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THE EXTERNAL MORPHOLOGY OF THE CLOUDED SULPHUR

(COLIAS PHILODICE GODART, LEPIDOPTERA, PIERIDAE)

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THE EXTERNAL MORPHOLOGY OF THE CLOUDED SULPHUR

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by

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INTRODUCTION

Colias is a genus which exhibits such great variation and interbreeding throughout its widespread distribution in the Holarctic Region that there is much confusion as to its systematic condition and it is greatly in need of revision. This problem was undertaken to work out the external morphology of a representative species which might be of value in a taxonomic revision of the genus or as a reference work illustrating the morphology of higher Lepidoptera.

Colias philodice Godart was selected because of its availability and the fact that it is a member of a complex of seasonal and geographical varieties and supposed valid species about which there is considerable doubt.

TAXONOMY

Generic Name

At present the correct name of this genus is undecided. Colias Fabricius is used entirely throughout most of the world although Eurymus Swainson has been popular to some extent in the United States. Klots (1931) discusses this situation and indicates why Colias should be retained even though it is a name which according to the International Code of Zoological Nomenclature is incorrect.

Colias was first proposed by Fabricius 1807. Latreille 1810 designated rhamni as the genotype and this was declared valid by Opinion 11 of the International Commission on Nomenclature. Leach 1815 set up a new genus, Gonepteryx, genotype rhamni, and restricted Colias to hyale.

Thus, according to the Code, Gonepteryx Leach will give way to Colias, and Scalidoneura Butler 1871 will be the next oldest eligible name. Eurymus Swainson, now used in this country, must be rejected as it is a homonym (Eurymus Rafinesque 1815 takes precedence).

From all this it is evident that the confusion which would result from adhering strictly to the Code would be intolerable. It is probable that the International Commission will eventually hand down an opinion on this case to suspend the Code and uphold Colias, as has often been

done in other cases where circumstances warranted such a procedure. Until this is definitely settled it seems best to use the name which will cause the least confusion.

Synonomy of Colias

Colias Fabricius ... hyale L. 1807

Eurymus Swainson ... hyale L. Homonym 1829

Eriocolias Watson ... edusa Fabricius 1895

Scalidoneura Butler ... herminia Butler 1871

Coliastes Heming ... hyale L. 1932

Systematic Position of Colias philodice Godart

At present it is impossible to give an acceptable synonomy for philodice or for any of the Nearctic species, due to the confusion which exists within the genus. Taxonomic workers tend more and more to take the attitude that in many cases a distinct species of this insect can not be defined and that instead there may exist several complexes of "species" which commonly interbreed and produce various degrees of intermediates accompanied by seasonal and geographical forms.

It is well known that eurytheme Boisduval, and philodice Godart interbreed readily and produce intermediate types; the work of Gerould (1911, 1913, 1923) has brought

out considerable information as to the actual genetical relations concerned. In recent years it has been repeatedly noted that _eurytheme_ is extending its range eastward at the expense of _philodice_. _Eurytheme_ is now common in New York State; and at Amherst, Massachusetts, in the fall of 1932, it occurred, in ratio to _philodice_, approximately 1 to 10. Several intermediate forms were taken; i.e., specimens with varying amounts of the typical _eurytheme_ orange on the wings.

Alexander B. Klots, at present the foremost worker on the Pieridae, states (in litt. May 5, 1933) that careful breeding work on all forms of _Colias_ in their typical localities may be necessary for a complete understanding of the affinities of this genus. He regards _philodice_ as belonging to the _eurytheme_ complex along with several seasonal and altitudinal forms. Included in this group would be -

eurytheme Boisduval - extends throughout North America and into Central America. Nymotypical form.

philodice Godart - originally Eastern United States and Canada but later spread westward although it never approached _eurytheme_ in numbers.

Seasonal and altitudinal forms.

autumnalis Cockerell .... ariadne Edwards ....

eriphyle Edwards .... amphidusa Boisduval.

A superficial comparison of a few specimens of eurytheme with philodice tends to confirm this view since no significant differences were observed other than wing colorations. It is probable that a detailed examination of a large series of both forms would yield important results in this respect.

Male genitalia are not considered as reliable characters to use for specific differentiation chiefly because of the lack of variation to be found, in many cases, even between evidently distinct species. This is especially true of North American Coliads. On the other hand, the following note indicates that at least in some cases male structures may be used to distinguish Palaearctic species of Colias.

