coxal processes of the pleuro-sternal sclerites is found a rather poorly defined sclerite known as the furcisternum (fs) which forms the base to which a portion of the sternal apophyses of the endoskeleton of the mesothorax is attached. A tuberculate elevation, which has been called the mesopleural tubercle (mt) by systematists, occurs on the surface of the pleuro-sternal sclerite near the lateral margin of the central surface.

Metathorax.—The tergum of the metathoracic segment is divided into two parts which are called the metanotum (N) and the metapostscutellum or metanostnotum (M). The metanotum is a long, curved, transverse, band-like sclerite which bears an elevation in the middle of its dorsal surface and terminates laterally at the points of attachment of the hind pair of wings. The metapostscutellum is not separated from the metapleura (Pl) by a suture, but the statement made by Snodgrass concerning this sclerite that "...the upper parts of the metapleura are nearly always fused with the lateral parts of the metapostnotum..." Snodgrass (1910, p.79) applies in this case. Thus we may consider
the metapostscutellum to be the saddle-like band which extends over the dorsum between the metanotum and propodeum and which is partially fused posteriorly with the propodeum and completely fused laterally with the metapleura. A deep, longitudinal groove cuts the metapostscutellum in the middle, the groove being the external evidence of the line of attachment of a part of the endoskeleton. A depression of similar origin is found on each side at the hinder margin of the sclerite near the hypothetical point of fusion of the metapleura with the metapostscutellum.

The pleurum of the metathorax is considered to be made up of one sclerite, the metapleuranum (Pl), which is divided into two parts by a secondary suture. The upper portion is fused above with the metapostscutellum and, at the tip of its anterior dorsal angle, is a small sclerite which bears the spiracle (si) of the metathoracic segment. The secondary suture, which separates the upper from the lower portion of the metapleuranum, ends posteriorly in a deep depression. The posterior margins of the lower portions of the metapleura form the lateral margins of the metathoracic coxal cavities. The posterior inner angles of the metapleura are prolonged and fused with portions of the metasierum (S₃), and furcisterum (f₃) to form
the coxal processes (cp₃) on which the coxae (Cx₃) of the hind legs articulate.

A lateral, longitudinal carina, extending from the posterior margin of each mesothoracic coxal cavity to the sterno-pleural coxal process of the metathorax, probably indicates the line of fusion of the pleurum and the sternum. There is a median longitudinal groove in the metasternum, similar to that found in the sternum of the mesothorax, which is the external evidence of the line of attachment of the sternal apophyses of the metathorax. Caudad of the sternum is found a broadly triangular sclerite which is known as the furcisternum (fs₃) which also bears a portion of the sternal apophyses on its inner surface.

Endoskeleton of the thorax.— (Pl. II, figs. 14-18.) The inner surface of the chitinous skeleton of the thorax is greatly modified to provide attachments for the muscles of the wings and legs or extra "braces" to withstand the strains to which the chitinous plates are subjected when the insect is in flight. These internal thickenings or bars are called phragmas, if attached to the tergites; apodemes if attached to the pleural plates; or apophyses if attached to the sternal plates.
The prescutum (Pr) is prolonged anteriorly to form a prothorax (ph2) which extends for some distance under and caudal of the pronotum (Pn). It extends as a roll-like thickening along the ventral anterior and lateral margins of the prescutum and scutum and is flattened to form a thin, plate-like lobe on each side of the middle of its anterior margin. A thickening occurs near the anterior margin of the scutellum which Snodgrass (1910) calls the ventral V-shaped ridge of notum (ven). Its presence is marked on the dorsal surface of the scutellum by the transverse groove already referred to in the previous discussion of the scutellum. The ridge is seen to be situated near the front margin of the ventral surface of the scutellum and is narrower across its dorsal portion and broader near its lateral extremities dorsad of the points of attachment of the fore wings. The posterior margin of the scutellum is folded inward and an internal ridge is formed along the margin. The postscutellum (sn2) of the mesothorax is entirely internal and occurs as two, separated, flat, scale-like lobes, one of which occurs on each side just caudal of the posterior margin of the scutellum and dorsad of the point of attachment of the hind wing. The post-
acutellum may extend dorsally along the posterior margin of the acutellum as a very narrow,cutaneous strip, but this is not distinct and the two lateral portions apparently are separated. The \textit{postphragma} (phg₂) of the mesothorax is well-developed and large. It extends caudad nearly to the inner surface of the hind margin of the \textit{propodeum} (pro) as a canopy-like, weakly chitinized plate which tapers posteriorly. The anterior margin of the \textit{postphragma} is joined to the median posterior margin of the acutellum and the posterior margins of the lateral postscutellar plates. The lateral, thickened rim of the \textit{postphragma} is attached to the lateral margins of the postscutellar plates. The \textit{postphragma} lies dorsad of the apophyses of the mesothorax and passes through the central opening formed by the thickenings to be found on the inner surface of the exoskeleton along the line of fusion of the metapostscutellum and the propodeum and the apophyses of the metathoracic endoskeleton.

The \textit{metanotum} (N₃) is folded inward so as to form a hollow, tub.-like structure across the median part of the dorsum. Laterally the inner fold is modified to form a thin, phragma-like structure on each side of the median, tube-like formation and this phragma-like structure extends caudad from
the front margin of the metanotum as a chitinous plate. The line of fusion between the metapostscutellum and the propodeum is marked on the inner surface by a thickening or infolding of the chitin. The depressions which were mentioned above in the discussion of the external characters of the sclerites concerned are also marked by chitinous thickenings which extend cephalad of the main internal ridge as short prolongations of the ridge. The outlines of the various sclerites which enter into the composition of the thorax appear, for the most part, on the inner surface of the exoskeleton as thickenings of the chitin along the line of meeting of the two adjoining sclerites or as thickenings running parallel to and just inside of the margins of the sclerites.

As a rule, the endoskeletal projections of the pleural and sternal sclerites are fused to form a rather complicated structure so that it is more logical and convenient to consider the pleural apodemes and the sternal apophyses of one thoracic segment at the same time than to consider the apodemes and apophyses separately.

A structure known as the occipital process (op) occurs on the inner surface of each laterocervical near its anterior margin. This structure
is not connected with that formed by the fusion of the apodemes and the apophyses which occurs near the posterior margin of the latero-cervical and which is attached to the furcisternum and sternum of the prothorax. Plate II, figure 14 shows the endoskeletal structure on the prothorax in cross section while Plate II, figure 16 shows the caudal aspect of the prothoracic endoskeleton. The furcisternum occurs as a plate dorsad of and fused with the sternum. The sternal apophyses (sa₁) occur as two erect bars, one on each side of the dorsal surface of the furcisternum. They are fused together at their apices so that a mesal aperture is formed between them. A dorsal prolongation of the apophyses extends posteriorly dorsad of the mesal aperture as a pointed lobe. Each apophysis extends laterally to meet with the pleural apodeme (pa₁) which lies along the inner surface of the posterior margin of each latero-cevical and which terminates ventrally just above the coxal process (cp₁).

That portion of the endoskeleton of the mesothorax which is formed by the apodemes and apophyses may be described as follows (Pl. II, fig. 17). The apophyses (sa₂) are fused together at the base and arise as a single, erect, median and longitudinal plate the basal margin of which extends along the median
line of the mesosternum and furcisternum. The distal portion of the plate is divided into two pairs of arms which extend laterally to fuse with the apodemes (pa₂). The most conspicuous portions of the apophyses are a pair of anterior arms, each of which extends from an internal ledge (the apodeme) just ventrad of the dorsal inner margin of the fused mesepimeral and mesepisternal sclerites obliquely caudad to the point of fusion with the other anterior arm. A transverse, weakly chitinized plate occurs just cephalad of the point of fusion of the two arms. A pair of weakly chitinized (almost tendon-like) posterior arms arise one on each side of the point of fusion of the anterior arms, and each extends obliquely caudad to become attached near the posterior terminus of the apodeme.

In the metathorax (Pl. II, fig. 16) the sternal apophyses (sa₃) are fused near the base as in the mesothorax and are separated above to form two arms which extend obliquely dorsad to meet the pleural apodemes (pa₃). The anterior margin of the fused bases of the apophyses terminates at the raised anterior margin of the metasternum. The apodemes are not distinctly separated from the internal ridge, which is found along the line of fusion of the pro-
podeum and metapostscutellum, but seem to form continuations of it extending ventrad across the inner surface of the pleural sclerites to meet the raised anterior margin of the sternum. That portion of the ridge formed by the apodemes is much more developed than the other portions and it extends into the body cavity to a much greater extent than do those parts formed by the anterior margin of the metasternum or by the line of fusion of the propodeum and metapostscutellum.

Legs.—The legs of this species are very long in proportion to the size of the body. In common with most of the exterior chitinous surface of the insect, the surface of the legs bears a short pubescence. On the inner surface of the tibia of the hind leg a long, plush-like pad of short hairs is found which extends from near the base to the apex of the tibia. In female specimens the tibiae bear numerous irregularly placed, sagitta-shaped spines as well as numerous finer ones and, on the outer surface of the middle and hind legs, is a row of blunt, tuberculate teeth at the base of each of which is a heavy, sharp spine. The legs of the male specimens are much less heavily and more sparsely spined than those of females and the blunt teeth are absent on the middle and hind legs.
Long, sharp spines, which are more or less regularly arranged in rows running the length of the segment, occur on the tarsal segments, particularly on those of female specimens. Besides these spines there are heavy, long, articulated spurs on each leg. These will be considered later in connection with the segment of the leg to which they are attached.

Each leg (Pl. III, fig. 25) is made up of a rather short coxa (Cx), a distinct trochanter (tr), a very long femur (Fe), an elongate tibia (Tb), five tarsal segments (ta₁, etc.) of varying length and a pretarsus (pt) bearing a pair of claws. The coxae are robust and rounded. In the fore legs each coxa has a single antero-lateral articular surface which is moulded to receive the coxal process of the propodeum. The coxae of the middle and hind legs each moves on a similar articulatory apparatus which consists of an inner articular surface and coxal process. A pair of laterally placed, tubercle-like condyles are found near the distal portion of each coxa projecting inward from the walls. These condyles, together with the peculiarly shaped base of the trochanter, make up the articulation between the coxa and the trochanter. The femora are long, somewhat cylindrical
segments which articulate with the tibiae by means of an arrangement similar to that found between the coxa and the trochanter.

The fore tibiae are somewhat enlarged distally. Each fore tibia bears a long, movable spur (Pl. III, fig. 26) at the base of an incision in its inner distal margin and this spur bears a weakly chitinized flap or brush on the surface next to the tibia. The flap, together with the modified inner basal surface of the basitarsus (ta₁) forms the so-called *antenna cleaner* (ac). The tibiae of the middle and hind legs each bears, on its inner apical margin, two long, curved, movable spurs which are known as the *tibial spurs* (tbs). Of the five tarsal segments the first, or basitarsus, is much the longer while the second, third and fourth segments are successively shorter. The fifth tarsal segment is about as long as the third and is not cylindrical, for the base is much narrower than the apex and the ventral surface of the segment is flattened. In the female, the tarsal segments of all the legs are, in general, rounded and cylindrical although the fifth, as mentioned above, has a distinctive shape. The tarsal segments of the hind leg of the male are different from those of the other legs in that they are not
only proportionately longer, but are strongly compressed laterally. A cross section of one of the segments shows its shape to be triangular. At the apex of each of the first four tarsal segments is to be found a very small, nearly-membranous flap which projects from the margin of the ventral surface of the segment. These flaps are called the tarsal pulvilli or euplantulae.

The praetarsi (pt) of both sexes are very similar although female specimens have the tooth (to) at the base of each claw better developed than it is in the male and more spines are to be found on the orbicula (or). In general, the structure of the parts comprising the praetarsus (Pl. III, figs. 27 and 28) is very similar to that described by Snodgrass (1925) for the honeybee.

The unguictractor (un) is seen on the ventral surface of the praetarsus as a large, basal plate, the base of which is partially hidden by the apex of the fifth tarsal segment (tag). The claws (cl) are large and curved and each bears a small tooth (to) near the base of its inner ventral surface as well as two long spines just basad of the tooth. The planta (p) is a hairy, pad-like structure and the camera (cm)
appears as a heavily chitinized girdle. The arolium (ar) is membranous and very soft and is bent dorsad between the claws. The orbicula (or) is seen on the dorsal surface as a rounded sclerite from the back of which projects a chitinized bar which extends distally to the dorsal prolongations of the girdle-like camera.

Wings.—Lepelletier (1845) described the color of the wings of P. elegans as "... nigro-violaceae, margine postico minus opaco ..." (p.499). In preserved or old specimens the violet lustre is nearly lost and, when the wing is seen against a light background, a dark brown color is predominant. The tips of the wings are lighter in color and the wing surface is covered throughout with fine, black hairs.

The approximate average size of the wings is as follows:--

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width at pterostigma</th>
<th>Width at hamuli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fore Wings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>18 mm.</td>
<td>6 mm.</td>
<td>4 mm.</td>
</tr>
<tr>
<td>Female</td>
<td>22 mm.</td>
<td>7 mm.</td>
<td>5 mm.</td>
</tr>
<tr>
<td>Hind Wings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>13 mm.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>15 mm.</td>
<td></td>
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</tr>
</tbody>
</table>

The new system of nomenclature for hymenopterous wing veins and cells as presented by Tillyard (1926)
has been used in preference to the Comstock-Needham and other systems as it seems to offer advantages which are not to be found in the others.

Fore Wings.—(Pl. III, figs. 19 and 20.)

Costa (C) forms the basal portion of the front margin of the wing. It is moderately strong and is considerably thickened at its base. The principal vein (Sc+R+M) is the strongest of the wing veins. It is formed by the fusion of Sc, R and M, but media (M) is given off much before the middle of the wing as a separate vein and the fused subcosta and radius (Sc+R) continue to the pterostigma (pt). Radius (R) continues distad of the pterostigma as the marginal vein.

The pterostigma is found slightly beyond the middle of the margin of the fore wing. It is elongate and, except for the veins limiting its area, is not greatly thickened. The first radio-median cross vein is lost, but the second (rm2) is given off from the distal portion of the pterostigma and reaches the first branch of media (M1+2). This cross vein is the radial cross vein of Comstock.

Media is given off from the principal vein before the middle of the wing and, after making an acute turn at the point of junction with the first
medio-cubital cross vein \((mcu_1)\), proceeds towards the apex of the wing and divides near the middle of the wing into two branches which are called the first branch of media \((M_{1+2})\) and the second branch of media \((M_{3+4})\). The first branch of media meets the second radio-median cross vein and, towards the apex of the wing, curves forward and joins with the radial sector to form the serial vein \((Rs+M_{1+2})\) which limits the third radial cell distally. According to Comstock the basal section of \(M_{1+2}\) is the radio-median cross vein while the terminal serial vein is formed by the third branch of radius. The second branch of media \((M_{3+4})\) proceeds towards, but does not attain the outer margin. The two branches of media are joined by the first and second inter-median cross veins \((im_1, im_2)\) which are, respectively, \(R_5\) and \(R_4\) of Comstock.

The first branch of cubitus \((Cu_1)\) follows a zigzag course towards the anal angle of the wing, but the free terminal section does not attain the margin of the wing. The first medio-cubital cross vein \((mcu_1)\) serves to connect \(Cu_1\) with media and two other cross veins \((mcu_2, mcu_3)\) connect \(Cu_1\) with the
second branch of media. These last-named cross veins are, respectively, the veins $M_{3+4}$ and $M_2$ of Comstock.

Cubitus, as interpreted by Tillyard, is made up of parts of the veins $Cu$, $M_4$, $M_3$, $M_2$ and $m$ of Comstock. The second branch of cubitus and the anal vein are fused to form a straight vein ($Cu_2+A$) which does not quite attain the margin of the wing near the axillary excision (ax). This vein is the first anal of Comstock. The first inter-cubital cross vein is lost, but the second ($icu_2$) and third ($icu_3$) (which are, according to Comstock, the veins $Cu_1$ and $M_3$) serve to connect $Cu_1$ and $Cu_2+A$.

The axillary excision is moderately developed and the area immediately surrounding it is considerably thickened. The anal furrow, which should be known as the inter-cubital furrow (ic) in order to agree with the terminology used by Tillyard, is well developed and extends from the base of the wing to the axillary excision. It is situated in front of and parallel to the anal vein.

Tillyard changes the names of the various cells of the hymenopterous wing to agree with the changes which have been made in the names of the veins. In general it may be said that the cells are considered
to be arranged in six longitudinal (from base to apex of wing) series which are, beginning at the front margin of the wing, the costal and subcostal, radial, median, submedian, cubital and anal series. The homologies of the cells found in the fore wing of *P. elegans* in the Tillyard, Comstock-Needham and the usual system of other authors are given in the following table which is adapted from Tillyard (1926, p. 258).

<table>
<thead>
<tr>
<th>Tillyard System Name</th>
<th>Notation</th>
<th>Comstock-Needham Notation</th>
<th>Usual System of Previous Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costal+subcostal</td>
<td>C+Sc</td>
<td>C+Sc1</td>
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</tr>
<tr>
<td>Pterostigma</td>
<td>pt</td>
<td>Pt</td>
<td>Pterostigma</td>
</tr>
<tr>
<td>1st+2nd radial</td>
<td>1R+2R</td>
<td>R+1st R₂</td>
<td>1st cubital</td>
</tr>
<tr>
<td>3rd radial</td>
<td>3R</td>
<td>2nd R₁+R₂</td>
<td>Radial</td>
</tr>
<tr>
<td>Basimedian</td>
<td>BM</td>
<td>M</td>
<td>Median</td>
</tr>
<tr>
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<td>1M</td>
<td>R₃</td>
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</tr>
<tr>
<td>3rd median</td>
<td>3M</td>
<td>R₅</td>
<td>4th cubital</td>
</tr>
<tr>
<td>1st submedian</td>
<td>1SM</td>
<td>M₁</td>
<td>1st discoidal</td>
</tr>
<tr>
<td>2nd submedian</td>
<td>2SM</td>
<td>M₂</td>
<td>3rd discoidal</td>
</tr>
<tr>
<td>3rd submedian</td>
<td>3SM</td>
<td>M₃</td>
<td>2nd apical</td>
</tr>
<tr>
<td>Basicubital+cubital</td>
<td>BCu+1Cu</td>
<td>Cu+Cu₁</td>
<td>3rd discoidal</td>
</tr>
<tr>
<td>2nd cubital</td>
<td>2Cu</td>
<td>M₄</td>
<td>Submedian</td>
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<td>3Cu</td>
<td>2nd M₂</td>
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</tr>
<tr>
<td>Anal</td>
<td>A</td>
<td>A</td>
<td>1st apical</td>
</tr>
</tbody>
</table>

**Hind Wings.**—(Pl. III, figs. 20 and 21)

The veination of the hind wings is found to be greatly modified. C+Sc and R+M are fused for about one-third of the distance from the humeral angle of the wing to the hamuli (h), but, at the apex of the fused portion,
this composite vein divides into two branches, the anterior of which (C+Sc) forms the front margin of the wing as far as the hamuli where it again joins the posterior branch (R+M). Media (M) is given off posteriorly in the region of the hamuli as a separate vein while radius (R) continues along the front margin of the wing. Media proceeds towards, but does not attain, the outer margin of the wing. It is, to all appearances, an unbranched vein, but in reality the first branch of media (M₁+₂) is the only portion clearly seen for the basal section of the second branch, which usually connects the two branches of media, is lost although the remainder of the second branch is present as is discussed below.