There is a very distinct difference between the type of male genitalia found in philodice and eurytheme and that of the genotype, hyale L. and other Old World species; i.e., the wide basal portion of the harpe of hyale is produced into a distinct "spur" which extends dorsally. In another Palaearctic species, myrmidone Esper, this "spur" is only slightly produced while in another, erate Esper, it is

indicated only by a rounded angle, as shown in the accompanying figures.

philodice *erate* *myrmidone* *hyale*

According to the views of Klots, *philodice* would be considered as a race of *eurytheme* but as the whole question remains to be definitely settled, probably only by adequate breeding experiments, the common usage, *Colias philodice* Godart, is followed for this general morphological study.

EXTERNAL MORPHOLOGY

General Description

Philodice is a medium sized butterfly distinguished chiefly by its yellow color. Dorsally the head is thickly covered with pinkish-brown hairs and scales except for a central oval area, just caudad of the antennae, where they change to yellowish green. The eyes are yellow in life or as preserved in alcohol, but turn brown in dried specimens. A fringe of yellow hairs is present between the fronto-clypeus and the eyes. The antennae are light brown to the clubs which are dark brown except for the last two smoky-yellow segments. Ventrally the antennae are pinkish but may vary to dark red over the whole surface proximad of the club. The labial palpi are fringed with long lemon-yellow hairs.

The patagia and prescutum are thickly clothed with long rufous hairs. The dorsum of the thorax is black, with scattered yellow hairs and the pleura and sterna are covered with yellow scales and hairs. The legs are yellow, slightly tinged with pink. The abdomen is black but the pleura and sterna are heavily scaled with yellow.

This insect is sexually dimorphic in respect to wing pattern and the female is slightly larger than the male.

Male - Fore Wing. Above - ground color lemon yellow with a narrow black border on the outer margin, its inner edge irregular; costa narrowly edged with black; basal angle with a small black area; an oval black spot at the apex of the discal cell.

Beneath - lighter yellow, very lightly dusted with black scales; no black outer border but outlines of it are faintly indicated by grayish area; row of light brown spots one between each vein, about 3.5 mm. from the outer margin of the wing; discal black spot with a narrow light line in its center.

Male - Hind Wing. Above - g round color lemon yellow, like fore wings; black border extending along outer margin from Sc R_1 to Cu_2; its inner edge irregular. Costal and inner borders pale yellow; basal angle dusted with black scales; a pale orange spot at the apex of the discal cell; bordered anteriorly by a very small similar spot.

Beneath - ground color darker yellow, very lightly dusted with dark scales throughout; no dark border but a row of reddish-brown spots as in the fore wings; a small pinkish area at basal angle, and anal lobe pale yellow; discal spot a silver-centered rufous ring with a very small similar spot bordering it anteriorly.

Female - Fore Wing. Above - ground color lemon yellow, as in male, but the black border is much wider and contains

irregular yellow spots. The basal area and costal margin are more thickly dusted with black than in the male; single black discal spot present.

Beneath - ground color lighter yellow; no black border but its limits are indicated by slight grayness and row of five spots between veins; discal spot with light center present.

Female - Hind Wing. Above - ground color lemon yellow, like fore wings; costal and anal borders pale; outer black border more or less invaded by yellow at inner margin; entire wing dusted with black; discal spot orange, bordered anteriorly by a very small similar spot.

Beneath - darker yellow, lightly dusted with black; no black border, but a row of reddish-brown spots, as in male; small pinkish area at basal angle and anal lobe pale yellow; discal spot a silver centered rufous ring with a very small similar spot bordering it anteriorly.

Both wings in male and female are edged with a pinkish fringe.

HEAD.

Head Capsule (Figs. 1, 2, 3).

The shape of the head of Colias philodice and the character of its sclerites are not visible until the scales and hairs are removed. The head capsule is the same in both sexes, and in general appearance it is oval and slightly flattened dorso-ventrally.

The compound eyes (e) are yellow, ovoid, and so greatly developed as to extend over two-thirds of the entire head; viewed from the front they compose the entire lateral margins of the head. Their mesal margins converge slightly from dorsum to venter so that the distance between the eyes at the base is approximately two-thirds that at the vertex. The eyes are slightly raised from the surface of the fronto-clypeus by narrow sclerites, the parafrontals (pa). From the posterior aspect (Fig. 2) the compound eyes appear as narrow bands on the outer margin of the head. Ocelli are absent in both sexes.

The antennae (an, Fig. 6) are clavate; the number of segments, including scape and pedicel, varies from thirty-one to thirty six, although the most common number is thirty-two or thirty-three. The first segment of the antennae or scape (se) is sub-globose and is set in the antennal fossa in the vertex, close to the eye. The pedicel (p) or second segment, is broader than long while the first segment of the

flagellum (fl), sometimes called the post-pedicel, tapers somewhat and is about twice the length of the pedicel. The first two or three segments of the remainder of the antenna, or flagellum, are ring-like while those following become gradually elongate until they begin to widen again to form the club. The terminal six to eight segments which make up the club are sub-quadrate. Oval, pit-like structures (spt) which are thought to be sense organs are present on the last eighteen to twenty segments; those of the distal segments are distinct but become gradually fainter until they disappear towards the base of the antenna.

The average length of the antennae is 10 to 10.5 mm.

The labrum (l) is a small sclerite extending perpendicular to the plane of the fronto-clypeus (fc); its shape is that of a triangle with a length less than half that of the base. The "base" forms the margin of the fronto-clypeus and the rounded "apex" projects over the bases of the maxillary galeae or proboscis. On either side the labrum is produced into lateral extensions or pilifers (pfr) which bear several stiff hairs. (Crampton thinks that the structure here referred to as the labrum may be the clypeus and that the true labrum has disappeared, but feels that further study of primitive Lepidoptera is necessary before accepting this hypothesis)

The fronto-clypeus (fc) is the most prominent sclerite of the cephalic aspect of the head. It is strongly convex and is formed by a complete fusion of the frons and clypeus. The anterior margin of this structure is sinuate and forms the posterior border of the labrum or upper lip, ventrad of the convex surface of the fronto-clypeus.

The vertex (vx) is not sharply demarked but is the flattened dorsal area between the eyes and surrounding the antennal fossae. Anteriorly it merges with the fronto-clypeus, which is distinguished by its convexity, and its posterior limits are indicated by the raised convex rim of the occiput (occ) which extends between the eyes just caudad of the antennae.

The occiput (occ) is shown in a posterior view of the head (Fig. 2). It is moderately convex and is demarked by faint sutures running from the dorso-mesal corners of the occipital foramen (of) to the margins of the compound eyes just caudad of the antennae. A narrow sclerite (po) surrounding the occipital foramen dorsally appears to be homologous with the sclerite called the paroccipout by Peterson 1916, in Diptera.

The occipital foramen (of) is a small quadrate opening through which the nervous and alimentary systems pass to the thorax. On its ventral margin are two thickened oval structures, the occipital condyles (ocd) articulating with

the cephaligers (cg) or head-bearing rods of the lateral cervical sclerites.

The great development and downgrowth of the compound eyes has completely obliterated the genae while the postgenae (pge) are large, strongly convex sclerites on the posterior aspect of the head capsule and border the occipital foramen and gular membrane.

The tentorium (tnt) is composed of two chitinous bars which run from the occipital condyles to the margins of the fronto-clypeus and labrum, and serve to support the head capsule and also serve for muscle attachment. The tentorium is formed by invaginations of the ectoderm and its external manifestations are the frontal pits (f), anteriorly, and the gular pits (gp), posteriorly. In Colias their position is not distinctly visible as in lower insects and may be determined accurately only from the interior. The frontal pits are found to lie on the clypeo-labral suture against the mesal margins of the compound eyes and just dorsad of the vestigial mandibles. The gular pits are closely associated with the ventral margins of the occipital condyles.

MOUTHPARTS. (Figs. 1, 2, 3, 20)

The labrum or upper lip has been discussed in the description of the parts of the head capsule.

The mandibles (md) are vestigial and their rudiments are found to appear as small lobes close to the compound eyes, just laterad of the labrum. The pilifers are sometimes called the vestigial mandibles but both pilifers and mandibular rudiments occur in some forms (Protoparce); and the pilifers are clearly appendages of the labrum, as dissection will show. (Fig. 20)

The maxillae are large and specialized to form the principal feeding organ of the adult. The cardo (cd) is a small basal sclerite of the maxilla applied to the inner margin of the eye just above the base of the labial palpus (lp). The stipes (stp) is large and strongly concave so as to form the sides of the cup-like, membranous, gular region. The maxillary palpi (mp) are represented only by vestigial papilliform structures, or palpuli borne on the outer surface of the stipes just ventrad of the base of the galeae. The galeae (ga) are the most prominent of the mouthparts as they form the long, coiled, proboscis. They are hollowed out on their inner surfaces and may be linked together by "spines" and "hooks" to form a long tube, typical of Lepidoptera and used for sucking liquid food. At their bases the galeae are enlarged and interlock beneath the labrum to form the mouth opening closed by the flap-like epipharynx (ep). The laciniae have entirely atrophied, or, according to Berlese, may be embodied in the base of the proboscis.