The single existing inter-median cross vein (im) joins the two branches of media near their apices. The obliteration of the basal section of the second branch of media allows this vein to fuse with the medio-cubital cross vein to form the serial vein (mcu+M₃+₄) which joins the first branch of cubitus (Cu₁) basally and, as mentioned above, is joined near its apex to the first branch of media by the first inter-median cross vein. The first branch of cubitus is a well developed vein which curves posteriorly until it nearly attains the margin of the wing in the region of the anal angle. It is joined near
its tip to the serial vein (Cu$_2^{+}$+icu) composed of the second branch of cubitus, the anal vein, and the inter-cubital cross vein.

The medial furrow, which should be known as the \textit{inter-median furrow} (imf) in order to agree with the nomenclature of the region in which it occurs, is well developed and extends as a distinct line from the base of the wing nearly to the inter-median cross vein (im). The \textit{inter-cubital furrow} (ic) of the hind wings (usually known as the anal furrow) is also well developed and extends from the base of the wing nearly to the anal margin and crosses the vein Cu$_2^{+}$+icu at a point over half the distance from the base to the apex of the vein. The axillary furrow or second anal furrow forms the anterior margin of the anal lobe.

It is difficult to discern the homologies of the various cells of the hind wing because of the modifications which are found in the veination of the wing. Plate III, figure 22 shows the names which have been given to the cells in the Tillyard system and the following table gives the homologies as they have been worked out in the Tillyard, Comstock-Needham and the usual system of previous authors.
Articulation of the wings.—Several articulatory sclerites occur at the base of each wing.

Plate III, figures 23 and 24 show the most important of these, figure 23 indicating the arrangement to be found in the front wing and figure 24 that occurring in the hind wing. Crampton (1927 and 1928) has studied the wing bases of several insects and has applied names to the various sclerites found there. His nomenclature is used in this paper in preference to that used by Snodgrass (1927) although the nomenclature used by Snodgrass is included in the following descriptions.

Fore wing.—When the fore wing is extended and the base is flattened so as to show all the parts, a small sclerite is found near the anterior margin of the wing just beneath the tegula. When the base of the wing is not flattened the sclerite is visible on the ventral front margin, but, when the base is
flattened out, the sclerite twists around so as to appear as a dorsal sclerite or ossicle which is known as the basalar sclerite (ba) and is joined at its base to the anterior portion of the dorsal margin of the mesopleurum. The distal portion articulates with the ventral basal margin of the parategula (ptg) which is situated basad of the proximal portion of the fused costal and the subcostal veins (C+Sc). The notale (n), which Snodgrass calls the first axillary sclerite, articulates distally with the parategula and is prolonged at its base to articulate with a portion of the lateral margin of the tergum. The notale lies dorsad of and hides the greater portion of the first mediale (ml₁) which is the second axillary sclerite of Snodgrass. The second mediale (ml₂) or median plate lies distad of the first mediale and between the bases of the veins Sc+R+M and Cu₂+IA. It is an oval sclerite. The basanale (bas) or third axillary sclerite is seen on the dorsal surface as a long and thin chitinized plate. Below the surface of the membrane surrounding the sclerite, however, it flares out on each side making the plate somewhat broader than is apparent on the surface. Basad of the basanale is the adanale (ad) which is made up of three
separate sclerites comprising the fourth axillary of *Anodonta* and the so-called muscle bearing sclerite associated with it.

In the hind wing the **basalar sclerite** (ba) is present, but distally it articulates directly with the enlarged base of the fused veins C+Sc+R+M instead of with the parategula as is the case in the fore wings. The **notale** (n) is distinct, but does not cover the **first mediale** (ml₁) as in the fore wings. The **second mediale** (ml₂) is present between the bases of veins Cu₁ and Cu₂+Al+mcu, while the **basanale** (bas) is approximately the same as in the fore wings. Apparently there is no adanale in the hind wings, the basanale articulating directly with the posterior lateral margin of the metanotum. There is a rather heavy deposition of chitin (al) at the base of the anal lobe in the hind wing, but this is evidently merely a secondary modification.

**Abdomen**

**Propodeum.**—(Pl. II, fig. 11, tr.). The propodeum (known also as the median segment and erroneously as the metanotum), which is morphologically the tergite of the first abdominal segment the sternite of which has been lost, appears at first sight to be a very large, posterior and dorsal sclerite of the
thorax. It extends posteriorly from the meta-
postscutellum (Ms), to which it is rather closely
attached, to the abdomen proper. Its hind margin
forms the dorsal plate surrounding the aperture for
the attachment of the abdomen. It is bordered by
the metapleura (Pl) on its latero-ventral margins
and a pair of spiracles (ps) occur near the anterior
margin of the sclerite. The surface of the propodeum
bears numerous features of systematic importance in
the form of sculpturing, depressions and protuberances.
These, however, seem to have no morphological significance,
merely being modifications of the single propodeal
sclerite.

The dorsal surface of the propodeum is divided
into two distinct parts. These are the so-called
horizontal surface (hs) or upper surface, which is
the anterior, nearly horizontal portion and the sloping
surface (ss). The lateral margins of the horizontal
surface are formed by the lateral carinae to be des-
cribed later. The horizontal surface has a rather
broad, median, longitudinal raised area which begins
at the front margin of the propodeum and ends in a
low transverse ridge (td) (also known as the median
transverse fold or as the median hump) at the junction
of the horizontal and sloping surfaces. A very shallow, longitudinal median furrow is to be found running the length of the median raised area. This furrow is more conspicuous in the female than in the male. The median raised area is crossed by regularly placed, transverse striations which become indistinct in the depressions between the raised area and the low, longitudinal lateral carinae (11) one of which occurs on each lateral margin of the horizontal surface. The transverse striations become distinct again on the lateral carinae and extend more or less irregularly downward across the sides of the propodeum. Each lateral carina starts just behind and dorsad of the spiracle as a low elevation which becomes more pronounced posteriorly and ends at or just behind the line of division of the two main surfaces of the propodeum as a lateral tooth (lt) or tubercle, the apex of which is crossed by a few short transverse striations. Just ventrad of the spiracle is found a low, broad, elevated area which is known as the subspiracular tubercle. This elevation is not distinct in P. elegans.

The sloping surface is flat behind the transverse ridge and falls away laterally to the line
of fusion of the metathoracic pleura with the propodeum. The sloping surface has but a few weak, transverse striations near its anterior margin. The hind margin of the propodeum is thickened and forms a narrow, shelf-like ledge which is projected laterally to form a rounded lateral angle on each side. The posterior surface of the thickened marginal ledge (Pl. II, fig. 13) is excavated in the middle of its ventral margin and has two arms (aa) which project into the excavation and form points of attachment for the funicle of the abdomen.

Abdominal segments. (Pl. IV, fig. 29)
Correct morphological diagnosis would show the propodeum to be the tergite of the first segment of the abdomen, the sternite of the first segment having been lost. The propodeum, however, being more closely joined to the thorax than to the other segments of the abdomen, is usually described with the thorax and the segment directly behind the propodeum is usually counted as the first segment on the abdomen. It is so considered in this paper and the segments following the constriction are numbered consecutively from front to rear, that directly behind the constriction being called the first abdominal segment.
When seen from above the abdomen is somewhat elongately ovate in outline, its shape being dependent on the degree of distention. The abdomen is flattened on its ventral surface and the outline of its dorsal surface, when seen from the side (except for that part of the outline formed by the tergite of the first segment), is a nearly regular arc. The entire surface is covered with a short, thick, purplish pubescence. Longer hairs are scattered irregularly over the apical dorsal and ventral plates of the female while, in the male, there is a well-formed hair tuft on the fourth sternite and scattered long hairs are to be found on the posterior segments, subgenital plate and coxleara. The hair tuft on the fourth sternite is a character of specific value. It occurs in the middle of the anterior portion of the sternite and is composed of long black hairs arranged transversely in a thin line forming an arc across the sternite. The outer hairs are the longer and have their tips curved abruptly inward while the hairs themselves are bent over so as to be directed caudad. They are less erect than the shorter ones which occur nearer the median line of the body. Directly behind the hair
tuft on the fourth sternite is a somewhat depressed, half-moon shaped, glabrous and shiny area. The fifth and sixth sternites each has a smaller median glabrous area, that of the fifth being depressed, that of the sixth being much smaller and slightly elevated along its longitudinal axis.

The connection between the abdomen and propodeum (Pl. II, fig. 13) is made by the insertion of the small basal portions of the tergite and sternite of the first segment into an aperture which is bounded dorsally by the hind margin of the propodeum (PrO), laterally by the coxae of the metathoracic segment (Cx3) and ventrally by the metafurcisterum (fs3). The tergite of the first segment bears, near its base, a pear-shaped aperture with a raised rim from which extends a ligament-like band known as the funicle. This band is attached to arms (aa) projecting into the excavation in the hind margin of the propodeum.

The first tergite is abruptly swollen or enlarged posteriorly (less suddenly in the male than in the female) and the maximum width and thickness of the abdomen is reached near the middle of the second segment. There are six tergites (1T, 2T, etc.)
visible in the female and seven in the male, the second being the broadest. Six sternites (1St, 2St, etc.) are to be seen in both sexes although a small seventh (as will be discussed later) is sometimes visible in the male insect. On each visible tergite and on the seventh of the female, which is hidden under the sixth, is found a pair of spiracles (sp), one near each antero-lateral margin of the tergite. The second sternite bears a distinct and deep, somewhat sinuate, ventral furrow (vf), the lateral extremities of which are curved and projected posteriorly. This furrow, which is a character of generic value, is less distinct in male than in female specimens.

The sixth tergite is the last one visible in the female. It completely covers the small, narrow seventh which lies just over the structures composing the sting and which is connected with the sting mechanism and the sixth tergite by membrane. The sixth sternite carries two lobes near its apex which bend upward and around the protruding sheath (sh), lancets (not visible in fig. 29) and palpi (pp) of the sting, thus forming a cone-shaped covering having an opening at its apex through which
the sting can operate. The eighth sternite is not to be found as a separate segmental plate and probably enters into the composition of the basal portion of the sting.

Modifications occur in the sclerites forming the terminal abdominal segments of the male (Pl. IV, figs. 31-33). The seventh tergite (7T) is clearly visible as a dorsal sclerite. The eighth tergite (8T), which is known as the epiproct, is hidden under the seventh. It is divided into two lateral, heavily chitinized portions connected by membrane. There is a hairy, one-segmented, palpus-like structure borne at each outer, lateral angle of the tergite which Saunders (1884) termed a penicillum (pe). The sixth sternite (6St) usually appears to be the last ventral sclerite (exclusive of the subgenital plate (SP)), but the seventh sternite (7St) is present and hidden although it sometimes shows if the abdomen is distended. There is a deep, broadly rounded incision in the middle of the hind margin of the sixth sternite and, on each side just laterad of the mouth of the incision, is found a small, hook-like protuberance which arises abruptly from the surface of the plate. It is not
a separate structure but part of the sternite and its functions are not known. The seventh sternite (7St) is of a half-moon shape and lies just below and in front of the subgenital plate (SP) or hypandrium which was considered by Saunders (1884) to be the basal portion of the true ninth sternite (eighth sternite according to the system of nomenclature used in this paper). The subgenital plate is elongate, being about three times as long as wide at its widest part. Its lateral margins are concavely arcuate and the apical lateral angles are rounded. The ventral surface of the plate is elevated at its base to form a low, longitudinal carina. The apical portion of the ventral surface of the subgenital plate is covered with short and stiff black hairs.

**Endoskeleton of the abdomen.**—The abdomen has no distinct endoskeleton of the type found in the thorax. The chitinized portions of the sting and genitalia, although internal in position, are considered to be highly modified tergites, sternites and terminal appendages of the abdomen so that they cannot be classed as true endoskeletal structures. The inner surfaces of most of the tergites and sternites are much the same in appearance, so that figures 35
and 56, which are views of the inner surfaces of the tergite and sternite of the second abdominal segment of the female, can be considered as typical.

The tergite (Fig. 56) is seen as a broad, quadrate plate which extends over the dorsal and lateral surfaces of the segment. The anterior margin of the plate is inserted under the hind margin of the tergite of the preceding segment and is connected to it by membrane which is attached to the preceding tergite some distance cephalad of its posterior margin. (Attachment of third tergite to second is shown in figure 56 by the broken line near the posterior margin). The anterior margin of the tergite is raised so that a thickened rim is formed which extends to the pointed anterior lateral angles. The spiracles, as mentioned before, are placed near the antero-lateral margins of the tergite.

The sternite of the second abdominal segment is also a quadrate plate which covers the ventral surface and a portion of the lower lateral surfaces of the segment. Its anterior margin is inserted above the hind margin of the sternite of the preceding segment and the front margin is thickened by a transverse rim which extends to the pointed anterior lateral
angles of the sternite. The lateral margins of the sternite are inserted under the lateral margins of the tergite of the same segment. The ventral furrow (vf), which is present only on the sternite of the second segment, is seen on the ental surface as a raised area, the outlines of which follow those of the furrow as it is observed on the ectal surface of the sternite.

Sting.—(Pl. IV, fig. 30.) The sting is, with the exception of a few modifications in the structure of its component parts, very much like that of the honeybee as described by Snodgrass (1925) whose nomenclature for the various parts is used in this paper. The sting proper consists of three parts; a dorsal sheath (sh) and two ventral lancets (let) which slide in a groove on the under surface of the sheath. The sheath is long, pointed, and heavily chitinized. It has a relatively smooth surface distally and lacks the barbs which are found on it in the honeybee. It is enlarged basally to form a bulb (sb) which has, connected to it by two lateral articulations, an upward-crooked, heavily chitinized basal plate (bp). In addition the sheath is prolonged anteriorly to form two curved lateral arms (sha).
Each arm is flattened near the bulb to allow the lancets to slide over its dorsal surface. The arm then extends anteriorly as a long, thin and curved, chitinous plate which is mesad of the lancet and which joins a less heavily chitinized prolongation of the oblong plate (ob). The lancets extend along the ventral groove of the sheath as long, thin, hair-like structures. Each is attached at its base to a so-called triangular plate (tp) which is articulated at its base with the quadrate plate (qp) and the oblong plate. The oblong plate extends over and covers the basal plate and bulb of the sheath and is joined dorsally to the oblong plate of the other side of the sting structure by a heavily chitinized narrow band. It bears a so-called palpus (pp), which consists of two distinct segments, near its dorsal surface. The quadrate/articulates at its base with the triangular plate and extends over and partially covers the oblong plate. It is joined dorsally to the quadrate plate of the other side by a chitinized band. A peltate dorsal plate (dp), the homologies of which have not been determined, occurs on the dorsal surface between the chitinous bands connecting the two quadrate plates and the two oblong plates.
Genitalia.--(Pl. IV, fig. 34) The genitalia or copulatory apparatus of the male lies dorsad of the subgenital plate or hypandrium and ventrad of the eighth tergite or epiroct, but it is inserted between these two plates to such an extent that the distal portions of the cochlearum (cc) are usually the only parts visible (Pl. IV, fig. 31). Boulangé' (1924) has collected the material written concerning the genitalia of Hymenoptera in his paper "Recherches sur L'Appareil Copulatoire des Hymenopteres et especialment des Chalastogastres" while Radozskowski (1938) gave names to the various parts of the genitalia of Psammocharidae.

The basal ring of the genitalia is a simple ring or chitinous band which, as its name indicates, is basad of the remainder of the genitalia and extends around and covers the bases of the gonostipites (gst). When seen in dorsal aspect each gonostipes appears as a heavily chitinized, somewhat triangular plate which is prolonged at its inner, distal angle to form a long, flat, ribbon-like structure which I would term the distal prolongation (id) of the gonostipes. The cochlearum (cc)
or "branch" of adomskowski is articulated at the outer corner of the conostipes. A ventral view of a conostipes shows it to have a very irregularly triangular outline which is cut into by a deep excavation in the inner (mesal) margin near the base. The ventral surface of the conostipes terminates distally in a blunt point, to the dorsal margin of which is attached the sacitla (sag) or volsella. The ventral, inner (mesal) margin of the conostipes is bent dorsad and forms a flange which bears two small teeth on its inner edge and the ventral, outer or lateral margin is moulded to form an articulation with the base of the cochlearum. Each conostipes is rounded laterally and the pair, taken together, make up a hollow, shell-like structure which partially encloses the adecrum (ae).

The cochlearum (cc) is elongate; its dorsal surface is convex; its ventral surface is flattened. Towards the apex of the cochlearum the outer surface is somewhat flattened and the apical inner, dorsal and lateral surfaces bear long, dark, spine-like hairs. The sacitla (sag) is joined to the conostipes by membranes, its base being placed between the distal
blunt point of the ventral surface and the distal prolongation of the dorsal surface. A small, sharp-pointed tooth or protuberance is found on the inner margin of the sagitta near its base. The sagitta is enlarged apically to form a spoon-like structure, the inner edge of which is prolonged to form a pointed, beak-like structure which gives the enlargement the general outline of a bird's head although it may be said to be spoon-like in that the ventral surface is convex while its dorsal surface is concave. The penis valves, which, together with the penis are called the aedeagus (ae) form a single, rather weakly chitized structure which lies between the gonostipites.
STUDY II

GENERAL CONSIDERATIONS
GENERAL CONSIDERATIONS

Historical

The genus *Pepsis* was erected by Fabricius in his "Systema Piezatorum" (1804, p. 207) to include forty-seven species. There were two groups included in the original genus, the first having petiolate abdomens, the second having sessile abdomens. The group of twenty-seven species having petiolate abdomens has since been removed to other genera in various families of Hymenoptera, while the second group formed the nucleus on which the genus *Pepsis*, as it is known today, was built. Until 1810 no genotype had been designated, but in that year Latreille (1810, p. 437) designated *Pepsis stellata* (Fab.) 1793, one of the original species, as the type species of the genus. *P. stellata* (Fab.), however, is considered a synonym of the earlier described *P. sanguigutta* (Christ) 1791, which, as shown by Schulz (1903, p. 466) and others, is the male of *P. rubra* (Drury) 1773, a species described at an earlier date than either of the others and thus the valid name of the species. *P. rubra* (Drury), therefore, may be considered the genotypic species.

In the monograph "Die Gattung Pepsis" Lucas (1895) summarized in a masterful manner the knowledge
of the genus at that time and the same author later (1919) published a supplementary study which included the data and new species (chiefly those of Brethes in his papers of 1908 and 1914) that had appeared after the publication of the monograph. Since 1917 several short papers dealing with species of the genus have been published by Banks ('19, '21, '25, '26, '28), Bodkin ('18), Montet ('21), Petrunkevitch ('26), Foulton ('17), Salman ('28, '29) and others.

Schrottky (1909, p. 240) suggested the name Brethesia for Pepsis. He stated that as P. arenaria (Fab.), which he considered the genotype of Pepsis, was an Ammophila, the name Pepsis was a synonym of Ammophila. Examination has failed to reveal any designation of a genotypic species earlier than that of Latreille and no reason can be found for relinquishing Pepsis as the name of the genus. This view agrees with that expressed by Lucas (1919, p. 2).

In his monograph, Lucas (1895) dealt with approximately two hundred species. Brethes (1914) treated of three hundred and seventy-six species and varieties and since that time other species have been described. Because of the present chaotic condition of the taxonomy of the genus, it is inadvisable to
present an estimate as to the number of valid species now known.