The tube formed by the interlocked galeae opens into the pharynx (ph, Fig. 3) which is ovoid in cross-section and posteriorly narrows into the oesophagus (oes). The dorsal wall of the pharynx is very muscular and is connected by contractile fibers to the inner surface of the vertex. This organ evidently serves as a pumping mechanism to suck liquid food up through the proboscis and force it back to the stomach. Burgess (1880) describes this process in the Milkweed Butterfly:

> "The proboscis is unrolled and inserted in the nectary of a flower; at this moment the muscles which suspend the pharynx contract, and its cavity thus extended, creating a vacuum which must be supplied by a flow of honey (sic) through the proboscis, into the pharynx. When the latter is full its muscles contract, the valve closes the aperture to the proboscis, and the honey is forced backward into the oesophagus. The pharynx is again opened and the same process repeated."

The epipharynx (ep) is a small triangular flap, closely associated with the labrum, which serves as the valve at the opening of the proboscis.

The hypopharynx (hp, Fig. 20) is a chitinous, shield-shaped structure forming the floor of the pharynx. Beneath this lies the salivary duct (sd) which opens at the base of the proboscis anterior to the epipharynx.

The labium, mentum, and gular regions are greatly altered and specialized so that no separate sclerites are evident. A narrow, concave plate, extending from the ventral

aspect of the mouth widens into a triangular sclerite which connects with the cardo on either side; ventrally it is produced into a small lobe. This structure (mn) possibly represents the fused palpigers, ligula, and mentum.

The labial palpi (lp) are three-segmented, well developed, and are covered with scales and hairs which give them a brush-like appearance. The first segment is somewhat angulate so that the palpi extend upward in front of the eyes while the proboscis is held coiled between them. The second segment is straight and tapers moderately towards its distal end. The third segment is oval and relatively very small.

THORAX.

The thorax of philodice is in general typical of the order. The mesothorax is large and well developed for accommodating the wing and leg muscles while the metathorax is considerably smaller. The prothorax is much reduced, bears only the first pair of legs, and is surrounded by membrane to a greater extent than the other thoracic segments.

Meso- and metathoracic spiracles (sp) are present. The spiracle of the mesothorax is situated laterally in the membrane, behind the epimeron of the prothorax. Embryologically it arises in the mesothorax but moves forward to this position during development. The metathoracic spiracle is found at the dorso-cephalic angle of the metepisternum and

is covered by a small hemispherical plate.

The spiracles are not easily perceived as they are pale in color like the surrounding membrane and their lips appear as minute folds protected by fine hairs. Under the compound microscope the openings are seen to be supported by lightly sclerotized loops or rings.

NECK or CERVIX. (Figs. 8 and 13)

The cervical region is intersegmental and chiefly membranous. A pair of small triangular sclerites, the lateral cervical plates (lc) or laterocervicalia, is located close to the anterior margins of the episterna (esl) of the prothorax. These sclerites are prolonged anteriorly to form the rod-like cephaligers (cg), which articulate with the occipital condyles and permit motion of the head.

Sometimes in Lepidoptera a narrow sclerite, the presternum, is present connecting the meso-ventral sides of the laterocervicalia, but in Colias philodice the ventral membrane is complete and has not been sclerotized.

PROTHORAX.

Notum (Figs. 8, 9).

The patagia (pt) are the most noticeable dorsal structures of the prothorax. They are lobe-like sclerites (pyriform in lateral aspect) which project slightly above the

pronotum (pm). The patagia are thickly clothed with scales and long hairs as are all of the prothoracic and cervical sclerites.

Patagia (Mouffet 1634) is the correct name for these structures as pointed out by Crampton (1914), and not "tegulae" which are structures overlapping the bases of the mesothoracic wings.

The pronotum (pm) from the dorsal aspect, is a Y-shaped sclerite anterior to the prescutum. The patagia are attached at the cephalic portions of the arms of the "Y" which are connected by a narrow extension of the pronotum to the episterna just caudad of the laterocervicalia.

Pleuron (Figs. 8, 13).

The episternum (es_1) lies just caudad of the laterocervicale; its posterior margin is convex and is bordered by a very narrow epimeron (em_1). Postero-ventrally the epistermum is hollowed out to receive the prothoracic coxa and also has a small prolongation which fits into a pocket in the coxa. (Fig. 13, cx_1, es_1)

Sternum (Fig. 13).

Ventrally the prothoracic episterna are connected by a relatively wide bridge, the precoxale (pr), with the basisternum (bs) or principal sternal sclerite. The

basisternum is followed by the ovate furcasternum (fs) which bears the furca internally, and a triangular spinasternum (ss) which bears the "spina" or unpaired internal median process for muscle attachment.

MESOTHORAX.

Notum (Figs. 8, 9).

The prescutum (psc) is a narrow, collar-like sclerite cephalad of the scutum; on each side of the prescutum an elongate structure, the prealare (pra), or prealar sclerite, is produced towards the pleuron. The scutum (sc_2) of the mesothorax is the largest and most evident sclerite of the notum. It is strongly convex dorsally and a faint median carina runs from its anterior border to the scutellum (sl_2) where it is continued in two faint sutures which, curving anteriorly, form the cephalic margins of the scutellum.

Caudad of the prealare is a broad extension of the scutum called the suralare (sur) (Crampton) or anterior notal wing process (Snodgrass). The area between the prealare and suralare is called the tegular incision (tin) and it contains narrow bar-like structures, the sub-tegulae (st).

The tegulae (teg) (synonyms: paraptera, pterygodes, epaulets) are well developed and are found just above the bases of the mesothoracic wings. The anterior portion is

oval but tapers gradually to a narrow process which extends back over the suralare about half the length of the scutum. The cephalic portion of the tegula bears a ventral projection, curved slightly caudad, which is supported by the subtegula.

Postero-ventrally the scutum is produced into the adanal sclerite or adanale (ad)(Crampton) or posterior notal wing process (Snodgrass), a wide plate which forms the posterior point of articulation of the fore wings. The anterior and ventral margins of the adanale are thickened while the central portion appears less heavily sclerotized. Crampton (1928) figures, for the Lepidopteron, Ctenocha virginica, the adanale as a narrow sclerite but also shows a postadanal sclerite, or postadanale, just caudad of the adanale and a small membranous area between them. It is possible that in the present case the membrane between these two has sclerotized to form the wide plate, called here the adanale (ad).

Between the suranale and the adanale is the adnotale (al), a finger-like process which extends into the notal incision (ni); this sclerite forms a second anterior pivotal point for the wing. The notal ossicle or notale (n) or first axillary sclerite of Snodgrass (probably derived from the lateral margin of the notum) borders on the adnotale and suranale mesally while a cephalic projection of this sclerite articulates with the head of the sub-costal vein (sh). The notale also

abuts on a series of plates, the median ossicles, or medialia (m) or second axillary sclerite of Snodgrass located at the bases of the wing veins. Thus the notale serves as a pivotal point between the notal wing processes and the sclerites at the base of the wing. The parategula or basicosta (ptg) is found at the cephalic margin of the subcostal head and, according to Crampton (1928), may represent a detached basal portion of the costal region of the wing although this has not been definitely determined.

At the head of the anal vein there is a small lobe, the basoplica or basal ridge (bp) and between this structure and the median ossicles is a small membranous pocket, the marsupium or basosinus (r) into which the basoplica fits when the wings are folded back. The basanal sclerite or basanale (ba) or third axillary sclerite of Snodgrass borders the margin of the wing from the basoplica to the adanale where it forms a posterior point of articulation for the wing.

(In Fig. 9 the wing plates have been pulled out and drawn in one plane for the sake of clearness. Normally they are more or less convex and are fitted together closely.)

The scutellum (sl_a) is much smaller and, in lateral aspect, is continuous with the curvature of the scutum. Ventrally the scutellum becomes narrow and fuses with the margin of the adanal plate. The axillary cord or spring

vein (axc) arises from the scutellum and joins the basanal border of the fore wing.

The postscutellum (psl_2) is a very small sclerite caudad of the scutellum and is normally hidden beneath and between the mesothoracic scutellum and metathoracic scutum.

Pleuron (Figs. 8, 13).

The preepisternum (pes) borders the cephalic margin of the sternopleurite from its apex to the presternum. The pleural half of the preepisternum is very narrow but ventrally it becomes abruptly enlarged to about four times its dorsal width. The sternopleurite (spl), composed of fused sternal and episternal elements, is a large sclerite which meets the opposite sternopleurite, ventrally, in the mid-ventral suture (mv). The epimeron (em_2) is posterior to the episternal part of the sternopleurite and is reduced to a narrow U-shaped sclerite by the extreme development of the basal leg sclerites, eucoxa and meron, which are closely applied to the episternal and epimeral regions. The anterior prong of the epimeron follows the postero-dorsal margin of the sternopleurite to its apex and the posterior arm extends to the scutellum. In the alar membrane just dorsad of the apex of the sternopleurite is the quadrate basalar sclerite or basalare (bl) and between this plate and the adanale is an elongate subalar sclerite or subalare (sal).