No division of the genus into groups or subgenera has been found earlier than that rather indefinite grouping given by Brethes (1914, pp. 350-355) in his discussion of the geographical distribution of the species in the genus. This grouping, however, seems to have no taxonomic basis and so is of little value in dividing the large number of species included in the genus into smaller taxonomic groups of species. The species described by Brethes in 1908 are stated by him to belong to certain "groups" in the monograph of Lucas, but reference to that paper shows these "groups" to be but the primary divisions of the key to species given there. Lucas (1919), however, furthers the idea of a grouping for convenience in taxonomic studies and mentions twenty-six distinct groups, each group being given a type species. It does not appear that these group designations were made with the idea of creating subgenera, except in the case of Giganteopepsis or the gigantea group which was definitely described as a subgenus, the distinction alone indicating the difference. The present author does not consider it advisable or expedient to call
these groups subgenera for they are erected almost entirely on the basis of similarity of coloration, the presence or absence of golden bands of pubescence, or similar characters which, in some of the groups at least, bring together in the same group species which are very different morphologically. Thus the *P. formosa* (Say) of Lucas (=*nephele* Luc.) is much more closely related morphologically to *P. grossa* (Fab.), which is placed in another group, than it is to the other species of its own group. Similarly *P. terminata* Dahlb. and *P. pulchripennis* Mocs., which are placed in different groups, are very closely related, if morphological similarity is to be considered of value in indicating relationships. As the above mentioned "groups" of Lucas cannot be considered as subgenera, the genus *Pepsis* may be held to consist of the subgenera *Pepsis* Fab., 1804 and *Giganteopepsis* Lucas, 1919. In the study following this one, a third subgenus will be recognized and described.

**Geological Distribution**

As far as can be determined, there have been no fossil species of *Pepsis* described. Rohwer (1909, p. 27) listed an undescribed species reported by Burmeister (1832, p. 636) from the Baltic Amber of the
Lower Oligocene. Burmeister noted the following concerning the specimen:— "Gallwespen in Bernstein find mir nicht vorgekommen, wohl aber ein Raupentoter, der ohne Zweifel in die Gattung Pepsis gehört, aber ganz verblichen ist, so dass die Art nicht gut bestimmt werden kann. Er hat etwa die Grosse der Pepsis lutaria Fabr. (Amphiphila Latr.), allein der Brustkasten ist schlanker und der Hinterleib kurzer gestielt, wodurch er den amerikanischen und besonders africanischen Arten ahnlicher wird."

Burmeister's comparison of the fossil specimen with "Pepsis" lutaria (Fab.) which, according to Dr. H. T. Fernald is probably a reference to that species now known as Podalonia lutaria (Fab.) a Sphecid, would lead one to believe that the fossil is not of the genus Pepsis as now constituted. In addition, the fact that it has a petiole of considerable length and the fact that it is reported from Europe, would be additional reasons for considering it as of some genus other than Pepsis for no species now known has an abdominal petiole of the type exhibited by the genus Podalonia and no recent species, as far as I have been able to determine, has been found in Europe.

The fact that there are no fossil species known
would lead to the thesis that the genus is of a relatively recent origin. Lucas (1919, p. 5) made the statement that "...evidently the genus was developed in the most recent period of the world." (Trans.). He based this statement on the fact that distinctive morphological characters are but weakly developed in this group and that color characters, particularly those associated with bright reflections of light on the wings, which are usually not well developed in more or less archaic groups, are surprisingly important in *Pepsis*. In his studies of the morphological and colorational characters exhibited by species of *Pepsis*, the present author has found that great variability is the rule, a variability much greater than would be expected in a group comprised of old, well-established insect species. This, in itself, would suggest that the group is in a state of flux and change and possibly is relatively "young". Although the biology of the species in this genus has not been studied to any great extent, the fixity of habit and the relative stability of host relationships in the species that have been studied, would indicate that the biological phase of development, at least, may be relatively "old".
Geographical Distribution

The genus is exclusively one of the western hemisphere and is predominantly South American. Brethes (1914) has very ably discussed this subject and there is little to add to his notes. He recorded P. euterpe Brethes as the southernmost species and described it from the state of Santa Cruz in Argentina, near the forty-seventh parallel south latitude. According to Brethes (1914) the greater number of species are concentrated in the Minas Gerais region of Brazil with fewer species in other portions of South America, the West Indies, Central and North America. The northern limit of the species of this genus was said by Brethes to be about thirty-seven degrees, forty minutes north latitude, specimens of P. cinnabarina Lucas having been recorded from Coulterville, California. The present author has studied specimens of P. elegans Lep. from about the same latitude as that recorded as the northern limit of species in this genus by Brethes. Specimens of P. formosa (Say) have been seen from Norton County, Kansas, which lies between the thirty-ninth and fortieth parallels north latitude and from Beaver County, Utah, which lies between the thirty-eighth and thirty-
ninth parallels. Although Lucas mentioned that, in North America, the Mississippi River is the eastern limit of species of this genus, specimens of *P. elegans* Lep. are common east of that limit while specimens of *P. mildei* Stål, *P. marginata* Palisot, and *P. ruficornis* (Fab.) have been seen from this area. Species of this genus occur from near sea level to an altitude as great as 9000 feet, the altitude at which those specimens described by Cameron as *Pepsis chilloensis* from Chillo, Ecuador, were taken. (Cameron, 1903, p. 227)

Although several species have been described in or referred to the genus *Pepsis* from land areas other than those of the western hemisphere, it has been shown by Lucas (1895) that the species are either unrecognizable, may be referred to other genera, or, as in the case of *P. gronza* (Fab.), the place of origin probably has been given incorrectly.

**Biology and Habits**

Relatively little or nothing is known concerning the biology and habits of most species of *Pepsis* although it has been stated that the species of this genus prey on spiders and no exceptions are known.
Lucas (1895) quoted Say concerning the habits of *P. formosa* (Say) and its activities in catching spiders of the species *Mygale avicularia* (?). Buckley (1862), Linsecum (1867) and Walsh and Riley (1869) also described the attack of *P. formosa* (Say) on a spider and indicated the prey to be *Eurypelma* (Mygale) *hentzi* Girard. McCook (1890) discussed the habits of *P. formosa* (Say) and figured (Pl. V, fig. 2) the species attacking *Eurypelma hentzi* Girard. If the figure is correct, the species is not *formosa* but may be *mildei* Stål, for the former species has black antennae and the fore wings have a distinct white tip while, in the figure, the antennae are yellow, the white tips of the fore wings are lacking and the dark terminal bank of black is typical of *mildei*. Laboulbene (1895) exhibited a specimen of *Pepsis* and its prey (*E. hentzi* Girard) before the Entomological Society of France. He thought the wasp to be *P. formosa* (Say), but his description of the specimen does not fit that species and agrees with that of *P. mildei* Stål. In his report he discussed other records of Psammocharids attacking various species of spiders and quoted Darwin's (1875) record of a combat between a Brazilian species of *Pepsis* and a spider of the genus *Lycosa*. 
and cited Simon as having seen a blue species of Pepsis trailing a Eurypelmid of a species other than E. hentzi in Venezuela.

Poulton (1917) listed a trapdoor spider (Idiops sp.) as the prey of an undetermined species of Pepsis in Piracicaba, Sao Paulo, Brazil. He also recorded that a male of an undetermined species of Pepsis was found as the prey of the Reduviid Apionerus lampes Fab. in the same locality.

The most complete account of the method of attack used by any one species has been presented recently by Petrunkevitch (1926) who made extensive observations on P. marginata Falisot and its prey Cyrtopholis portoricae under conditions of confinement. P. marginata was found to attack and lay its eggs only on this species of spider and, although many encounters between the wasp and spider were noted, stinging of the spider was resorted to only when the wasp was ready to lay an egg. In all cases noted the wasp showed no fear of the spider. The spider abandoned its ordinary efficient methods of defence and attack of other insects and seemed to be helpless before the attacks of the wasp. The wasp crawled underneath the prey, grasped a leg
in its mandibles, held off the adversary with its legs and stung in the soft membrane at the base of the coxa, semi-paralyzing the spider. A later insertion of the sting was often made in the membrane near the sternum, the poison usually acting more quickly when introduced near the anterior end of that sclerite. Feeding at the wound by the adult wasp was noticed.

The eggs were laid on the paralyzed host after it had been placed in a "grave" dug for it by the wasp and earth was packed down tightly around the prey, preventing any movement. Petrunkevitch gave no data concerning the development of the wasp larva, but it is known that, as in other closely related groups of wasps, the larva is external and feeds on the spider, pupating in a cavity in the soil and emerging later by pushing its way up through the soil to the surface.

Systematic Position and Characters of the Genus

The genus *Pepsis* is placed in the subfamily *Pepsinae* (Ashmead, 1900). For the characters of this subfamily see Ashmead (1900), Banks (1911), or Haupt (1927). The genus may be separated from
others in the subfamily by the following characters:

Second medio-cubital cross vein (m: cu₂) meets M₁+2 in the basal third of that portion forming the posterior margin of the first median cell (1M). See Pl. III, fig. 19.

Anterior distal angle of the radial cell (1R+2R+3R) of the fore wing rounded, due to the manner in which the radial sector (Rs) joins Radius (R). See Pl. III, fig. 19.

Tibia of hind leg in females with a longitudinal row of toothlike projections on the dorsal surface. See Pl. III, fig. 25.

Hind margin of propodeum distinctly divided into a median and two lateral portions (subfamily character). See Pl. II, fig. 13.

Specific Characters

Historical

In the past and up to the present time, the classification of species in this genus has rested largely on color differences. Up to the time of the publication of the monograph of the genus *Pepsis* by Lucas (1895), few morphological characters were given in descriptions of species or used in classification although Smith (1855), Cameron (1893), Cresson (1867)
and others occasionally made vague references to striations and tubercles on the propodeum, but in such a general way as to make their statements concerning these characters almost useless in the determination of species. Lucas introduced and utilized many new structural characters in his descriptions and keys, but color characters still formed the basis of his classification. Brethes (1908, 1914) returned to the use of color while other writers, such as Fox (1898) and Banks (1921), have followed Lucas to a greater or less extent, in some cases supplying additional morphological characters for a few species.

Variation

Workers in other groups of Hymenoptera, such as Mickel (1928) working on Mutillidae and Fernald (1926) studying Sphecidae, have found that the extent and degree of development of color markings is very variable in single species, seemingly varying according to changes in environmental conditions. The author has had no opportunity to study the effects of environmental factors on the colors of species in this genus, but has found, in studies of relatively large series of specimens of single species, that the color
characters exhibited are not stable and vary greatly, the variations being correlated to some extent with changes in geographical distribution of the specimens. As this variability in color is so marked and as many of the distinctions formerly drawn between species on the basis of color characters appear to be artificial and lead to confusion in the classification of species, the author will attempt to evaluate the various color characters exhibited by species of the genus and used by previous workers on the group and to discover the limits within which they may be considered as representing usable taxonomic characters.

There is also a great variation in the size of body of specimens of the same species. The degree of development of the various structural characters used in classification varies according to the size of the specimen so that this factor must be taken into consideration in utilizing the various morphological characters exhibited. An evaluation of the various structural characters which have been utilized in classification, to determine their limits of variation and thus their value, will be attempted in the discussion of morphological characters to follow. For
the terms used in the discussion see the first study reported in this thesis - "The External Morphology of *Pepsis elegans* Lepeletier."

**Color**

Dependence on color in the classification of species in the genus has, in the opinion of the author, led to the many misidentifications of specimens and has contributed, in part at least, to the chaotic state in which the taxonomy of the genus is to be found. Color characters in the genus cannot be said to be stable enough to warrant the dependence that has been placed on them as definite differentiating characters.

**Color of antennae.**—The first two segments of the antennae are, as a rule, black, or nearly so, but there may be great differences in the color of the various segments beyond the second. Species in which the flagellum is normally black may show variations in which an extreme is represented by a flagellum having practically every segment showing a definite terminal brownish or yellow ring, or an entire segment may be yellow. This type of variation is exhibited by *P. nephele* Lucas.

Species in which the flagellum is normally yellow or orange show great variation, an extreme of
which may be that condition where all the flagellar segments, except the distal portion of the terminal segment, are of a brownish black color. This type of variation is shown by *E. mildei* Stål. That species has definite morphological characters in both sexes and, in grouping together all the specimens at hand when this examination was made that showed these characters, forty females and thirty-seven males were found. The antennal color, in many of the specimens, however, varied far from the normal for the insect described by Stål from California. In that state male specimens from the same locality (San Jose) and having the same morphological characters, were found to have the flagella entirely yellow in some specimens and in others they were entirely black, except for the apical half of the terminal segment, which was yellow. Other specimens showed various intermediate types of coloration. The same variation was found in the antennae of both sexes from other parts of California, while in other states the variation was somewhat less pronounced, although series of specimens from each state showed a tendency to vary from the mean condition for that state. As the eastern portions of the range of the species were approached, the antennae tended to have a greater number of black segments and the condition typical of
the form described by Fox as *P. bogaci* (= *mildei* Stål) in which only the apical portion of the last flagellar segment is yellow, was common. Specimens of *mildei* have been seen from Arizona, Colorado, California, Texas, Nevada, New Mexico, Georgia and Louisiana. The antennae of those specimens from the western part of the range of the species were usually more yellow than black, although, as mentioned before, both extremes of coloration were found. Specimens from New Mexico and Arizona were intermediate, a larger number of segments being black. Specimens from Nevada, Colorado, Texas, Louisiana and Georgia showed a greater number of black segments, the terminal, or possibly several of the distal segments being yellow. A change of the wing color was found to be correlated with the change in type of antennal color exhibited by this species as the eastern portions of its range were approached.

Some species that have been described in the past have been differentiated almost entirely on the number of antennal segments exhibiting a certain color. The data presented above, which can be matched to a greater or less extent by data on other species, indicate that such a practice might be doubtful value and, unless
characters of this type can be correlated with other, more stable characters, their use is hedged with limitations and uncertainties.

Color of body.—All species of _Iepsis_ that have been seen by the author have a definite body color which may be called black. A lighter, brownish color may occur in some cases due to age, fading, or some other factor. Thin portions of the cuticula, portions of the mandibles and other mouthparts may have a slightly different color. Statements have been made in descriptions of species that the body color is purplish, greenish, bluish or of some other color, but the colors referred to in those statements are due to the short velvety pile or pubescence that is present on practically all portions of the body in fresh specimens and are not the colors of the cuticula.

Color of wings.—Wing coloration has been given an important place in the classification of species of _Iepsis_ and is undoubtedly of some value. There is some question, however, as to whether the characters provided by the different patterns, markings or basic colors are sufficiently constant to warrant the confidence that has been placed in them as characters. The basic wing colors may be considered
as blackish or blackish brown and yellow or yellowish brown. In those species in which the wing is entirely black or blackish brown, differentiation of species has been made on the basis of the different lustres or sheens exhibited by the wing surface. These are chiefly greenish, bluish, purplish or metallic and iridescent. The author has found, in some cases, that such characters may be of slight value but, in view of the fact that the treatment of specimens subsequent to their collection may change these characters and that environmental conditions also may have some effect, it appears to be a better policy to eliminate such minor variable characters from the classification of the species and to rely on characters that are less affected by external factors.

In some dark-winged species the discs of the fore and sometimes of the hind wings are marked with light colored or brightly colored areas. The extent and outline of wing markings of this type is extremely variable and thus not usable in many cases. In a few species, however, the extent and intensity, and in other species the presence or absence of such markings are valuable characters.

The presence or absence of hyaline wing
tips appears to be a relatively stable character, but a slight lightening of color near the wing tip is a common feature and may be mistaken for a hyaline wing tip. The broad, clearly-defined wing tip, as exhibited by *P. rubra* (Drury), is a distinctive character, but it may vary as in *P. pulchripennis* Moes. In that species a well-defined wing tip is present in typical specimens of the species, but the extent and intensity of the hyaline portion varies greatly in specimens from different localities. In *P. grossa* (Fab.) and species in which the hyaline wing tip is but poorly defined, the utilization of such a character in the differentiation of species is a delicate and not always accurate procedure.

The pubescence of the wings consists largely of a pile-like surface covering that contributes to the color of the wings. The author has found no specimen in which this pubescence was absent, yet its presence or absence on the wings has been utilized by some authors as a taxonomic character. The color of the pubescence has been relied upon by some authors to differentiate species, but environmental conditions appear to play an important role in modifying the color and treatment subsequent to the collection of the specimen may make it impossible to determine species by this means. When the pubescence on the wing is arranged to form a pattern,
the color of which differs markedly from that of the
pubescence on the remainder of the wing surface, such
a pattern seems to furnish a character of value in
identification although there is much variation in the
size and extent of markings of this type.

In conclusion, it has been the author's
experience that the characters furnished by the color
of various portions of the body, wings and antennae
have been utilized in the past to a greater degree than
the constancy of those characters would warrant. Some
color characters, particularly when correlated with
morphological characters, may serve as an easy means
of separating species, but must be used advisedly and
only when it has been ascertained that other characters
exhibited by the species substantiate the evidence
supplied by the color characters.

Size

A great variation in the size of body often
is found within a species which, in some groups of
insects, would be considered a basis for the erection
of new species. If, however, no constant characters
can be found to separate specimens of a series in which
a great variation of size is exhibited, it seems logical
to conclude that the series is of but one species and
the range in stature is the range for that species. Size
may have some value, but it does not seem advisable to
utilize size alone as the determining character for, considering the type of life lived by the immature stages of insects in this genus, there is much reason to believe, as brought out by Mickel (1928) in his study of the Mutillidae, that the size of the prey provided by the parent as food for the larva determines the size of the later stages.

**Pubescence**

The cuticula of the body usually is covered by a short pubescence or pile and, in many species, there are, in addition, larger hairs which are more or less abundant on different parts of the body.

**Pile.**—A short pubescence is present on the surface of the body of fresh specimens, but on some portions, such as the propodeum, it sometimes appears to be absent. Because this pubescence is subject to wear in nature and the active life of the insect is conducive to loss of it, the presence or absence of the pile on parts of the body seems to be a very unstable character. Although it may be usable, it is rather difficult to manipulate with any degree of certainty. The color of the pile has been used as a character, but, as the pile is subject to many different kinds of treatment both before and after death, the color is likely to be
modified from its original condition. Some species, however, have pile, the color of which is distinctly different from the usual bluish or purplish and in such species the color of the pile appears to be a valuable character.

Hairs.—The hairiness of the body, considered apart from the pile, offers many characters that appear to be of importance in the taxonomy of the genus. These characters cannot be too closely defined, however, for there may be much variation. *P. cerberus* Luc., for example, is known from Arizona, Texas, Mexico and Guatemala. The specimens that have been seen from Arizona and Texas had relatively few hairs on their bodies while those from Mexico and Guatemala were very hairy, showing enough difference to raise some question as to the value to be placed on this character.

The degree of hairiness of the head offers a general character that does not appear to be of importance. Lucas often described the condition of the spines and hairs found on the clypeus and labrum, but it is the experience of the author that the hairs on these parts of the body are subject to wear and thus vary greatly in the same species. The hairiness of the thorax has been used as a general character, but experience teaches
that it is no more than that. Banks, in differentiating *P. formosa* (Say) from closely related species, relied on the presence or absence of hairs on the posterior portion of the pronotum. The study of a large series of specimens of *formosa* failed to show this character to be of importance as there is usually a variable number of relatively long hairs present on the pronotum in fresh specimens, but worn specimens of the same species lack the hairs.

The coxae are hairy, but the hairs seldom furnish any taxonomic characters. In a few species, however, the extremely thick hair covering present on this leg segment constitutes a character of importance. The femur, in many species, lacks hairs, except for a few short hairs on the dorsal surface near the apex of the segment. Some species, however, have a few scattered, short, or long hairs on the upper and lower surfaces of the femora and show distinct types of hairiness that are available and usable in the differentiation of species. As the pile on the femora is usually short and often scarcely discernible, the pits left by the hairs when broken off, serve to indicate that they were present when the specimen was fresh and a normal one for the species. Lucas first used the hairiness of the femora as a taxonomic character and Banks utilized
it in separating other species. The author has found that these characters are available for a much wider application than was made by those authors. The hairs on the tibia are available as characters in some species. Their value is due to their shape rather than to their abundance or scarcity. The characters shown by them, however, usually are not available in differentiating between males of the species concerned. The spines of the legs will be considered later under morphological characters.

The propodeum shows varying degrees of hairiness in specimens of a single species. Within limits, however, the presence or absence or the relative abundance and scarcity of long hairs on the propodeum may be useful in separating some species.

With the exception of a few species that exhibit an unusually heavy covering of hairs on either ventral, dorsal or both surfaces, the hairiness of the abdomen is of no value in the classification of females. The presence of hairs on the terminal segments of the abdomen has been described by many authors, particularly by the early writers, but definite characters do not seem to be present. In males, however, a different situation exists. The general hairiness of the abdomen has practically the same value as in females, but in many
species important characters are to be found in the hair tufts present on a variable number of sternites. The presence or absence of such tufts constitutes a primary character while the sternites on which the tufts occur, the placement of the hairs on the sternites, the relative density and shape of the tufts and the shape of the hairs all provide characters of the utmost importance in differentiating between species. The hairiness of the subgenital plate also may provide characters.

Morphological characters

Lucas (1919) mentioned that this genus presents but weakly developed morphological characters. This appears to be so when the group is compared with some others and the females in particular seem to show few significant morphological differences. It is apparent, however, that the lack of morphological characters was not the reason for omitting them from keys and classifications, but that the lack of knowledge of the comparative morphology of the various species in the genus might have been the reason. Characters of the propodeum were mentioned by early workers in the group, but only in a most general manner with the result that the characters, as they gave them, were of little value. Lucas and some later writers gave rather definite morphological characters
in their descriptions of species and used some of them in differentiating between species in their classifications. For the most part, however, they retained and seemed to prefer color characters. Their use of morphological characters does not seem to have placed enough value on that type of character and it seems to the writer that many opportunities for the application of morphological characters were overlooked.

Head.—The color and character of the dorsal surface of the labrum has often been described by writers, but it appears to have but little value in differentiating between species. The margin of the clypeus has been used as a character by several authors and, within limits, may be used advantageously as a supplementary character. A distinct type of clypeal margin is present in some species, but the distinction between an arcuate or angulate incision, that is often used, is of little importance for gradations from one form to the other may be found in the same species. As the clypeus often shows wear, the characters of the clypeal margin indicative of a specific differentiation, may be obliterated. The females of many species exhibit a clypeus having a flattened marginal band and, above this, a raised roll-like area called by Lucas a "querwulst". This transverse raised area appears to be common to a certain group of species having other features in common
and may be used as a supplementary character.

The sculpturing of the vertex, mentioned in many descriptions of species and used to some extent to differentiate between species, seems to be an unfortunate choice of a character. It is true that, in most females, (usually so much less so in males as to preclude its use), there is a certain degree of development of the pits laterad of the posterior ocelli, of a transverse carina across the vertex, and of various elevations anterior to or laterad of the ocelli, that differs in the various species. References to the development of these characters as "well-developed", "weak", "shallow", "deep", however, are vague and unsatisfactory for they apply to structures showing relatively small, variable or almost undefinable differences. Although we may say that certain species show tendencies to have these structures developed in certain ways, it seems as if the degree of development is dependent on the size of the head or on the distance between the eyes which gives the appearance of depth or shallowness, etc.

The distance of the posterior ocelli from one another, as compared with the distance between them and the anterior ocellus, or as compared with the distance of the hind ocelli from the compound eyes, has been used as a character. Due to the fact that these
comparative measurements are on an object so large as to make the measurement of such short distances under a microscope rather difficult and the differences of these distances are so small that minor errors in the measurements have a high value, it seems as if these characters might well be substituted by others easier to use. The inner margins of the compound eyes, which are sinuate, usually have a tendency to converge above.

The antennal segments appear to be relatively constant in number and comparative length in the different species. The antennae of female specimens usually are twelve-segmented while those of males are thirteen-segmented. Two species have been found, however, the males of which have twelve-segmented antennae. Lucas utilized, both in his descriptions and in his classification of females, the length of the third antennal segment as compared with the width of the vertex from inner margin to inner margin of the compound eyes at about the level of the hind ocelli. This comparison appears to furnish a relatively constant character. In some females (Subgenus Trichopepsis), the inner surface of the segments near the tip of the antennae is flattened.

The antennal segments of male specimens present clear, distinct and important characters in the form of depressions or modifications of the ventral and inner
surfaces. They appear to be associated with cells of a sensory nature. On the surface of these sensory areas may be discerned minute dots which I take to be the processes of sensory cells, although no histological examination has been made to confirm this. In many species the dots do not appear to be grouped in any particular portion of the segment, but closer examination shows that the ventral surface is distinctly differentiated. Such a type shows minute dots scattered over the entire ventral surface and may be termed a "wide-band" type of grouping. (Pl. V, fig. 37). Other species show a more or less distinct grouping of the sensory cells into a narrow band extending the length of the ventral surface of each segment. This may be called a "narrow-band" type. (Pl. V, fig. 38). In this and the following types, the sensory areas usually are more or less impressed or excavated and the antennal surface within the limits of the sensory areas lacks the short, silvery pubescence found on the remainder of the segment. A modification of the narrow-band type may occur in which the sensory area of each segment is constricted near the middle of the segment. This may be called a "constricted-band" type. (Pl. V, fig. 41). The constriction becomes more marked in some species and finally the
band becomes broken in the middle of the segment and two, more or less triangular areas, one basal and one distal, are formed. (Pl. V. fig. 39). The basal and distal areas may be large or small and, in different species, may be hemieliptical, semicircular or may have some other shape. The distal areas are lacking in some species, only the basal areas remaining. (Pl. V. figs. 40, 42, 43). In other species the basal areas are well developed and the distal areas may remain as small, ovate or obovate areas. The sensory areas are not present in a state of equal development on every segment of the antennae, but such structures as are shown reach their greatest and probably their most useful development, as far as their taxonomic value is concerned, on the middle segments of the antennae, the fifth, sixth and seventh segments. The characters exhibited by these sensory areas are relatively stable in each species and appear to be of great value in differentiating the males. These characters are not developed to as great an extent in females as in males and the simple broad-band grouping seems to be the only type exhibited.

Thorax.—The thorax presents but few structures that are useful in determining species. The development of the shoulders of the pronotum, or the convexity of the anterior surface, is rather constant within a
species. The differences between closely related species, however, usually are so slight as to make the use of these characters difficult. The scutum may exhibit a median elevation, but this scarcely can be used as a specific character. The hind margin of the pronotum, used in other genera of Psammocharids as a means of differentiation between species usually does not lend itself for use in this genus as very few constant and definable differences are present. The degree of development of the mesopleural tubercles has been used rather extensively in the past. Although much variation is present and although closely related species usually cannot be separated on the strength of this character, the degree of development of the tubercles, when correlated with the degree of development of propodeal characters, has some value.

**Legs.**—The legs, in most cases, present but few structural characters of importance. As they are long, the tarsal segments slender and easily broken off, it seems advisable to utilize characters of parts less likely to be destroyed in the ordinary handling of the insect. Lucas separates the subgenus *Giganteocephalopsis* almost entirely on the basis of the characters shown by the tarsal segments. There are noticeable differences
in the relative abundance of spines on the tibiae and tarsi in the females of various species. Although this relative abundance often has been expressed in descriptions, it has not been used in classification. In males, the spines on the tibiae and tarsi are absent, or nearly so. Lucas and others have used the ratio of the length of the inner tibial spur of the hind legs to the length of the basitarsus as a character. In some cases this ratio seems to offer a means of determining the species, but the ratio for different species must not be so close that the variation within the species, or wear, will make enough difference to raise a question as to which ratio holds. The shape of the tibial spurs of the middle and hind legs presents characters that are useful in the classification of a few species. In some species the tips are distinctly bent but in most species they are straight or but slightly curved.

Lucas and others have used the length of the hind legs, from the apex of the femur to the tip of the tarsus, as compared with the measurements of certain parts of the body, usually the distance from the hind margin of the pronotum to the margin of some abdominal segment, as a character. These distances are extremely difficult to measure accurately, chiefly because the legs and tarsal segments are scarcely, if ever, straightened, the body is often flexed or bent and the
abdomen may be distended or retracted. There is some
doubt in the mind of the author as to whether such
measurements can be utilized in practical classification
with either accuracy or satisfaction.

Wings.—The structure of the wings is remarkably
uniform. The venation, although varying greatly in
details is very constant in general plan. Certain cells
and veins have been used by workers to differentiate
between species. The cells used have been the second
medial and third medial cells. The courses followed
by the first and second intermedial cross veins and the
ratio of the length of the anterior margin of the second
medial cell \( M_{1+2} \) in part) to the width of that cell
also has been used. The author has examined these
characters in series of specimens of single species
and has found variation to be so great as to make them
unusable. In certain species there are, it is true,
tendencies for the anterior margin of the second medial
cell to have a certain ratio to the width of the cell,
but even here the variation is so great that, in species
in which the anterior margin usually is less than the
width, there will be found gradations from such a type
to the type in which the anterior margin is distinctly
greater than the width of the cell.

Propodeum.—The rugosity of the horizontal and
sloping surfaces of the propodeum often has been used
to differentiate between species, but as it is extremely variable in form and as the degree of its development is correlated directly with the size of the specimen, it does not seem that the characters offered by it are of importance. The form and degree of development of the median longitudinal carina and median longitudinal furrow of the horizontal surface, although variable, may be used in conjunction with other propodeal characters. The transverse ridge, subspiracular tubercles, lateral carinae and lateral teeth also vary greatly in form, but show tendencies which, within limits, may be utilized. In males, the length of the horizontal surface, measured from the middle of the anterior margin of the propodeum to the transverse ridge, when compared with the length of the sloping surface, measured from the transverse ridge to the middle of the hind margin of the propodeum, gives a ratio that may be used successfully in some species. Measurements of these distances, as well as other measurements of the propodeum, as utilized by Lucas in his descriptions of species, do not appear to be of value for they are given as actual measurements which vary according to the size of the specimens.

The presence or absence of concavities and
carinae, and the rugosity and the convexity of the sloping surface as a whole may be of value when used advisedly, but it appears, from studies that have been made, that these characters are extremely variable. Many species, however, show a certain undefinable distinctness in the structure of both horizontal and sloping surfaces. The degree of development of the posterior lateral angles of the propodeum sometimes furnishes a character of importance, although, in some species, it is very variable.

Abdomen,—The structures of the abdomen do not supply many characters for the classification of female specimens. The first tergite may be elongate and almost petiolate, or sessile. It may widen gradually or abruptly and may be flattened above and anteriorly or may be convex. The presence or absence of the lateral posterior prolongations of the transverse furrow on the second sternite seems to offer a relatively constant character. The apparent position of the furrow on the sternite is dependent upon the degree of distention of the abdomen and so is of little value.

The abdomen of male specimens shows many characters of value. The ventral hair tufts already have been described. The character of the surface of the tergites in the vicinity of the hair tufts is also
important, in some species being smooth and shining, in others punctate, and in still others pubescent. The shape of the incision in the hind margin of the sixth sternite, although not showing a great variety of form is occasionally distinct enough to be used.

The proportions of the seventh sternite provide many characters, but as dissection of the specimen is necessary if these characters are to be used, they may not be of general application in determination of specimens. The eighth tergite also provides important characters in the form of variations in the shapes of the scleritized areas but the use of these characters also is subject to the criticism that dissection of the specimen is necessary. It is the opinion of the author, however, that the characters furnished by these sclerites must be used by the taxonomist in determining specimens of doubtful position or at least they must be used until enough experience has been accumulated to allow the worker to sense the identity of specimens from what may be termed "undefinable" characters. The structure
of the subgenital plate furnishes characters of the utmost importance, but even here there may be a great variation, as shown by the following plate.

Text Plate I

Text plate I depicts the variation found in the structure of the subgenital plate of males of the species *P. formosa* (Say). Figures 1 and 5 show the extremes while figures 2, 3, and 4 show the gradations between the extremes.

The genitalia of the males although showing much less variety in different species than is
shown by the genitalia of other groups of insects, furnish important supplementary characters. The shape of the cochlearum is important, although descriptions should be made of a stated view, for each side presents a different outline. The shape of the inner basal prolongation of the sagitta and the shape and degree of development of the head and beak of the sagitta also supply important characters.
STUDY III

SPECIES OCCURRING IN NORTH AMERICA,

NORTH OF MEXICO
SPECIES OCCURRING IN NORTH AMERICA, NORTH OF MEXICO

Introduction

The large number of species described in the genus *Pepsis* and the scarcity of material available has made it almost impossible to study and determine the status of all the species of the genus over its entire range. As a result the author has deemed it wise to divide the range of the genus into smaller areas and to study the compact and more conveniently handled groups of species found in those areas as units. This paper is the result of a study of the group of species occurring in one of these smaller areas—that of North America, north of Mexico.

Distribution

The *pepsis* fauna of the land area of North America, north of the United States-Mexican boundary, is discussed in this study. Species of the genus are not found in all parts of this region, however, for the fortieth north parallel appears to mark the northern limit of any species. The greater number of species found in the area inhabit the southwestern and western states, but it is evident that some of these do not have their centers of distribution in the states mentioned and are normally more southern
species. One species (*elegans* Lep.) is common east of the Mississippi River, but few of the western species appear to extend their normal range into this region. There have been representatives of two species, *marginata* Pal. and *ruficorns* (Fab.), seen from Florida, but evidently they are typical insular species and usually do not occur on the mainland.

**Species Recorded and Studied**

Lucas, who summarized the knowledge of the genus in 1895 and whose work is utilized and referred to frequently in this paper, recognized but ten species from the area under consideration. Of these, he described five as new. Some of his records appear to be erroneous and others doubtful, as will be discussed later. Cockerell (1898) proposed a new name for one of Lucas' species. Fox (1898) described four new species from the area and gave a key to fifteen species. He recorded seven species not listed by Lucas. Viereck (1908) described a new species and Brethes (1914) keyed all members of the genus known to him, including those from North America but gave no data concerning the species in that area. Lucas (1919) summarized the data appearing since his monograph.
and recorded fourteen species from the area under consideration. Banks (1921) gave a key to seventeen species known to him from the United States and discussed the records of three other species. He described the males of two new species and, in 1926, described another species. The present author described the male of a new species in 1928.

The author has seen and recognized but twenty distinct species in the material examined. One of these is described as new and is placed in a new subgenus. The following are the species recognized:

Subgenus **PEPSIS**: *angustimarginata* Vierck
  - azteca Cameron
  - arizonica Banks
  - bequaerti Salman
  - cerberus Lucas
  - chrysothemis Lucas
  - cinnabarina Lucas
  - elegans Lepeletier
  - formosa (Say)
  - grossa (Fabricius)
  - lucasii Fox
  - marginata Palisot
  - mexicana Lucas
  - mildei Stål
  - nephele Lucas
  - novitia Banks
  - pallidolimbata Lucas
  - ruficornis (Fabricius)
  - venusta Smith

Subgenus **TRICHOPEPSIS**: *hirsuta* n.sp.

Species of Pepsis that have been reported
from this area, but which are not considered in
detail and are not considered synonyms of any
of the above-named species, are as follows:

charon Mocsary
circularis Fox
cupripennis Taschenberg
cyanea Linnaeus (Pepsis?)
domingensis Lepeletier
montezuma Smith
luteicornis Fabricius
rubra (Drury)

The date presented in this paper are drawn
from the study of over nine hundred specimens.

Classification

Species of Pepsis reported or seen from
the region of North America, north of Mexico, are
of the two subgenera Pepsis and Trichopepsis, which
may be separated as follows:

Tibiae of middle and hind legs with distant
longitudinal furrow on antero-lateral and
postero-lateral surfaces; inner spur of
hind tibia one half or more the length of
basitarsus..........TRICHOPEPSIS N. SUBG.
Tibiae of middle and hind legs without
longitudinal furrows as above; inner spur
of female specimens
of hind tibia/distinctly less than half the
length of basitarsus......PEPSIS FABRICIUS
TRICHOPEPSIS N. SUBG.

The species of this subgenus have the general characters of *Pepsis*. Body densely hairy; inner spur of hind tibia over half the length of basitarsus; antenna with inner surface of distal segments flattened; abdomen depressed; tibiae of middle and hind legs with longitudinal furrow on antero-lateral and postero-lateral surfaces.

Type species. *Pepsis (Trichopepsis) hirsuta* n. sp.

This subgenus has been erected to include *hirsuta* n. sp., *cassiope* Mocs., a Brazilian species, and possibly *cassandra* Mocs., from Chile. Specimens of the last-named species have not been seen, but the descriptions of authors indicate that it may belong to this subgenus.

**PEPSIS (TRICHOPEPSIS) HIRSUTA N. SP.**

Female. (Length 34 mm) Body and legs black with bluish or purplish pile. Antennae black, shading to brown towards apex. Wings yellowish-brown with black basal band about one-sixth length of fore wings and one-fourth length of hind wings; apical field light fuscous, somewhat darker near margin of wing. Head, thorax, propodeum and abdomen thickly hairy.
particularly beneath. All femora with long, thickly-placed hairs beneath. Clypeus broadly convex; margin weakly and arcuatey incised. Epicranial furrow distinct. Vertex rather strongly sculptured. Inner eye margins slightly convergent above. Third antennal segment distinctly shorter than width between eyes across vertex. Antennae thick, tapering to apex; inner surface, particularly of segments near apex, flattened.

Shoulders of pronotum rounded; anterior surface convex; posterior margin arcuate. Scutum convexly arched anteriorly, flattened posteriorly. Scutellum broadly rounded above. Mesopleural tubercles wanting. Antero-lateral and postero-lateral surfaces of middle and hind tibiae with distinct longitudinal furrow extending from near base almost to apex. Inner tibial spur of hind leg more than half length of basitarsus.

Propodeum thickly hairy; longitudinal and sloping surfaces distinct. Horizontal surface rather regularly convex; median carina distinct, flattened above or with weak median longitudinal furrow; lateral carinac indistinct; lateral teeth moderately developed, although nearly hidden by hairs; subspiracular tubercle
well-developed; transverse ridge moderately high, short, flattened above. Sloping surface weakly convex; excavated immediately behind transverse ridge; surface weakly rugose. Posterior lateral angles of propodeum rounded. Abdomen flattened dorso-ventrally. Ventral furrow of second sternite, though not deep, distinct, sinuate, without well-marked lateral posterior prolongations.

Holotype.—Female, Southern Arizona Bequaert). To be deposited in the collection of the Museum of Comparative Zoology at Harvard University.


This species agrees very closely with the existing descriptions of cassandra Mocs., but differs from the characters given for that species by Lucas in the color of the antennae. It is possible that this newly described species is identical with cassandra. In view of the fact that that species has been reported only from Chile, while hirsuta is known only from Arizona and that the status of some of the characters exhibited by hirsuta is not known for the Chilean species, it appears better to consider
hirsuta as new until more complete data concerning cassandra are available.