Sternum (Fig. 13).

A small triangular sclerite, the presternum (pn_2) connects the spinasternum, anteriorly, with the sternopleurites, laterally. Its apex lies in the mid-ventral suture. The sutures separating the sternum from the pleuron have entirely disappeared so that the sternal plates are fused with the opisternum into one large sclerite, the sternopleurite (see above), which extends to the mid-ventral suture.

METATHORAX.

Notum (Figs. 8, 9).

The notum of the metathorax is much smaller than that of the mesothorax. The scutum (sc_3) is only slightly convex and is triangular in lateral aspect; dorsally it is divided into two lobes by a longitudinal suture.

Notal wing processes and wing sclerites are reduced in comparison with those of the mesothorax, and some are completely lacking. The suranale and adanale are present but the adnotale has disappeared. The notale is large and connects the suranale on its mesal side with the median ossicles on its distal side. The tegula and corresponding tegular structures are absent as is also the subcostal head. This sclerite may possibly be embodied in the median ossicles

at the head of the fused Subcosta-Radius-Media. The marsupium is found between the median ossicles, and the basoplica is at the head of the Cubitus. The basanale is a small triangular sclerite articulating, as in the fore wing, with the adanale.

The scutellum (sl_3) is small and inconspicuous; ventrally it is produced into a triangular lobe which gives rise to the axillary cord.

The postscutellar region (psl_3) is greatly modified and specialized for articulation with the abdomen. The phragmas (pg) for muscle attachment are well developed and may be seen through the visceral opening projecting downward from the notum.

Pleuron (Figs. 8, 9).

The metathoracic episternum (es_3) is elongate, and its posterior margin is convex. The epimeron (em_3) is posterior to the episternum and as in the mesothorax is reduced to a narrow sclerite by the great development of the eucoxa and meron which are closely associated with the ventral margins of the episternum and epimeron. Anteriorly the epimeron narrowly borders the episternum to its apex, while caudally it reaches the scutellum and postscutellar region and extends beneath the visceral opening of the thorax. In the alar membrane are the basal wing sclerites - the basalare (bl)

situated close to the apex of the episternum, and the <u>subalare</u> (sal) just beneath the adanale.

LEGS. (Figs. 4, 5, 8, 12)

The mesothoracic and metathoracic legs are quite similar but the prothoracic legs exhibit a few different features.

<u>Coxae</u>.

The coxae (cx_1) of the prothoracic legs are large and elongate and are somewhat swollen proximally where they articulate with the episternum. The mesothoracic coxae are divided into <u>eucoxa</u> (ecx_2) and <u>meron</u> (me_2), a condition typical of the Lepidoptera. The meron is large and triangular and is united with the eucoxa to its apex; the eucoxa is bordered anteriorly by the sternopleurite. The metathoracic coxae are also divided into <u>eucoxa</u> (ecx_3) and <u>meron</u> (me_3). The eucoxa is ovate and is bordered anteriorly by the episternum and posteriorly it joins with the concave margin of the meron, which meets the opposite meron mesally to form the lower posterior aspect of the thorax.

Trochanters.

In all three legs the trochanters (tr) are much alike; they are small and irregular in form and they serve as pivotal points between coxa and femur.

Femora.

The femur (fe) is long and slender in the first and second pairs of legs and somewhat shorter in the last pair. Although a fringe of long hairs is present, there are no spines or spurs on the femur such as are found on the remaining segments of the leg.

Tibiae.

The tibia (ti) is slightly shorter in the prothoracic leg than in the last two pairs and does not bear a pair of apical spurs (spu) such as are found on the second and third pairs of legs. In all cases the tibia are armed with several alternate rows of short spines.

Tarsi.

The tarsi are five-segmented and are also armed with spines, which, however, are more numerous than on the tibia. The first segment or basitarsus (bt) is nearly as long as

the tibia in the prothoracic legs but in the second and third pairs of legs it is but little more than two-thirds the length of the tibia. The second tarsal segment of all three legs is about one-third the length of the basitarsus, while the remaining three segments are slightly shorter than the second. The last tarsal segment or the <u>distitarsus</u> (dt, Fig. 7) is provided with a pair of bifid claws or <u>ungues</u> (ung). Paronychia and pulvilli, which are found in many Pierid genera, are absent in <u>Colias</u>, although two pairs of fine hairs are present between the ungues.

WINGS.

The venation is interpreted according to the Comstock-Needham system and is based on the interpretation of Forbes (1920) and Klots (1931).

<u>Fore Wing</u> (Fig. 10).