PEPSIS FABRICIUS

Key to Species

1. Antennae usually thirteen-segmented, porrect; subgenital plate visible at tip of abdomen (males)........................................(2)
   Antennae twelve-segmented; loosely coiled; sting present at tip of abdomen (females)......................(17)

2. With distinct ventral abdominal hair brushes.......(3)
   Without distinct ventral abdominal hair brushes.
   (Scattered hairs usually present)......................(9)

3. Hair brushes present on fourth and fifth sternites.(4)
   Hair brushes present only on fourth sternite.......(6)

4. Hair brushes on both sternites in middle of hind margin; hairs short, erect..............azteca Cameron
   Hair brushes of fourth segment thicker laterally and forming two tufts; hairs curled at tips..............(5)

5. Antennal sensory areas distinct, triangular, basal; wings yellow...............................mildei Stål
   Antennal sensory areas less distinct; elongately triangular and basal and distal or narrowly band-like and constricted in middle; wings black
   ....................................................ruficorns (Fabricius)
6. Antennal sensory areas deeply impressed, hemi-elliptical, basal; subgenital plate long, narrow...............................*angustimarginata* Viereck
Antennal sensory areas band-like, constricted in middle or even separated into triangular-shaped basal and distal areas; subgenital plate spatulate. (7)

7. Apex of incision in sixth sternite angulate; antennal sensory areas normally constricted in middle of segment or separated into basal and distal areas; subgenital plate distinctly spatulate....................(8)
Apex of incision in sixth sternite rounded; antennal sensory areas narrow bands; subgenital plate with sides gradually divergent posteriorly.*novitía* Banks

8. Basitarsus of hind legs twice or less than twice the length of inner tibial spur; wings black; antennae orange.................................*elegans* Lepeletier
Basitarsus of hind legs distinctly more than twice the length of inner tibial spur; wings for most part yellowish; antennae black........*cerberus* Lucas

9. Antennal sensory areas small, deeply impressed, basal; incision in sixth sternite deep, narrow, rounded at apex.............................*venusta* Smith
Antennal sensory areas scarcely impressed, basal and distal, or band-like.................................................(10)

10. Subgenital plate with two transverse carinae or with median tooth and apical carina.........................(11)
Subgenital plate not as above, usually with elevation near base...........................................(14)

11. Preapical transverse carina angularly bent in middle or toothlike, sometimes with longitudinal median carina connecting the two transverse carinae...................(12)
Subgenital plate with transverse portion of preapical carina straight or regularly curved and not angulate or toothlike..................................................(13)

12. Subgenital plate with preapical transverse carina toothlike, usually weakly carinate laterally...........

.................................................formosa (Say)
Subgenital plate with preapical transverse carina angulate and low, connected with apical carina by longitudinal ridge..................mexicana Lucas

13. Preapical carina extending nearly across width of plate and rising directly from main surface of plate........

.................................................bequaerti Salman
Preapical carina not extending across entire width of plate and terminating a secondary level of plate, the lateral limits of which are formed by the anterior prolongations of the preapical carina..................

.................................................chrysothemis Lucas

14. Anterior femora and subgenital plate with long hairs beneath, the latter with low, broad median keel ex-
tending nearly entire length of plate; antennae
twelve segmented..............................(15)
Anterior femora lacking long hairs beneath; subgenital
plate with or without hairs beneath, but without median
keel as above; antennae thirteen segmented............(16)

15. Wings black except for whitish hyaline apical margins..
.............................................grossa (Fabricius)
Wings for the most part yellowish or reddish brown.....
.............................................nephele Lucas

16. Subgenital plate lacking long hairs beneath; smooth,
shining; with high, toothlike median longitudinal
carina anteriorly; flattened or excavated posteriorly..
.............................................marginata Palisot
Subgenital plate with hairs beneath in distinct
excavation in distal third of plate; a triangular,
flat-topped elevation present at base of plate...........
.............................................arizonica Banks

17. Anterior femora with many distinct long hairs beneath..
.............................................(18)
Anterior femora with but few scattered hairs beneath
or lacking hairs..................................(19)

18. Third antennal segment equal to width between eyes
at level of posterior ocelli; wings for most part
black............................................grossa (Fabricius)
Third antennal segment usually shorter than width between eyes; wings for most part yellowish or reddish-brown..........................nephele Lucas

19. Tip of outer tibial spur of middle leg distinctly bent.....................................(20)

Outer tibial spur of middle leg straight or gently curved.....................................(21)

20. Hairs of posterior tibiae long and abruptly bent towards apices; wings for most part yellowish brown....

..........................cerberus Lucas

Hairs of posterior tibiae not long and bent; wings black, antennae yellow or orange...elegans Lepeletier

21. Third antennal segment distinctly longer than distance between eyes; wings for most part yellowish brown; antennae yellow..........................azteca Cameron

Third antennal segment equal to or distinctly shorter than distance between eyes at level of posterior ocelli.....................................(22)

22. Third antennal segment shorter than distance between eyes at level of posterior ocelli.....................................(23)

Third antennal segment equal to distance between eyes at level of posterior ocelli.....................................(26)

23. Hind margin of pronotum distinctly angulate; wings black with whitish hyaline apices...mexicana Lucas
Hind margin of pronotum arcuate; wings for most part yellow or yellowish brown.........................(24)

24. Sloping surface of propodeum with distinct excavation behind transverse ridge; posterior femora with scattered, but noticeable hairs above; mesopleural tubercles distinct..................angustimarginata Viereck
   Sloping surface of propodeum nearly flat across; posterior femora lacking hairs above; mesopleural tubercles indistinct........................................(25)

25. Vertex rather strongly sculptured, but noticeably flattened or even sunken between the eyes; fore wing with distinct hyaline tip..............formosa (Say)
   Vertex less strongly sculptured and convex; fore wing with fuscous marginal band..........luasii Fox

26. Sloping surface of propodeum excavated immediately behind transverse ridge; mesopleural and subspiracular tubercles distinct; antenna with at least distal half of apical segment yellow.................................(27)
   Sloping surface of propodeum nearly flat across; antenna with no segment of a clear orange or yellow color.................................................................(28)

27. Wings black; antennae, except two basal segments, yellow..........................ruficornis (Fabricius)
   Wings yellowish brown; antennae with variable number of segments yellow...............mildei Stål
28. Horizontal surface of propodeum strongly convex;
lateral posterior prolongations of ventral furrow wanting..........................marginata Palisot
Horizontal surface of propodeum convex, but not strongly so; median longitudinal furrow well-developed;
lateral posterior prolongations of ventral furrow distinct.................................(29)

29. Wings fiery reddish brown, lacking whitish hyaline tips..............................cinnabarina Lucas
Wings light yellowish brown with whitish hyaline tips....................................pallidolimbata Lucas

PEPSIS (PEPSIS) RUFICORNIS (FABRICIUS)

Sphex ruficornis FABRICIUS, Syst. Ent., 352, n. 37, 1775.(2)
Pepsis ruficornis FABRICIUS, Syst. Piez. 215, no. 36, 1804

(2)References to the original description, the first paper reporting the inclusion of the species in the genus Pepsis, Dalla Torre's "catalogus Hymenopterorum" (1897) and taxonomic papers (excluding lists) appearing since 1897 are the only ones given under each species. For other references before 1897 see volume 8 of Dalla Torre's "Catalogus Hymenopterorum".
Pepsis ruficornis DALLA TORRE, Cat. Hym. 8: 261, 1897.♀


Location of type:—Unknown to me. Possibly in the collection of the University of Copenhagen.

Distribution:—America, West Indies (Dalla Torre); Cuba, St. Thomas, St. Croix, British Guiana, Cayenne (French Guiana), Colombia, Honduras (Lucas); Porto Rico (Ashmead). The material studied was from Cuba, Isle of Pines, Florida, Bahamas, Porto Rico and Guatemala.

Description:—Lucas (1895, p. 596) gave excellent descriptions of both sexes and figured the genitalia of the male. The type of development of the sensory areas may vary. Normally they are in the form of a constricted narrow band, or the band may be broken in the middle of the segment to form triangular basal and distal areas.

Remarks:—This species usually does not occur on the mainland, but, as material has been seen from Florida,
it is included in this study. The males exhibit a remarkable constancy of structure, but their size may vary greatly. The females, which were examined, may be divided into two groups exhibiting slightly different characters. The differences, however, may not be clearly defined. The females from Florida, Isle of Pines and Cuba are of a dark blue or purple color. The wing color, when compared with that of the other group, is much darker. The clypeal margin of females from the above-named areas is rather deeply and roundly incised and the basitarsus of the hind leg is three times the length of the inner tibial spur. Females of the second group came from Porto Rico and Guatemala. They are of a lighter, brighter blue color. The clypeal margin is shallowly and arcuately incised and the basitarsus of the hind leg is but two and one-half times the length of the inner tibial spur. These differences are slight and, though distinct in some specimens, do not appear to be of sufficient value to warrant the placing of the specimens of the two groups as members of different species. As the males from the same localities apparently present no characters that would separate them into two groups, strength is given to the thesis that perhaps the differences exhibited by the females may be indicative of the effect of environmental conditions in the different areas.
P. ruficornis (Fab.) and P. elegans Lep. are so similar in appearance as to offer some difficulty in determining specimens of the two species on any but a morphological basis. Both species are of approximately the same size and exhibit the same antennal, body and wing color. The females of the two species may be separated by the fact that the outer tibial spur of the middle leg is straight or but gently curved in ruficornis, while the tip is bent distinctly in elegans. In addition, the length of the third antennal segment is, in ruficornis, equal to the width of the vertex between the eyes while, in elegans, it is distinctly less than the width of the vertex. The males of these two species may be separated by means of the characters exhibited by the ventral hair tufts. Ruficornis has a pair of lateral tufts on the fourth sternite and a transverse band of hairs on the fifth. Elegans has no hair tuft on the fifth sternite and those on the fourth, although grouped laterally to some extent, form a curved, more or less semicircular band across the anterior portion of the sternite.

Material examined: Twenty-seven males and sixteen females.
Figures:

Antennal sensory areas - Pl.VI, figs. 39, 41.
Subgenital plate - Pl.V, fig. 9.
Seventh sternite - Pl.V, fig. 16.
Genitalia of male - See Lucas (1895) Pl.XXVIII, fig. 63.

PEPSIS (PEPSIS) ELEGANS LEPELETIER


?Pepsis auranticornis DALLA TORRE (LUCAS). Cat. Hym. 8: 247, 1897. ♀♂ (♀)

Pepsis dubitata DALLA TORRE (CRESSON). Cat. Hym. 8: 251, 1897. ♀♂

Pepsis elegans DALLA TORRE. Cat. Hym. 8: 252, 1897. ♀♂

Pepsis elegans FOX. Ent. Soc. Wash. 4: 143, no. 1, 1898. ♀♂

(3) A question mark (?) preceding a reference indicates that the inclusion of the species or reference in the synonymy is questionable. The use of an asterisk (*) indicates that the reference has not been seen but that the status of the species referred to has been established by previous writers and is not questioned by the present author.


Location of type:—Probably in the Museum of Natural History, Paris.

Distribution:—Pennsylvania (Lepeletier); Georgia, Texas, (Cresson – dubitata); South America, Brazil, Mexico (Lucas – auranticornis). The material studied was from Georgia, Alabama, North Carolina, Tennessee, Mississippi and Texas.

Description:—Although some doubt still remains as to whether elegans and auranticornis are the same species, the description of the latter, as given by Lucas (1895, P. 605), is an excellent one of elegans. The tip of the outer tibial spur of the middle leg is distinctly bent in female specimens. Although this character tends to appear in males, it is not well-developed. The sensory areas of the male antennae are of the constricted band type or may consist of large triangular basal and distal areas, the tips of which may meet.
Remarks:—It is a generally accepted fact that dubitata Cress. and elegans Lep. are the same species. There is some question, however, as to whether auranticornis Luc. is also the same species, but it is the belief of the author that auranticornis Luc. will prove to be a synonym of elegans Lep. This belief is based on the following facts:—The description of auranticornis, as given by Lucas, applies in detail to the specimens from North America that agree with our conception of elegans Lep. In addition, the type specimens of auranticornis exhibit the bent tibial spur in the female and the sensory areas of the male antennae also are as in elegans Lep.

Lucas failed to consider either elegans or dubitata as valid species. He separated auranticornis from these species first, because of slight differences in color,—differences that might be due to the age of the specimens or the treatment they had received; second, because of a slight difference in the size of the specimen studied by him and the recorded size of dubitata; third, because of the fact that the recorded distribution of the different species were different. The first reason, in the light of our present knowledge of the insignificant value such slight color differences
have, is of little importance. As most species show a variation in size that is greater than the five millimeter difference between *auranticornis* and the species described by Cresson, the second reason also may have but little weight. The third reason has some value, but even here the fact that Lucas recorded a specimen from Mexico detracts from its force. In spite of the fact that the exact locality in Mexico was not given, this record shows that the range of *auranticornis* approaches, if it does not actually overlap, the range of *elegans*. This leads to the logical conclusion that *elegans* and *auranticornis* may be the same species.

The characters separating *elegans* Lep. from *ruficornis* (Fab.) have been given under the latter species.

**Material examined:**—Fifty-three males and twenty-one females.

**Figures:**

- Antennal sensory areas - *Pl. VI*, figs. 39, 41.
- Subgenital plate - *Pl. V*, fig. 11.
- Seventh sternite - *Pl. V*, fig. 17.
- Cochlearum - *Pl. VI*, fig. 25.
- Sagitta - *Pl. VI*, fig. 31.
- Genitalia - See Lucas (1895), *Pl. XXIX*, fig. 58.

Other details of structure - Plates I-IV, figs. 1-36.
Pepsi (P. marginata) Palisot


Pepsi marginata Dalla Torre. Cat. Hym. 3: 256, 1897.♂♀


Location of type: Unknown to me. The type of *P. heros* Dahlbom, a species considered to be a synonym of *P. marginata* Palisot is probably in the collections of the Berlin Museum.

Distribution: San Domingo (Palisot); Haiti, Porto Rico (Schulz); Cuba (Cresson). Specimens have been seen from Florida, Bahamas, Cuba, Porto Rico, San Domingo and Haiti.

Description: Reference must be made again to Lucas (1895, p. 793), who gave good descriptions of both sexes of this species. Lucas did not mention the following characters exhibited by female specimens:
The distance between the eyes at the level of the hind ocelli is equal to the length of the third antennal segment. The transverse furrow of the second sternite lacks lateral posterior prolongations.

The sensory areas of the male antennae are not clearly demarked, but appear to be of the broad band-ventral/type of grouping. In some specimens examined, however, there were discerned faintly outlined, elongate, triangular areas.

Remarks:—There is, as remarked by Cresson (1867, p. 145) a great variation in size within this species. Specimens examined by the author from Cuba and Florida were much larger than those seen from the Bahamas and Porto Rico. Correlated with the variation in size are corresponding variations in structural features. The lateral posterior angles of the hind margin of the propodeum are more angulate, the lateral posterior prolongations of the transverse furrow of the second sternite are more evident, and the difference between the length of the basitarsus of the hind legs and the inner tibial spur is greater in the larger specimens of this species. Variation in the size and the outline of the basal tooth of the subgenital plate also is very noticeable.

Lucas (1895, 1919) and Schulz (1903) indicated
that *P. domingensis* Lep. was to be considered a synonym of *P. marginata* Pal. The present author cannot concur in that opinion for the male of *domingensis* exhibits a subgenital plate having a structure entirely different from that exhibited by *marginata*, and the female does not exhibit the same propodeal features as do the females of *marginata*. In addition, the third antennal segment is shorter than the width of the vertex between the eyes and the lateral posterior prolongations of the transverse furrow of the second sternite are present in *domingensis* while these characters are as described above in *marginata*. The similarity of coloration undoubtedly has had some part in the confusion of the two species.

*P. marginata* Palisot is a typical insular form, and but one specimen has been seen from Florida. Cresson (1872, p. 209) recorded a specimen of *marginata* from Texas. Because of the fact that it was covered with a dense "silvery-sericeous pile", he gave it the varietal name of *sericata*. Specimens of this variety have not been seen.

Material examined:—Thirty-six males and seven females.

Figures:—

Antennal sensory areas — Fl. VI, fig. 37.
Subgenital plate - Pl. V, fig. 6.
Seventh sternite - Pl. V, fig. 14.
Genitalia - See Lucas (1895) Pl. XXVIII, fig. 70.

PEPSIS (PEPSIS) MILDEI STÅL

*Pepsis mildei STÅL. Ofvers. Svensk. Vet-Aked. Forh. 14:
   64, 1857.
Pepsis hesperiae PATTON, Proc. Ent. Soc. Wash. 3:
   46, 1894.$
Pepsis mildei DALLA TORRE, Cat. Hym. 8: 257, 1897.$
   261, 262, 1914.$
Pepsis mildei LUCAS, Arch. Natg. 83: Abt. A, Heft 5, 126
   130, 1919.

Location of type: - Museum of Stockholm (mildei):
Philadelphia Academy of Natural Sciences (boguei).
Distribution: - California (Stål); Colorado,
Oklahoma Territory (Fox); Specimens have been seen from
California, Texas, Arizona, New Mexico, Colorado, Nevada, Louisiana and Georgia.

**Description:** Lucas recognized but one sex, the male. Fox (1898, p. 146), in describing *boguet*, gave the characters for both sexes.

The sensory areas on the male antennae are small, distinct, basal; and usually are triangular in outline. The propodeum of the male is moderately haired; median carina distinct, rounded above; median furrow wanting; transverse ridge moderately high, short, weakly developed. The shape and placement of the hairs and hair tufts on the fourth and fifth sternites and the shape of the subgenital plate, as given by both Lucas and Fox, are important characters.

Fox gave the length of the third antennal segment of female specimens as being slightly shorter than the width of the vertex between the eyes, but most specimens show it to be approximately as long as the width between the eyes. The rather deeply incised clypeal margin, the well-developed mesopleural tubercles, and subspiracular tubercles and the development of other propodeal structures are important in the identification of the females of this species.

**Remarks:** The degree of development of the structural characters exhibited by this species evidently is dependent on the size of the specimen, the larger specimens showing the greater development.
Examination of the type female of *boguei* and paratypes of the same species has failed to reveal any structural characters in either sex that would serve to distinguish it as different from typical specimens of *mildei*. The chief differences are those of antennal color, but, as shown in a previous study, all gradations from the typical form of *mildei*, where all the flagellar segments are yellow, to the typical form of *boguei*, in which only the tip of the terminal flagellar segment is yellow, have been found. These differences apparently have no taxonomic value.

Examination of the male genitalia has failed to reveal any differences and other morphological characters are the same in specimens typical of either extreme of coloration.

Patton (1894) described *hesperiae* as a new species but, as recorded by Fox (1898) his species is to be considered as a synonym of *mildei* Stål.

**Material examined:**—Seventy-six males and twenty-six females.

**Figures:**

Antennal sensory areas - Pl. VI, fig. 42.
Subgenital plate - Pl. V, fig. 10.
Seventh sternite - Pl. V, fig. 13.
Cochlearum - Pl. VI, fig. 27.
Sagitta - Pl. VI, fig. 36.

PEPSIS (PEPSIS) FORMOSA (SAY)


Pepsis formosa DALLA TORRE, Cat. Hym. 8: 253, 1897.♀

Pepsis thisbe DALLA TORRE (LUCAS), Cat. Hym. 8: 264, 1897.♂♀


Location of type:- Royal Museum of Vienna and Berlin Museum (thisbe); Museum of Comparative Zoology at Harvard University (sayi). The type of formosa (Say) was destroyed.

Distribution:- Arkansas (Say). A later statement (LeConte, Say's Amer. Ent. 1: 92, 1891) that the specimens
were found "within one hundred miles of the Rocky Mountains on the banks of the Arkansas River" would indicate Colorado to be the state in which the type specimens were taken. Cuernavaca and Durango, Mexico (Lucas - thisbe); California (Banks - sayi). Specimens have been seen from California, Arizona, New Mexico, Texas, Utah, Kansas, Nebraska and Mexico.

Description:—The identity of this species has been obscure, various writers having given different forms the name formosa (Say). Banks (1921) determined as formosa the form which, to my mind, more closely agrees with Say's meager description. Lucas, in describing thisbe (=formosa) gave some of the morphological characters of the species, but others were not mentioned. Accordingly, the following diagnosis of the morphological characters exhibited by formosa is offered.

Female. (Body length 32-45 mm.) Clypeus convex, its margin arcuately incised; a roll-like transverse carina present parallel to and just above flattened marginal band. Vertex flattened or sunken between eyes; strongly sculptured. Inner eye margins convergent above; third antennal segment distinctly
shorter than distance between eyes at level of hind ocelli. Pronotum sparsely haired; shoulders moderately developed; anterior surface flat across; hind margin arcuate. Mesopleural tubercles indistinct or wanting. Anterior femora lacking long hairs beneath; tibiae and tarsal segments of middle and hind legs moderately spined; basitarsus of hind legs about two and one-half times length of inner tibial spur. Propodeum moderately haired; median carina broad; median furrow distinct; subspiracular tubercles wanting; lateral carinae weak; lateral teeth weakly to moderately developed; transverse ridge moderately high, broad, flattened or notched in middle above. Sloping surface nearly flat across; lateral posterior angles rounded. First tergite of abdomen abruptly swollen; transverse furrow on second sternite distinct, with lateral posterior prolongations.