The fore wing is triangular in outline and has a <u>costal</u>, or cephalic, margin, an <u>outer</u>, and an <u>inner</u> margin. The angles are rounded and are known as the <u>base</u>, or proximal angle, the <u>apex</u>, or distal angle, and the <u>anal</u> or posterior angle.

In the primitive condition the Pierid venation is as follows: Costa marginal; subcosta entire; radius with five branches and media with three, all arising from the discal

cell separately from each other; the cubitus is two-branched. The radio-medial cross-vein, or upper disco-cellular lies between the base of R_5 and M_1; the middle disco-cellular lies between M_1 and M_2 and the medial cross-vein, or lower disco-cellular lies between M_2 and M_3.

Colias philodice exhibits considerable specialization, chiefly in the coalescence of the radius and media. The costa merges with the anterior margin of the wing while the subcosta is unbranched and joins the wing margin about two-thirds the distance from base to apex. The radius branches one-third the distance from the base; R_1 reaches the margin just beyond Sc, and in the radial sector fusion of the branches takes place progressively from the discal cell towards the apex (R_2, R_3, R_4, R_5). The upper disco-cellular or radio-medial cross-vein is completely lost by fusion of M_1 with $R_{3\ 4\ 5}$.

The broken lines represent the original course of media (which has faded out basally) and not actual veins. Somewhere in the discal cell it early divides into $M_{1\ 2}$ and M_3. M_1 fuses with Rs for some distance along the radial sector, then breaks away and continues to the outer margin of the wing. At the point where it meets the medial cross-vein (m), M_3 turns sharply caudad to the medio-cubital cross-vein, where it again turns towards the outer wing margin. Thus the lower

disco-cellular is composed of an anterior portion, the medial cross-vein, and a posterior portion, a section of M_3.

The cubitus is two-branched; (Cu_1, Cu_2) the medio-cubital cross-vein joins Cu_1 with M_3 and appears as a false base of M_3. The first anal vein has atrophied leaving only 2nd A.

Hind Wing (Fig. 11).

The hind wing is nearly round in outline with only a slight indication of the anal angle. As is typical of Pieridae, R_1 fuses with the subcosta (Sc R_1), and the radial sector (Rs) arises near the base of the wing and is unbranched due to fusion of R_2, R_3, R_4, and R_5.

The radio-medial cross-vein (r-m), or the upper disco-cellular connects the radial sector with M_1 at the point where $M_{1\ 2}$ divides into M_1 and M_2. The middle disco-cellular is composed of that portion of M_2 which lies between M_1 and the medial cross-vein (m); as in the fore wings the anterior portion of the lower disco-cellular is the medial cross-vein while its remainder constitutes a portion of M_3.

The cubitus is two-branched as in the fore wing and Cu_1 is joined to M_3 by a short medio-cubital cross-vein. The first anal vein is lost and two anal veins remain in the hind wing, 2nd A and 3rd A.

ABDOMEN. (Figs. 8, 14)

The abdomen, like the rest of the body, is covered with scales (both on the membranes and sclerites) which must be removed to perceive its structure. The tergal sclerites are larger than the sternal plates so that they occupy an area equal, approximately, to the area of the pleurites plus sternites. In the male there are eight tergites and seven sternites and in the female seven of each.

The first segment of the abdomen is considerably modified in relation to its articulation with the thorax. The <u>first tergite</u> (1t) is shield-shaped from above and overlaps the cephalic portion of the <u>second tergite</u> (2t); anteriorly it articulates with the caudal aspect of the metathorax, or postscutellum. The first sternite has disappeared and the pleural and sternal regions are entirely membranous. The first abdominal <u>spiracle</u> (sp, Fig. 8) is found close to the metathoracic epimeron.

The second tergite is relatively long and its dorsal margin dips ventrally to accommodate the first, lobe-like, tergite. The <u>second sternite</u> (2s), likewise, narrows anteriorly where it and the first tergite articulate with the thorax. The spiracle of this somite is situated close to the tergite in a slight concavity of its ventral margin.

The next four segments (3,4,5,6) become progressively shorter; and the spiracles are situated in the pleural membranes, slightly dorsal and anterior to the middle of each segment.

In the male the seventh tergite (7t) and sternite (7s) are shorter than the sixth, while in thefemale they have become much elongated and form the last distinct abdominal somite, into which the genital structures may be withdrawn (Fig. 18).

The eighth tergite (8t) covers the genitalia and is produced posteriorly into a downward projecting hook which extends over the dorsal lobe of the harpes (h). The eighth sternite is very much reduced so that there remains only a narrow, weakly sclerotized, strip along the ventral margin of the pleural membrane.