Male. (Body length 18-30 mm.) Head moderately haired; clypeous convex; margin arcuately incised. Sensory areas broad ventral bands. Shoulders of pronotum weakly developed; anterior surface convex, posterior margin arcuate. Mesopleural tubercles indistinct. Propodeum moderately hairy; length of horizontal surface one and one-half times length of sloping surface; median carina narrow; median furrow
shallow; subspiracular tubercles wanting; lateral carinae and lateral teeth less developed than in female; transverse ridge relatively high, narrow, rounded above. Sloping surface convex. Transverse furrow on second abdominal sternite indistinct; ventral hair tufts lacking; incision of sixth sternite broad, deep, angular at sides and apex. Subgenital plate with sides converging distally; distal margin angular; apical carina, median tooth and preapical carina present on ventral surface; preapical tooth sometimes with distal carinate median prolongation connecting tooth and apical carina.

**Remarks:** Say gave but few characters of importance in his original description which read as follows:

"P. formosus. Purple, wings rufous, dusky at tip.

Inhabits Arkansas.

Body greenish purple; head, thorax, darker; antennae and feet black; wings bright yellowish red; base black; terminal submarg in of the superiores and terminal and inner sub-margins of the inferiores dusky; the corresponding margins pale."
Length of the body of the male 9/10th of an inch.

Length to the tip of the wings more than 1/10th of an inch.

Length of the body of the female 1 and 2/5 of an inch.

A very large and beautiful species, which arrests every eye by the unusual colour of its wings. It flies rather slowly and is often found on flowers in company with Stizus grandis.” Western Quarterly Reporter Col. 2: p. 76, 1823).

Undoubtedly the length of the wings, as given by Say, is incorrect. Say figured a female of this species in his "American Entomology" Pl. 42.

Cresson’s determinations of formosa (Say) may have been correct, but the one specimen seen by the author, that had been determined by him as formosa, was a male of cerberus Lucas in the M. T. Fernald collection. This raises some doubt as to Cresson’s conception of the species for it may be possible that he included several species in the material he determined

(4) This description was furnished through the kindness of Mr. E. T. Cresson, Jr.
as *formosa*.

The *formosa* of Lucas, when compared with the data provided by Say's description and figure, is found to be larger and to exhibit colorational features on the wings that are different from those shown in Say's figure. These differences ordinarily would not be considered of great importance in this group but, as Lucas described as *thisbe* a form that agrees very closely with Say's description and figure, consideration must be given this phase of the problem.

Disregarding the data offered by Lucas and relying only on Say's meager description and his figure, it is at once evident that there are two species in the fauna of North America, which fit the original description rather closely, but that one agrees more closely than the other. This agreement is based on size, colorational features of the wings and antennae and distributional data. Comparing this species with the data furnished by Lucas, it immediately becomes apparent that the species agreeing more closely with Say's description of *formosa* was described by Lucas as *thisbe*. This condition of affairs
was substantiated by information supplied by Dr. Bischoff of the Berlin Museum, who compared specimens ascribed to *formosa* (Say) by the author, with the type specimens of *thisbe* Lucas and pronounced them to be of the same species. Thus the *formosa* of Lucas is left as a species without a name. *Nephele* Lucas, was described as a possible color variety of *formosa* Lucas (nec Say). Examination of the type of *nephele* has convinced the author that the differences existing between the *formosa* of Lucas and *nephele* are not specific, so that the former species assumes the name *nephele* Lucas. Thus the status of the species involved in the problem is as follows:

\[
\begin{align*}
\text{thisbe} \text{ Lucas} &= \text{formosa (Say)} \\
\text{formosa} \text{ Lucas (nec Say)} &= \text{nephele} \text{ Lucas}
\end{align*}
\]

It is extremely unfortunate that Say's type of *formosa* was destroyed, for without it the determination of the species must rest on the data supplied by the inadequate original description of the species and on the characters shown by his figure. Although the author feels assured that the data substantiate his conclusions, it may be that they will not be accepted by taxonomists working on this group, for the conclusions undoubtedly are debatable. If such a stand is taken, in view of the inadequacy of the original description
of *formosa* (Say) and the lack of type material, thisbe Lucas would be recognized as a valid species, the *formosa* of Lucas would be considered as a synonym of *nephele* Lucas and the *formosa* of Say would be considered an unidentifiable species.

Cockerell (1898) recognized, but did not solve, the problem discussed above and Fox (1898) apparently recognized the female of *formosa*, but considered the male of *nephele* to be that of *formosa* (Say). Banks (1921) first recognized both sexes of *formosa*, but gave no reasons for his determinations and did not indicate the relationships of thisbe Lucas and *formosa* (Say).

The type male of the species described by Banks as *sayi* does not appear to exhibit any characters that would distinguish it from *formosa*, if the normal variation to be found in that species is taken into consideration. Accordingly, I consider the type male of *sayi* to be a specimen of *formosa* (Say).

*Pepsis formosa* (Say) varies greatly in size of body, but the greater portion of the variation in the color characters exhibited by the specimens studied, has been due to natural wear or to treatment of the
specimen after collection. The submarginal fuscous band of the wings and some other color characters show a remarkable constancy. The shape and size of the median tooth on the ventral surface of the subgenital plate varies greatly.

One male specimen, which was collected at Oceanside, San Diego Co., California, exhibited dark, fuscous wings. As this specimen showed no morphological characters different from those of typical males of the species, it was considered merely as a color variation.

Material examined:—Ninety-eight males and one hundred and two females.

Figures:-

Antennal sensory areas - Pl. VI, fig. 37.
Subgenital plate - Pl. V, fig. 1
Seventh sternite - Pl. V, fig. 24.
Genitalia - See Lucas (1895) Pl. XXVI, fig. 44.

PEPSIS (PEPSIS) NEPHELE LUCAS

Pepsis formosa LUCAS (nec SAY), Ber. Ent. Zeit. 39:736, 1895.♂
Pepsis nephele DALLA TORRE, Cat. Hym. 8: 257, 1897.♀
Pepsis formosa FOX (nec SAY), Proc. Ent. Soc. Wash. 4: 143, 1898.♂

Location of type: Hungarian National Museum.

Distribution: Texas (Lucas - nephele); Mexico (Lucas - formosa); New Mexico (Cockerell - pseudoformosa); Lower California (Fox). Specimens have been seen from Kansas, Arkansas, Texas, Arizona, Utah and Mexico.

Description: Lucas, in describing the species he identified as formosa (= nephele) gave a detailed description of the color characters of this species. As there is no description known to the author giving a complete morphological diagnosis of nephele Lucas, the following redescription of the morphological characters exhibited by this species is offered.

The description of the female is from the
type specimen, but takes into consideration the variation shown by the series of specimens at hand that agree with the type. The examination of the type was made possible through the kindness of Dr. T. Tsabo-Patay of the Hungarian National Museum, who loaned it to the author. The description of the male is from the series of specimens at hand.

**Female.** (Body length 36-47 mm.) Head moderately haired; epicranial suture distinct; inner eye margins convergent above. Clypeus convex, its margin arcuately incised. Distance between eyes at level of hind ocelli greater than length of third antennal segment. Pronotum moderately haired; shoulders rounded; anterior surface somewhat convex; hind margin arcuate. Mesopleural tubercles slightly or not developed. Coxae thickly haired; anterior femora with numerous long, curved hairs beneath; tibiae and tarsal segments of middle and hind legs strongly spined; basitarsus of hind legs two and one-half times length of inner tibial spur. Propodeum hairy; horizontal and sloping surfaces distinctly differentiated; median carina low, flattened above or with weak median longitudinal furrow; lateral carinae weak; lateral teeth distinct, tuberculate; subspiracular tubercles not developed; transverse ridge
moderately high, truncate or notched in middle above. Sloping surface flattened; posterior lateral angles obtusely-angled or rounded. Transverse furrow of second sternite distinct and with lateral posterior prolongations.

Male. (Body length 30-36 mm.) Clypeus long, its margin narrowly and arcuately incised. Antennae twelve-segmented; antennal sensory areas broad ventral bands. Shoulders of pronotum well developed; hind margin arcuate. Mesopleural tubercles slightly developed. Anterior femora with a few long, curved hairs beneath. Length of horizontal surface of propodeum one and one-half times length of sloping surface; median carina distinct; median longitudinal furrow wanting; subspiracular tubercles scarcely developed; transverse ridge high, narrow, rounded above; sloping surface convex; posterior lateral angles nearly right-angled, distinct. Transverse furrow on second sternite less distinct than in female; ventral hair tufts lacking; incision in sixth sternite broad, deep, angular at sides and apex. Subgenital plate elongate, sides converging distally; distal lateral angles rounded; distal margin straight across or notched in middle;
ventral surface broadly but strongly and transversely convex; apical third of plate bent ventrad; dense covering of long hairs present on ventral surface.

Remarks:—In describing nephele, Lucas stated that it might prove to be only a variety of his formosa (nec Say). Examination of the type of nephele showed that species and formosa (sens. Lucas) to be the same, the former being a type exhibiting a somewhat more extensive fuscous submarginal band on the wings, but differing from the latter only in some color characters. In view of this situation the species given by Lucas as formosa (Say) must assume the name nephele Lucas due to the fact, as discussed before, that his determination of formosa was incorrect.

Pepsis nephele Lucas appears to exhibit fairly constant structural characters. Color characters, particularly those concerned with the extent of the black basal bands and fuscous submarginal bands of the wings, vary greatly. The third antennal segment of the female is distinctly shorter than the width of the vertex between the eyes, but in two individuals the length of that segment was found to be very nearly equal to the width of the vertex. As
this is the only morphological character that has been found to separate the females of nephele Lucas from those of grossa (Fab.) there remains only the difference in wing color to separate these two apparently closely related species. I have found no morphological characters which will serve to separate the males of these two species. The males of nephele Lucas and of grossa (Fab.) are unique in that they normally have twelve-segmented antennae.

Material examined:—Eighteen males and fifty-one females.

Figures:

- Antennal sensory areas - Pl. VI, fig. 37.
- Subgenital plate - Pl. V, fig. 7.
- Seventh sternite - Pl. V, fig. 15.
- Cochlearum - Pl. VI, fig. 28.
- Sagitta - Pl. VI, fig. 35.

PEPSIS (PEPSIS) GROSSA (FABRICIUS)

Sphex grossa FABRICIUS, Ent. Syst. Suppl. 245, 1798.
Pepsis grossa FABRICIUS, Syst. Piez. 214, 1804.


Pepsis grossa DALLA TORRE, Cat. Hym. 8: 254, 1897.
Pepsis obliquerugosa DALLA TORRE, (LUCAS) Cat. Hym. 8: 258, 1897.

Location of type:— Reported by Smith (1855) to be in the University of Kiel collection. Berlin Museum (obliquergosa).

Distribution:— India (Fabricius. Undoubtedly incorrect or referring to the West Indies); New Granada, Colombia, Brazil (Lucas - grossa); Cuba, St. Thomas (Lucas-obliquergosa); Mexico, Arizona, Lower California (Fox - obliquergosa). Material has been seen from Arizona, New Mexico, Arkansas, Utah, Lower California, Mexico, Nicaragua, Honduras, Colombia, Cuba, Isle of Pines and Trinidad.

Description:— Lucas (1895, p. 563) gave excellent
descriptions of both sexes of this species. The sensory areas of the male antennae are in the form of broad, ventral bands. It should be noted that the antennae of the males are twelve-segmented.

**Remarks:** This species has been considered as occurring only in South America. All the males seen from North, Central and South America and from the West Indies, however, agree with the meager description of *grossa* given by Fabricius and, in addition, specimens of both sexes from these areas agree with the detailed descriptions given by Lucas. No valid structural or color differences could be found that would warrant the determination of any of these specimens as of other species.

Cresson (1867, p. 148) determined as *P. ornata* Lep. ( *terminata* Dahlb.) specimens that I believe to be *grossa* (Fab.). His mention of the fact that the wings were tipped with white excluded *terminata* Dahlb. as, in that species, the fore wings only exhibit that character. The fact that he recognized males furthers this belief, for the male of *terminata* is not yet known definitely, although Lepeletier (1845), Mocsary (1885) and Schulz (1903) have offered suggestions as to the identity of that sex.

Lucas described a form known to him only in the female sex and only from the West Indies as the species
obliquereugosa. Fox (1898) and Banks (1921) recognized both sexes of this species and reported it from the United States. Dr. Bischoff of the Berlin Museum, on request, compared the female specimens of grossa, as determined by Lucas, with the type of obliquereugosa and found that, except for the presence of V-shaped wrinkles on the horizontal surface of the propodeum and the fact that obliquereugosa was somewhat larger, the specimens appeared to be of the same species. In the material studied by the author, it was found that a larger size was not peculiar to those specimens from the West Indies, for specimens of equal size were seen from North, Central and South America as well. Similarly the V-shaped transverse wrinkles on the propodeum were found to be exhibited by specimens from all of the above-named areas, and gradations from the type in which the wrinkles are parallel and transverse to that in which the V-shaped form is exhibited, could be demonstrated within the series of specimens examined. This would indicate that the V-shaped form of the markings on the propodeum is but an extreme of a very variable structural formation and not a distinctive and specific character, as supposed by Lucas. Examination has failed to reveal any characters which might be considered as a basis for a separation of the large-sized
specimens exhibiting the V-shaped markings from other specimens typical of the species known as grossa (Fab.). Accordingly, as the characters given by Lucas for obliquerugosa appear to be mere variations of those exhibited by grossa (Fab.), the former species may be considered as a synonym of the latter.

The species determined by Banks (1928) as terminata (neu Dahlb.) does not differ from, and should be considered as, grossa (Fab.). The true terminata is easily separated from grossa by morphological as well as colorational characters.

There is a great variation in the color of specimens of this species. The wing tips may be rather broadly and distinctly whitish hyaline or may be indistinctly marked. The wing color, particularly in specimens from Arizona, may be lighter near the base or may even show a yellowish brown color, although in no case was this found to be well-marked. The individual antennal segments, in some specimens, may be tipped with brown or yellow. The variation in size and in the degree of development and form of the rugosity of the propodeum is, as already discussed, very noticeable.

The species in the United States that is most closely related to grossa (Fab.) is nephele Lucas. Both
sexes of both species are similar morphologically, the males exhibiting no structural differences and the females differing only in the ratio of the length of the third antennal segment to the width of the vertex between the eyes, measured at about the level of the hind ocelli.

**Material examined:** Forty males and fifty-three females.

**Figures:**
- Antennal sensory areas - Pl. VI, fig. 37.
- Subgenital plate - Pl. V, fig. 7.
- Seventh sternite - Pl. V, fig. 15.
- Cochlearum - Pl. VI, fig. 28.
- Sagitta - Pl. VI, fig. 35.
- Genitalia - See Lucas (1895) Pl. XXIV, fig. 24.

**PEPSIS (PEPSIS) MEXICANA LUCAS**


**Pepsis mexicana** DALLA TORRE, Cat. Hym. 8: 257, 1897.♂♀


**Location of type:** Royal Museum of Vienna.

**Distribution:** Mexico, Colombia (Lucas); United
States (Banks). Material has been seen from Arizona, Mexico, El Salvador and Nicaragua.

Description:— Lucas (1895, p. 566) gave excellent descriptions of both sexes of this species. The structure of the subgenital plate of the male is very distinctive. The antennal sensory areas are of the broad ventral band type.

Remarks:— Mexicana is a well-marked species and may be separated from grossa (Fab.) by its smaller size, by the fact that the male has thirteen-segmented antennae and by the differences in the structure of the subgenital plate. The anterior femora lack long hairs beneath and, in the females of mexicana, the third antennal segment is shorter than the distance between the eyes.

Material examined:— Twenty-seven males and twenty-five females.

Figures:—
Antennal sensory areas — Pl. VI, fig. 37.
Subgenital Plate — Pl. V, fig. 4.
Seventh sternite — Pl. V, fig. 18.
Genitalia — See Lucas (1895) Pl. XXIV, fig. 20.

PEPSIS (PEPSIS) VENUSTA SMITH

Pepsis venusta DALLA TORRE, Cat. Hym. 8: 264, 1897.♀


Location of type:— British Museum of Natural History.

Distribution:— Brazil (Smith); Mexico (Cameron); Honduras (Lucas); Arizona (Banks). Material has been seen from Arizona, Honduras, Costa Rica and Brazil.

Description:— The female is not known. An excellent description of the male was given by Lucas (1895, p. 555). The antennal sensory areas are deeply impressed and basal. The incision in the hind margin of the sixth sternite is very deep and narrow, the apex rounded.

Remarks:— This species exhibits some variation, particularly in the extent of the yellow color on the tips of the antennae and in the width and clarity of the hyaline tip of the fore wing. The single specimen reported from the United States by Banks and seen by the author, has a very clearly defined and broad hyaline wing tip. Other specimens, particularly those from Brazil, have the tip much narrower and less clearly demarked.

The male of terminata Dahlb., which was described by Lepeletier (1845), Mocsary (1885) and Schulz (1903), but
was not recognized by Lucas (1895, 1919), appears to be very similar to *venusta* in appearance, but apparently is not the same.

**Material Examined:** six males

**Figures:**
- Antennal sensory areas - Pl. VI, fig. 40.
- Subgenital plate - Pl. V, fig. 5.
- Seventh sternite - Pl. V, fig. 21.
- Genitalia - See Lucas (1895) Pl. XXIII, fig. 11.

**PEPSIS (PEPSIS) ARIZONICA BANKS**


**Location of type:** Museum of Comparative Zoology of Harvard University, no. 13722.

**Distribution:** Huachuaca Mts., Arizona (Banks).

**Description:** The following data may be added to that given by Banks in the original description of this species:

- Clypeus convex, its margin scarcely incised. The antennal sensory areas are broad ventral bands. Anterior femora with a few short hairs beneath. Mesopleural tubercles not developed. Horizontal surface of propodeum two times the length of sloping surface; median carina distinct, flattened above, narrowed posteriorly; median furrow indistinct; lateral carinae not well developed; lateral teeth distinct, tuberculate; subspiracular tubercles wanting; transverse ridge low, broad, terminating median carina.
Sloping surface flat, striate across; lateral posterior angles distinct, right-angled. Ventral furrow on second sternite of abdomen weak; sixth sternite with shallow, broadly rounded incision; hair tufts wanting on abdomen.

Remarks: - The type specimen of this species has been the only one examined. *Pepsis aquila* Lucas and *P. pyramus* Lucas appear to be rather closely related to *arizonica*, particularly as regards the shape and structure of the subgenital plate and genitalia. Even here, however, differences are to be found that may serve to separate the three species.

Material examined: - One male (Type).

Figures: -

Antennal sensory areas - Pl. VI, fig. 37.
Cochlearum - Pl. VI, fig. 29.
Sagitta - Pl. VI, fig. 32.

*PEPSIS (PEPSIS) BEQUAERTI* SALMAN

*Pepsis bequaerti* SALMAN, Pan-Pac. Ent. 5: 23, 1928.♂

Location of type: - Museum of Comparative Zoology at Harvard University, no. 16048.

Distribution: - Texas, New Mexico, Arizona, California, Lower California and Mexico.

Remarks: - This species may be separated from *chrysothemis* by the length of the preapical carina on the
subgenital plate, which is much shorter in chrysothemis than in bequaerti. The sensory areas are of the broad ventral band type. The female of this species is not yet known, but distributional data would seem to indicate that this species may prove to be the male of pallidolimbata Lucas. The data available at the present time, however, do not justify a definite statement.

**Material examined:**- Forty-seven males.

**Figures:**-

Antennal sensory areas - Pl. VI, fig. 37.
Subgenital plate - Pl. V, fig. 2.
Seventh sternite - Pl. V, fig. 23.
Cochlearum - Pl. VI, fig. 26.
Sagitta - Pl. VI, fig. 34.

**PEPSIS (PEPSIS) CHRYSOTHEMIS LUCAS**


*Pepsis chrysothemis* DALLA TORRE, Cat. Hym. 8: 249, 1897.♂

*Pepsis sanguigutta* FOX (nee CHRIST), Proc. Ent. Soc. Wash. 4: 143, 1898.♂


Location of type:— Berlin Museum.

Distribution:— Mexico, Texas (Lucas); Oklahoma, California, Lower California (Fox). Specimens have been seen from California, Arizona, Texas, Lower California and Mexico.

Description:— Lucas (1895, p. 739) gave an excellent description of this species and figured the subgenital plate and genitalia. The antennal sensory areas are of the broad, band type and the incision in the sixth sternite is shallow and regularly rounded.

Remarks:— Fox identified a variety of chrysothemis in which the terminal hyaline wing tip of the fore wing was absent. The author has not encountered such a type, but, in many specimens, the hyaline tip was found to be somewhat obscure. Specimens identified by Fox as sanguigutta (Christ) have been seen by the author, but they were typical of chrysothemis Lucas. They differed from normal specimens only in the color of the wings, a feature that is extremely variable in this species. The female is not yet known.
The *sommeri* of Patton (1894) apparently is the same species as the *chrysothemis* of Lucas. Although the male of *sommeri* (Dahlb.) and the female of *chrysothemis* are not known, it seems unlikely that the two species are but different sexes of the same species for neither exhibits characters that would be expected of the opposite sex of either species.

**Material examined:** One hundred males.

**Figures:**
- Antennal sensory areas - Pl. VI, fig. 37.
- Subgenital plate - Pl. V, fig. 3.
- Seventh sternite - Pl. V, fig. 22.
- Genitalia - See Lucas (1895) Pl. XXVI, fig. 35.

**PEPSIS (PEPSIS) ANGUSTIMARGINATA VIERECK**


*Pepsis sayi* BANKS, Can. Ent. 58: 202, 1926.♀

**Location of type:** University of Kansas (angustimarginata); Museum of Comparative Zoology at Harvard University (sayi).

**Distribution:** Arizona, Utah (Viereck). Material has been seen from Arizona, Utah and Texas.
Description:—Viereck and Banks have given good descriptions of the general color and appearance of both sexes. The morphological characters of this species are as follows:—

Female (Body length 27-31 mm.). Clypeus convex, its margin arcuately incised; a distinct roll-like transverse carina present above margin. Inner eye margins convergent above; third antennal segment shorter than width between the eyes. Shoulders of pronotum rounded; anterior surface convex; hind margin arcuate. Mesopleural tubercles well developed. Femora of middle and hind legs with scattered hairs above; tibiae and tarsal segments thickly spined. Propodeum moderately hairy; horizontal surface convex; median carina and median furrow weak or wanting; transverse ridge low, broad; lateral carinae moderately developed; lateral teeth weak though distinct; subspiracular tubercles weakly developed. Sloping surface convex, usually excavated behind transverse ridge; posterior lateral angles rounded. Ventral transverse furrow of abdomen deep, with lateral posterior prolongations.

Male (Body length 17-23 mm.). Head thickly hairy; clypeus convex, margin arcuately incised. Sensory areas on antennal segments deeply impressed, basal. Thorax thickly hairy; mesopleural tubercles blunt, weak.
Propodeum very hairy; horizontal and sloping surfaces not sharply differentiated; horizontal surface regularly convex above; median carina and median furrow indistinct or wanting; lateral carinae low; lateral teeth wanting; transverse ridge nearly absent; subspiracular tubercles wanting; lateral posterior angles distinct, nearly right-angled. Abdomen with short hairs on ventral surface; transverse furrow indistinct; fourth sternite with thin, nearly erect, lateral hair tufts; hairs bent at tips; middle portion of sternite shining, punctate. Fifth sternite shining, punctate, with few or no hairs. Incision in sixth sternite moderately deep, angulate at sides, rounded at apex. Subgenital plate elongate; lateral margins slightly converging anteriorly; distal margin somewhat convex; lateral distal angles rounded; ventral surface of plate pubescent.

Remarks:— The presence of scattered hairs on the femora of female specimens is a distinctive feature. It serves to separate the females of angustimarginata from those of lucasii Fox, which are very similar morphologically. The narrowness of the terminal fuscous band on the wings also will serve to distinguish the species, but often this character is obscured or destroyed.

There is some doubt as to whether angustimarginata
should be considered as a synonym of basifusca Lucas, a species described from male specimens taken in Mexico. The subgenital plate, genitalia, ventral hair tufts, size and color of male specimens of angustimarginata exhibit characters that agree very closely with those described by Lucas for basifusca. The only difference appears to be that the former species is not known from Mexico.

There have come to hand recently several specimens of Pepsis from Mexico that also agree very closely with the description given by Lucas for basifusca, but which differ from angustimarginata in some respects. There are a few hairs present on the fifth sternite of this Mexican form, which, in the author's opinion, are thick enough and obvious enough to be called a hair tuft. Hairs are not present on the fifth sternite of angustimarginata. In addition, the antennal sensory areas of the Mexican form are basal and distal, the basal ones being triangular in outline. In angustimarginata only basal sensory areas are present and those are hemielliptical in outline. The antennae of the type specimens of basifusca are broken and can furnish no data concerning the condition of the antennal sensory areas while Lucas made no statement concerning the hair tufts on the fifth sternite. Thus, although the two forms that have been studied can be
Separated by means of antennal characters and by means of the presence or absence of a hair tuft on the fifth sternite, the true status of the species involved and likewise the validity of the name "angustimarginata", must await further work.

The female of sayi Banks, the type of which was examined by the author, appears to have all the morphological characters of angustimarginata, but exhibits a slight difference in the coloring of the wing tip. The difference appears to be an abnormality and it is evident that the type female of sayi should be considered as a specimen of angustimarginata Viereck.

Material examined:— Eleven males and nine females.

Figures:—

Antennal sensory areas — Pl. VI, fig. 43.
Subgenital plate — Pl. V, fig. 8.
Seventh sternite — Pl. V, fig. 19.
Cochlearum — Pl. VI, fig. 30.
Sagitta — Pl. VI, fig. 33.

PEPSIS (PEPSIS) CERBERUS LUCAS

Pepsis cerberus DALLA TORRE, Cat. Hym. 8: 249, 1897.♂


Location of type: - Berlin Museum (cerberus);
Philadelphia Academy of Natural Sciences (inermis).

Distribution: - Mexico, Texas (Lucas - cerberus);
Texas (Fox - inermis). Material has been seen from Texas,
Arizona and Mexico.

Description: - Lucas (1895, p. 790) gave an ex-
cellent description of the male of the species and figured
the genitalia. The antennal sensory areas are of the
constricted band type, although there is some variation and
elongate, triangular basal and distal areas have been seen
on some specimens. The female was described by Fox (1898).
Banks (1911) called attention to the additional character
furnished by the shape of the hairs of the hind tibiae. The
author has found that the bent tips of the tibial spurs of
the middle and hind legs also are distinctive.
Remarks: - Lucas stated that the propodeum of the male was sparsely hairy. Specimens seen from Arizona and Texas agreed with that statement, but those from Mexico were very hairy. This variation may be the result of differences in environmental conditions.

*Pepsis inermis* Fox appears to be the female of *cerberus* Lucas. The geographical ranges of the two species agree. The series of specimens studied have yielded ten pairs of insects collected in the same place, at the same time and by the same collector. The tibial spurs of the male are shaped and have their tips bent over somewhat as in the female, and other morphological and colorational features are as would be expected for different sexes of such a well-marked species. *Cerberus*, being the older name, becomes the name of the species and *inermis* becomes a synonym.

Material examined: - Thirty males and twenty females.

Figures: -

Antennal sensory areas - Pl. VI, figs. 39 & 41.
Subgenital plate - Pl. V, fig. 12.
Seventh sternite - Pl. V, fig. 20.
Genitalia - See Lucas (1895) Pl. XXXI, fig. 100.
PEPSIS (PEPSIS) NOVITIA BANKS


Location of type:—Museum of Comparative Zoology of Harvard University. No. 13723.

Distribution:—Fedor, Texas (Banks).

Description:—The following points may be recognized in addition to those described by Banks.

Clypeus convex; margin arquately incised. Sensory areas forming a narrow, ventral band. Mesopleural tubercles but slightly developed. Propodeum sparsely haired; median carina low, broad; median furrow indistinct; lateral carinae, lateral teeth and subspiracular tubercles scarcely developed; transverse ridge wanting. Sloping surface convex, slightly flattened in middle; lateral posterior angles rounded. Fourth abdominal sternite with thin, lateral hair tufts; surface between and behind tufts somewhat depressed, smooth, shining. Fifth sternite lacking distinctive pubescence; median area smooth, shining. Sixth sternite slightly convex; median area flat, shining; posterior margin with broad, deep incision. Subgenital plate gradually widened towards apex, tip rounded. Genitalia typically as in cerberus Lucas.
Remarks:—The female of this species is not yet known.

This species, known only from two specimens, has the color characters of *mildei* Stal, but is very much like *cerberus* morphologically. The morphological differences are small and not easily seen. The antennal sensory areas are distinctly band-like and not constricted. The subgenital plate gradually widens posteriorly and is not spatulate as in *cerberus*. Other features, including the genitalia, are so much like those exhibited by *cerberus* that, if specimens of the latter species were known in which some of the antennal segments were yellow, the validity of *novitia*, as a species, would be doubtful.

Material examined:—The type specimen and one other male in the Banks Collection.

Figures:

Antennal sensory areas — Pl.VI, fig. 38
Genitalia — See Lucas (1895) Pl.XXI, fig.100

**PEPSIS (PEPSIS) AZTECA CAMERON**

*Pepsis azteca* CAMERON, Biol.Centr.-Amer. Hymen. 2: 215, 1893
Pepsis azteca DALLA TORRE, Cat. Hym. 3: 248, 1897.♂♀

Location of type:-British Museum of Natural History

Distribution:-Mexico (Cameron); Costa Rica (Lucas); Canal Zone, Panama (Banks). Material has been seen from Texas, Guatemala, Honduras, Nicaragua, Costa Rica and the Canal Zone.

Description:-Excellent descriptions of both sexes were given by Lucas (1895, p. 756). The antennal sensory areas are not distinctly differentiated and are of the broad bank type.

Remarks:-This species has not been recorded previously from North America, north of Mexico and but one male specimen has been seen from within that area. The center of distribution of the species is undoubtedly south of the United States; probably in Central America. Variation of structural features, in the limited number of specimens examined, was not great and the coloration of the species also appeared to be relatively constant. One female specimen from the Canal Zone exhibited a narrow terminal fuscous margin on the fore wings and the usual terminal margin on the hind wings was lacking.
All other characters apparently were normal.

Material examined: - One male and five females.

Figures:
Antennal sensory areas - Pl. VI, fig. 37.
Genitalia - See Lucas (1895) Pl. XXVII, fig. 51.

PEPSIS (PEPSIS) LUCASII FOX


Location of type: - Philadelphia Academy of Natural Sciences.

Distribution: - Texas (Fox). All the material examined was from Texas.

Description: - The female was described in an excellent manner by Fox (1898). The male is not known.

Remarks: - This species exhibits but few distinctive characters of a morphological nature. The female of domingensis Lep. a West Indian species, shows very similar structural characters, but in that species the subspiracular tubercles usually are better developed than in lucasii. Specimens of domingensis Lep. are larger and the wing disc usually is of a darker, more
fiery red color. One specimen that I have referred to
lucasi, is of the same size as other specimens of that
species, but has the fiery red wings of domingensis.
The mesopleural tubercles, however, are not developed.

Material examined:—The type specimen and nine
other females.

Figures:—No figures.

PEPSIS (PEPSIS) CINNABARINA LUCAS

Pepsis cinnabarina DALLA TORRE, Cat. Hym. 8: 249, 1897.♀
266, 1914.♀
Pepsis cinnabarina LUCAS, Arch. Natg. 83: Abt. A. Heft 5,
135, 136, 141; 1919.♀

Location of type:—Berlin Museum.

Distribution:—California, Mexico (Lucas); Mexico,
Lower California, California (Fox). Material has been
seen from Arizona, California, New Mexico, Lower California
and Mexico.

Description:—Lucas compared this species with
rubra (Drury), but cinnabarina Lucas differs sufficiently from that species to warrant a redescrip-
tion.

Female (Body length 24-39 mm.). Body, legs and antennae black with bluish or purplish pile.
Wings bright reddish brown with inconspicuous black basal band at insertion and poorly-defined terminal fuscous band. Head moderately haired. Clypeus convex, its margin arcuately incised; transverse roll-like carina present above margin. Inner margins of eyes nearly parallel, slightly convergent above; length of third antennal segment equal distance across vertex between eyes. Pronotal shoulders usually well-developed; anterior surface nearly flat across; hind margin arcuate. Mesopleural tubercles not well-developed; femora with at most a few short hairs above; tibial and tarsal segments of middle and hind legs thickly spined; basitarsus of hind leg three times length of inner tibial spur. Propodeum moderately haired; median carina distinct, median furrow deep; lateral carinae well-developed; lateral teeth low; transverse ridge moderately high, broad, rounded or flattened above; subspiracular tubercles scarcely developed. Sloping surface flat across; slightly excavated behind transverse ridge; lateral
posterior angles rounded. Ventral furrow of second abdominal sternite distinct, with lateral posterior prolongations.

The male of *cinnabarina* Lucas is not known.

Remarks:—Lucas considered *cinnabarina* and *rubra* to be very closely related. In the former species the third antennal segment equals the width of the vertex between the eyes, while in the latter the third antennal segment is distinctly shorter than the width of the vertex. The hyaline wing tip, present on the fore wing of *rubra*, is absent in *cinnabarina*.

Worn specimens of *formosa* (Say) have been studied, which bore the label "*cinnabarina* Lucas". *Formosa* differs in the character furnished by the comparison of the length of the third antennal segment with the width across the vertex. The propodeal tubercles are not as well developed in *formosa* and the propodeum presents a somewhat different aspect. Even worn specimens, in which the characters afforded by the wing markings are destroyed, can be determined by the morphological characters given above.

The morphological features of *cinnabarina* and *pallidolimbata* are almost identical. There usually are present several indefinable morphological differences between these two species, but the variation within
each species appears to provide intermediate forms so that there are no definite characters separating the two species. Accordingly, differences in the coloration of the wing, chiefly the presence or absence of the terminal hyaline apex, which is present in *pallidolimbata*, but absent in *cinnabarina*, are used as characters. It must be stated, however, that it is almost impossible to separate worn specimens of the two species.

**Material examined:** - Sixty-seven females.

**Figures:** - No figures.

**PEPSIS (PEPSIS) PALLIDOLIMBATA LUCAS**


*Pepsis pallidolimbata* DALLA TORRE, Cat. Hym. 8: 259, 1897.♀


**Location of type:** - Royal Museum of Vienna.

**Distribution:** - Northwest America (Lucas); Texas (Fox). Material has been seen from Texas, New Mexico, Nevada, California and Lower California.
Description:—Although Lucas described from a worn female specimen, the description he gave is an excellent one of the species. The male of this species is unknown.

Remarks:—The similarity of pallidolimbata and cinnabarina has been discussed under the latter species. The determination of specimens of this species has often been very unsatisfactory because of the lack of specific characters and some question remains as to the identity of some worn specimens.

Material examined:—Fifteen females.

Figures:—No figures.

Records of Doubtful Significance.

PEPSIS (PEPSIS) CIRCULARIS FOX


The type of this species has been examined by the author and, as far as could be ascertained, appears to be a specimen of chrysothemis Lucas. The color of the wings is somewhat darker than in a normal specimen of that species, but the morphological characters that could be seen, agree with typical specimens. It cannot be definitely stated, however, that circularis is not a valid species for Fox made definite statements con-
cerning the sixth sternite of the abdomen, which would distinguish it from *chrysothemis*. The posterior third of the abdomen of the type specimen is smeared with shellac and the genitalia apparently are withdrawn so that it is impossible, without dissection or other treatment, to determine the status of the sixth sternite.

**PEPSIS (PEPSIS) CUPRIPENNIS TASCHENBERG**

Lucas (1895 p. 725) recorded this species from Orizaba, Texas, but this locality was probably meant to be Orizaba, Mexico, the locality in which some of the material collected by Bilimek, was taken. The occurrence of this species in the fauna of the area under consideration is doubtful.

**PEPSIS (PEPSIS) RUBRA (DRURY)**

Lucas (1895 p. 728) recorded the male of *rubra (sanguigutta)* as occurring in Texas. It seems impossible that this species could be confused with any of those occurring in North America, north of Mexico, yet that may be the case. Fox (1898 p. 143) determined some specimens from the area under consideration as *sanguigutta* (Christ), but all of those seen, that had been determined by him as of that
species, were typical specimens of *chrysothemis*.

**PEPSIS (PEPSIS) LUTEICORNIS FABRICIUS**

Palisot de Beauvois recorded this species from South Carolina and Cresson (1867 p. 145) cited that record. The occurrence of this species in North America is extremely doubtful and, if the locality given by Palisot was correct, it is probable that the specimens seen by him were of *P. elegans* Lep.

*P. luteicornis* Fab. and *P. elegans* Lep., although similarly colored, present excellent morphological characters by means of which the two species may be separated.

**PEPSIS (?) CYANEA (LINNAEUS)**

This species, which was reported by Palisot de Beauv is from the United States, is believed to be a species in some other genus.

**PEPSIS (PEPSIS) CHARON MOCSARY**

A single male of this species was reported by Fox (1898 p. 143) from Texas. This species has not been met with in any material from the area under consideration and so has not been included in the key to the species found in this area.
PEPSIS (PEPSIS) MONTEZUMA SMITH
PEPSIS (PEPSIS) DOMINGENSIUS LEPELETIER

These two species were recorded from the United States by Snow (1907 p. 132). The occurrence of these species in the area under consideration in this study, is doubtful.
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Abbreviations
(Not including Figs. 19 to 24, inc.)
a......................Antennal socket
aa....................Arms for attachment of funicle
ac.....................Antenna cleaner
ae......................Aedeagus
ah......................Anterior articulation of mandible
an......................Antennifer
ar......................Arolium
at......................Anterior arms of tentorium
bp......................Basal plate of sheath
bt......................Body of tentorium
C.......................Clypeus
ca......................Cardo
ce......................Cochlearum
cm......................Camera
cl......................Tarsal claw
cp1, cp2, cp3...........Coxal processes
Cx1, Cx2, Cx3.........Coxae
dp......................Dorsal plate of sting
dt......................Dorsal arms of tentorium
E. Compound eye
Ep. Epicranium
Epm. Mesepimeron
Eps₂ Mesepisternum
es. Epicranial suture
ex. Base of extensor muscle of mandible
f. Frons
fc. Fronto-clypeal suture
Fe. Femur
fl. Flagellum
fo. Foramen
fp. Frontal pit
fs₁, fs₂, fs₃ Furcisterna
fx. Base of flexor muscle of mandible
G. Gena
ga. Galea
gb. Pregula
gl. Glossa
gs. Cular suture
gst. Gonostipes
hs. Horizontal surface of propodeum
hyp. Hypopharynx
id. Distal prolongation of gonostipes
il. Interlorum
L. Laterocervical
la. Labrum
lc. Lacinium
lct. Lancets
ll. Lateral carina of propodeum
lp. Labial palpus
lt. Lateral tooth of propodeum
Md. Mandible
mn. Mentum
mpg. Median episternal groove
Ms. Metapostscutellum
mt. Mesopleural tubercle
mxp. Maxillary palpus
N3. Metanotum
o. Ocelli
ob. Oblong plate of sting
oc. Occiput
op. Occipital process
or. Orbicula
ps. Occipital suture
p. Planta
pa. Posterior arms of tentorium
pd. Pedicel
pe. Penicillium
pf. Parapsidal furrow
Pg. Postgena
pgl. Paraglossa
ph. Posterior articulation of mandible
Prephragma of mesotergum
Postphragma of mesotergum
Metapleuralum
Pronotum
Mesopostscutellum
Palpus of sting
Prescutum
Propodeum
Propodeal spiracle
Parascutellum
Praetarsus
Quadrate plate of sting
S1, S2, S3
Sternal apophyses
Sagitta
Bulb of sheath
Scape of antenna
Scutellum
Scutum
Sheath of sting
Metathoracic spiracle
Submentum
Subgenital plate
Spiracles of abdomen
Sloping surface of propodeum
Sternites of abdomen
Stipes of maxilla
1T, 2T, etc. .......... Tergites of Abdomen

t. ..................... Tooth of mandible

ta_1, ta_2, etc. ......... Tarsal segments

Tb. ..................... Tibia

tbs. ..................... Tibial spurs

tc. ..................... Trophicava

td. ..................... Transverse ridge

tg. ..................... Tegula

to. ..................... Tooth of tarsal claw

tp. ..................... Triangular plate of sting

tr. ..................... Trochanter

ts. ..................... Tarsal spur

un. ..................... Unguictractor

v. ..................... Vertex

vf. ..................... Ventral furrow

vnr. ..................... Ventral V-shaped ridge of notum

Sclerites, Etc.
(Figs. 22 to 24, inclusive)

ad. ..................... Adanale

al. ..................... Chitinous base of anal lobe

ax. ..................... Axillary excision

ba. ..................... Basalar sclerite

bas. ..................... Basanale

h. ..................... Hamuli

ic. ..................... Intercubital fold

imf. ..................... Intermedian fold
Veins
(Figs. 19 to 21, inclusive)

C. .......... Costa
Sc. .......... Subcosta
R. .......... Radius
Rs. .......... Radial sector
M. .......... Media
M\textsubscript{1+2} .......... 1st branch of media
M\textsubscript{3+4} .......... 2nd branch of media
Cu\textsubscript{1} .......... 1st branch of cubitus
Cu\textsubscript{2} .......... 2nd branch of cubitus
A. .......... Anal
icu, icu\textsubscript{2}, etc............. Intercubital cross veins
im, im\textsubscript{1}, etc............. Intermediate cross veins
mou, mou\textsubscript{1}, etc............. Mediocubital cross veins
rm\textsubscript{2} .......... 2nd radiomedian cross vein

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PART II

NOTES OF THE IMMATURE STAGES AND BIOLOGY
OF A

BIRCH CASE-BEARER

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1930
NOTES ON THE
IMMATURE STAGES AND BIOLOGY OF A BIRCH CASE-BEARER

Introduction

During the summer of 1927 case-bearing larvae were found causing serious injury to white and gray birches near Newport Mountain, in the town of Bar Harbor, Mount Desert Island, Maine. The infestation was not considered important, as it occurred on an area that had suffered recently from fire and on trees that were in a somewhat weakened condition. During the summer of 1928, however, the insect was found in other parts of Bar Harbor attacking healthy trees and causing almost complete destruction of the leaves of those trees so that it can be said to be an important pest of birch trees in the infested area. The insect does not appear to be widespread in its distribution for, with the exception of the relatively heavy infestation on Mount Desert Island, most of which is within the limits of the town of Bar Harbor, there are but two towns on the mainland (Trenton and Ellsworth) in which the insect has been found. The limited area of the infestation on the island and the spread of the insect along the main road of travel from the island to the mainland and on the mainland would lead one to assume that the insect
concerned was either a relatively recent introduction from some foreign country or a species occurring in some other part of this country and but recently transported to Mount Desert Island. This was not found to be the case, however, for specimens of the adult which were sent to Mr. Carl Heinrich, of the United States National Museum, were determined by him as belonging to a new species \textit{(Coleophora salmani} Heinrich) the description of which appeared in the Proceedings of the Entomological Society of Washington, Vol. 31: 18, 1929.

Notes on the Immature Stages

\textbf{Egg.}

Length 0.35 to 0.44 mm.; width 0.24 to 0.28.

The egg is usually oval although its shape may be modified somewhat by the presence of other eggs touching it or by the hairs of the leaf to which it is attached. The surface of the egg is finely pitted, the micropylar portion having a number of rounded projections which give it a "pebbled" appearance. It is yellow or orange in color when first laid, but, as the embryo develops, becomes light yellow and a dark area appears at the micropylar end due to the color of the head capsule of the developing larva which shows through the shell.
Larva.

Four distinct instars have been observed, but calculations made according to Dyar’s Law (Psyche 5:420–422, 1890) from measurements of the head capsules indicate that there are five larval instars, the first, second, third and fifth of which have been observed and collected. The shape of the larva is eruciform. The thoracic segments are somewhat wider than the other body segments and the dorsum of the terminal abdominal segment, in the later instars at least, is scleritized heavily, possibly to act as a protection against injury for the distal portion of the case borne by the larva is open. The thoracic legs are well developed. The anal prolegs are the only ones which are distinct and each of these bears a single transverse row of crochets. The later larval stages show a slight development of prolegs on the 3rd, 4th and 5th abdominal segments and each of the prolegs bears a variable number of crochets.

1st Instar.—Length 1.17 mm.; width of head capsule 0.14 mm. Head capsule, thoracic legs and dorsum of the 1st thoracic segment scleritized. Body cream-colored or greenish.

2nd Instar.—Average length 1.55 mm.; width of head capsule 0.19 mm. Head capsule, thoracic legs
and dorsum of 1st and 2nd thoracic segments and of anal segment of abdomen scleritized. Body greenish in color.

3rd Instar.-- Width of head capsule 0.27 mm. Body very similar in appearance to larvae of the 2nd instar except that it is darker in color, and, during the period of hibernation, is contracted.

4th Instar.-- Larvae of this stage have not been observed, but calculations show there to be one instar having a head width of approximately 0.34 mm.

5th Instar.-- Width of head capsule 0.49 mm. (Calculated as approximately 0.46 mm.\(^1\)). Body shape and color similar to 2nd instar but somewhat larger and darker.

**Larval Cases.**

The larvae of the 1st instar do not form cases, but mine in the leaves. There have been four different types of cases found and the larvae of the 2nd to 5th

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\(^1\) The specimens from which the measurements were made had been pressed and dried in their cases. Although the specimens showed but very slight distortion of the head capsule, it is possible that the difference between the observed and the calculated widths is due to the flattening of the head capsule in the process of pressing the cases.
instars (inc.), as well as the pupal stage occur in one or another of these types. These types of cases are similar in shape to those of the Cigar Case-bearer (Coleophora fletcherella Fernald).

**Type 1.**—This type of case is formed entirely of the epidermal layers of the mined area of the leaf. It is of variable size, but on the average is about 2.5 mm. long from tip to tip. It consists of a curved tubular portion, open at both ends, one of which is attached to the leaf, the other serving as an opening through which the larval excreta is voided. There are two fin-like longitudinal ridges formed by the cut edges of the epidermal layers, one dorsal and one ventral. The dorsal one, which is on the convex side of the tubular portion, is narrow and soon wears (?) away. The ventral "fin" is more persistent, remaining on the case and forming a lamina which fills the space on the concave or ventral side formed by the curving of the tubular portion. Larvae of the 2nd instar only have been found inhabiting this type of case.

**Type 2.**—This type of case is of about the same size as the preceding and is made of the same material. It differs in that the distal portion of the central tube is flattened and nearly closed and that
the fin-like margins of the ventral and dorsal sides of the case are continued over the distal portion of the case. This case may be formed from a case of type 1, but the flattening of the distal end and the presence of the ridge extending over this portion would indicate that this is the second case to be formed by a larva. Larvae of the 3rd instar inhabit this type of case.

**Type 3.**—This case differs from the preceding in shape and in the material used for its construction. It is somewhat larger, being from 3 to 3.5 mm. from tip to tip and the curve of the tubular portion in which the larva remains is much more abrupt than in the preceding types. The distal portion only is composed of the epidermal layers of a leaf. The basal portion, usually nearly half the entire case, is composed of a granular material of indeterminate origin which has been placed in layers around the mouth of the portion formed from the epidermal layers. The granular material forming the layers is held together by silken threads. The distal portion of the case is somewhat flattened, although not as much as in a type 2 case. Only one larva has been found in a case that was distinctly of this type, but it is known that the 3rd and
4th larval instars occur at the time when these cases are to be found. This type is evidently a type 2 case to which the granular material has been added at the base. Several cases containing hibernating larvae of the 3rd instar have been found that had a small amount of granular material at the base, but the extreme development of this type of case does not usually occur until late spring or early summer.

**Type 4.**—An elongate, cigar-shaped case which is usually over 5 mm. in length and which has a width of from 1.5 to 2 mm. at its widest portion. It is formed entirely of epidermal layers of a leaf. When first formed it has relatively wide dorsal and ventral "fins" running the full length of the case, but these disappear after a few days and the case becomes nearly cylindrical. The basal opening is cut at an angle of about 45° so that, when it is attached to a leaf the case is not vertical to the leaf surface but slopes at about this angle. The apex of the case is open, but its edges are pinched together so that the larva contained therein is partially protected. Larvae of the last or 5th instar and pupae are to be found in cases of this type.
Pupa.

Length 3.3 mm. to 4.7 mm.; width 1 mm. It varies in color from a light to a dark brown, according to the age of the pupa. The tip of the abdomen is blunt and rounded and a protuberance bearing two short, conical spines at its apex projects from each side of the abdomen near the tip. The pupa is formed in a type 4 case.

Biology

General.

There is but one generation a year of this insect in the locality in which these studies were made. The eggs are laid about the middle of July and hatch during the first week of August. The larvae feed for a time between the epidermal layers of the leaf and form their cases from the layers of the area mined. They hibernate in their cases on the twigs of the host plant and begin their feeding activities again in the spring, becoming full grown about the last of June or first of July and pupating at that time.

Adult Habits.

The adults are not very active in intense sunlight and usually remain hidden on the undersides
of leaves, on stems, or in any partially shaded place affording shelter during the daytime. They rise up in numbers when the foliage is disturbed but soon alight and hide again. On cold or rainy days they also remain in protected places. They rest on the leaf surface with the anterior portion of the body raised from the leaf and with the tip of the abdomen touching the leaf surface. The grayish antennae are held together straight out in front of the body and the wings are folded so that the outline of the insect is triangular, the antennae projecting from the head or apex of the triangle as a single thread-like process. The habit of hiding, which is noticeable in the adult, would seem to indicate that the insect is negatively phototropic during this stage. Adults liberated in the laboratory, however, always flew to a window, but those which emerged in boxes into one side of which a bottle had been inserted were not attracted to the light entering through the bottle and remained motionless inside the box.

The first adults to be reared in the laboratory in 1927 emerged from field collected material on July 14, but, as eggs were found in the field at that time, emergence under natural conditions must start somewhat earlier. In 1928 the first adult was
found in the field on July 6 although the greater number of adults did not emerge from the field collected material held in the laboratory until after July 10. Few adults were to be found in the field after the first week of August.

The individuals mate a few hours after emergence and a pair has been noted as remaining in the copulatory position from 9:30 a.m. until 4:30 p.m., a period of seven hours. Other pairs noted separated after a shorter period. When mating, the two individuals remain nearly motionless, the tips of their abdomens joined and the insects facing in opposite directions. In one lantern globe cage which was attached to a twig of a white birch tree in the field an example of the attraction of males by females was observed. The cage contained three living females and two males, one of which was mating with a female at the time of observation. Outside the cage, however, six males were found to have crawled up under the cheese cloth covering of the top of the lantern globe in an attempt to gain access to the females. Four of these males were living and were endeavoring to pass the restricting rubber band which held the cheese cloth in position, while two had died in attempting to gain access to the interior of the cage.
In the glass cages on trees in the field two females laid 9 eggs each, one 10 eggs and one 21 eggs in one day of twenty-four hours. In the laboratory one female is recorded as laying 20 eggs on the first day, 8 between 8:30 a.m. and 5:00 p.m. of the second day, 2 between 5:00 p.m. and 8:30 a.m. of the following morning, 3 the third day, 2 the fourth day and 4 in the three days following or a total of 39 eggs laid over a period of seven days. Other records of females which were reared and mated in the laboratory show that the greater number of eggs are laid during the first day after mating and that seven days is about the average length of time during which eggs are laid. The length of life of adult females has been recorded as being from 7 to 10 days, from emergence from the pupa to death. Males usually live from 6 to 8 days.

**Egg.**

Eggs are found in the field only on the under surfaces of leaves although a few eggs were laid on buds or on the upper surfaces of leaves under the unnatural conditions imposed on the female by the lantern globe cages. Eggs have been found deposited under field
conditions on Betula alba, Corylus americana and Alnus sp. and, although the white birch seems to be the favorite host, many eggs are laid on the other two host plants. Gray birch is subject to extensive injury by the larvae of the case-bearer, but, in spite of careful search, no eggs have been found laid on the leaves of this species. This may be due to the lack of heavy pubescence on the under surface of the gray birch leaf for the plants on which eggs have been found all have the under surface of the leaf densely pubescent and the eggs are usually found among and attached to the hairs of the leaf. The eggs are usually laid among the hairs at the junctions of the midrib with the main lateral veins. They may be laid beside the midrib and some have been found beside the lateral veins. Few eggs have been found on the lower leaf surface away from the protection afforded by the larger veins. They may be laid singly or in groups and, when laid in groups, no definite order of placement is observed.

As many as 33 eggs have been found in the field on the under surface of a single leaf. All the leaves of several branches of trees occurring in the heavily infested locality in which this insect was first found were examined and it was found that there
was an average of 6.2 eggs per leaf. Similar counts were made of the leaves on branches which were shaded, branches exposed to the sunlight and branches in partial shade. There was an average of 10.5 eggs per leaf on shaded branches, 3.5 eggs per leaf on branches exposed to sunlight and 4.6 eggs per leaf on branches in partial shade. This indicates that the amount of exposure of the leaves of a tree to sunlight may have some effect on the number of eggs laid on them.

I have but a few records of the length of the egg stage and these are accurate only to within two or three days. Those which have been taken, however, indicate an egg stage of about three weeks. Eggs have been recorded as occurring in the field from the second week in July until the first week in August.

Larval Habits.

The eggs of the birch case-bearer hatch about the first week in August. The larvae emerging from these eggs bite their way through the distal "pebbled" portion of the shell and wander over the lower surface of the leaf for a short time. They soon select a place, bite their way through the epidermis and begin to mine through the inner tissues of
the leaf. One larva which was observed entering the leaf did not eat any of the epidermal tissue, but placed the particles beside the opening of the mine. When inside the leaf it fed normally on the tissues. It cannot, however, be definitely stated that the habit of rejecting the epidermal tissues is typical. It takes about two hours for a larva to completely bury its body in the leaf tissues.

Larvae have been observed in their mines in the leaf as late as August 26. All but a very few of the larvae collected from mines were of the 1st instar, but it is possible that they molt once in the mine and then cut their cases from the epidermal layers. This is suggested by the fact that a few larvae of the 2nd instar have been taken from mines.

Cases of type 1 have been found in small numbers as early as August 24th, the number of cases of this type being found in the field increasing rapidly after that date. Cases of type 1 have not been found to contain larvae of any but the 2nd instar. This instar is evidently completed by the second or third week in September, for collections made by Mr. H.B. Peirson on September 16 revealed but two type 1 cases.
Type 2 cases are abundant during the latter part of September and in October and all the cases examined have been found to contain larvae of the third instar. It is in the 3rd instar and in a type 2 case that the case-bearer hibernates. From the time of the cutting of the first cases from the leaves until the migration which precedes hibernation the larvae of the 2nd and 3rd instars have been feeding in the usual manner of Coleophorids. The larva moves its case from one part of the leaf to another and fastens it down with silken threads, mines through the leaf by crawling part way out of the case and, when it has eaten all the tissue it can in this manner, unfastens the case, crawls with it to another part of the leaf and repeats the process. When ready to hibernate it migrates to a twig and attaches the case.

The host plants attacked by these late summer and fall instars are the same as those on which the eggs were laid.

Feeding is resumed in the spring and the mines made by the larvae at this time are much larger than those made in the fall. Larvae of the 4th instar have not been collected or measured, but the type 3 cases occur during the spring and early summer and the 4th instar larvae must occur at this time so that it is permissible to speculate that the larvae of this in-
star do much of the feeding done at this time of year. It is not known when the majority of the larvae molt and enter the final or 5th instar. Cigar-shaped cases containing full grown and feeding larvae have been recorded in the field as early as July 2 and one individual has been noted as having left its type 3 case on July 9 and as forming its type 4 case on July 10. Usually, however, most of the larvae have formed their cigar-shaped cases before this time and have already pupated.

In addition to the host plants attacked by the early fall instars there are three others upon which the larvae of the later instars have been found feeding to some extent, although, to my mind, the occurrence and feeding on two of these plants was purely accidental. The plants concerned are Salix sp., Quercus rubra and Betula populifolia, the last-named evidently being a preferred host, although as noted above, no eggs have been found on plants of this species.

Pupa.

The case-bearer usually migrates to nearby twigs when ready to pupate, although many pupate on the leaves. It is probable that, during the migration, many drop from the trees on which they have been feeding to plants beneath for trunks, leaves and needles of a large
number of species of plants found beneath the infested trees had many pupal cases on them although no feeding injury was observed. The larva, on reaching the place at which it is to pupate, firmly fixes the base of the case to the object, sometimes merely by attaching it with silken threads, at other times, as was observed on white pine needles, by excavating a hole in the needle and firmly attaching the edge of the case to the rim of the excavation. Then it spins a silken plug to close the hole at the base of the case and turns around so that its head is facing towards the distal end. It molts again and enters the pupal period, the molted skin being pushed down on the silken plug. Full grown larvae enter the pupal stage over a period of several weeks and the majority of larvae have pupated by the first week in July. Although early adults appear before some late larvae have pupated the greater number of individuals do not emerge until the second week in July. The pupal stage has been recorded as lasting 14 or 15 days.

Natural Control

This species does not seem to be attacked by many predators or parasites although a few have been collected or reared. The mortality of hibernating larvae must be very high, however, for many dead larvae have been found in their cases on the twigs.

Nymphal stages of a mite (Trombidium sp.),
the identity of which was kindly determined by Dr. Nathan Banks, were found on the leaves of birch feeding on eggs of the case-bearer. The mites suck the contents from the eggs and were particularly abundant in the glass cages on the trees. In one cage sixty-two out of sixty-six eggs had been sucked and in another twenty-nine out of fifty-seven eggs had been destroyed. One mite was observed eating a dead case-bearer moth. Outside the cages the eggs of the case-bearer were attacked to some extent, but the activities of the mites were not very noticeable.

Several individuals of Ichneumonoid Hymenoptera were reared from the pupae of the case-bearer. Dr. C.F.W. Muesebeck kindly determined them as of the following species: Hemiteles tenellus (Say), Itoplectis conquisitor (Say) and Orgilus sp. and stated that the first and second-named "are very common species, the former usually, and the latter very frequently acting as hyperparasites." The exact relations of these with the case-bearer were not determined and it is very probable that they may constitute a portion of a hyperparasitic group of species. The status of Orgilus sp. was not determined.