MALE GENITAL STRUCTURES. (Figs. 15, 16, 17)

The terms used in describing the male genitalia are based on the interpretations of Forbes (1920) and Klots (1931).

The eighth tergite must be removed to reveal all of the male genital structures. In Figure 15 the right harpe has been detached to show the interior parts.

The ninth segment of the abdomen is modified to form the narrow-walled ring, or vinculum (v) which broadens dorsally

into the tegumen (tg) representing the ninth tergite, and ventrally is produced into a large lobe-like structure for attachment of the aedaeagus muscles. The saccus (su), represents the ninth sternite. Through the ring-like vinculum extends the aedaeagus (ae) enclosed in its membranous penis sheath (ps). The aedaeagus tapers towards its posterior extremity and the tip is provided with five tiny spines. The terms aedaeagus and penis are not applied uniformly by all taxonomists although according to the most generally accepted usage the term penis should be applied only to the membranous eversible tip of the ejaculatory duct and aedaeagus to the heavily chitinous tube through which this duct extends. At the anterior extremity of the aedaeagus is a large ventral projection, the basal prong of the aedaeagus (bpp), to which muscles are attached. Between the walls of the vinculum, beneath and supporting the aedaeagus, is the juxta (jx), a concave, shield-shaped sclerite, the apex of which is directed caudally.

The harpes (h), or valves, are structures which are used to clasp the female in mating. From a lateral aspect they are broad in the lower portion and narrow dorsally into a neck-like region. The distal process (dp) may be elongate and specialized in some forms but in *Colias* it is a short, rounded projection. The dorsal lobe (dl) is also small and

its cephalic margin is produced anteriorly to join the articulatory process of the tegumen (apt). Mesally the harpes exhibit a long, dorsal thickening or ridge, a margin (mr), bordered with seta-like hairs, and a ventral lobiform structure, also setiferous, the sacculus (sa). Ventrally the harpes are joined to the lower rims of the vinculum.

The tenth segment is represented by the uncus (un), a broad hook which projects between the dorsal lobes (dl) of the harpes. At the base of the uncus, dorsally, there is a small finger-like process, arising near the tegumen, which is called the basal prong of the uncus (bpu) by Klots. On either side of the tegumen there is a narrow extension, the articulatory process of the tegumen (apt) to which dorsocephalic extensions of the harpes are joined (see above). Klots (1931) considers that these (apt) may be homologous with the gnathos or parts of the transtilla of other Lepidoptera.

The rectum (rec) runs beneath the tegumen and the anal opening is just ventrad of the uncus. In some Pierids the ventral region of the anus is sclerotized and is known as the subscaphium but this is absent in philodice.

FEMALE GENITAL STRUCTURES. (Figs. 18, 19)

The female genitalia are eversible but normally they project but slightly from the seventh abdominal segment. In Figure 18 the structures are shown everted.

The eighth and ninth segments are greatly modified and their true homologies and relationships are not well known. The eighth segment forms a lightly chitinous area which surrounds the vagina (vg) or ostium bursae and tapers to a narrow band extending into the dorsal region. A chitinous plate forms the floor of the vaginal opening while above it there is a cluster of hairs (sn), probably sensory. Narrow projections or tendons (ten) extend forward to the seventh segment and may serve some function in the retraction of the genital structures. Similar tendons are present on the ninth segment.

Two hemispherical lobes, probably representing the ninth segment, (although some investigators consider it the tenth) form the "ovipositor" (op). (Labia of Petersen.) These are thickly clothed with long coarse hairs and each is provided, on its outer side, with an erectile, papilliform structure. Between the lobes of the "ovipositor" lie the opening of the oviduct (ov) and the anus (an). In Colias there are two external openings of the genital system, namely that of the oviduct and that of the bursa copulatrix called the vagina or

ostium bursae situated ventrad of the oviduct. This condition is rare for insects in general, although it is found in Lepidoptera and Mecoptera.

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ABBREVIATIONS

ad - adanale or posterior notal wing process
ae - aedaeagus
al - adnotal sclerite or adnotale
an - antenna
apt - articulatory process of tegumen
axc - axillary cord or spring vein

ba - basanal sclerite or basanale
bl - basalare
bp - basoplica or basal ridge
bpp - basal prong of aedaeagus
bpu - basal prong of uncus
bs - basisternum
bt - basitarsus (metatarsus)

cd - cardo
cg - cephaliger
cx - coxa

dl - dorsal lobe of harpe
dp - distal process of harpe
dt - distitarsus

e - compound eye
ecx - eucoxa
em - epimeron
ep - epipharynx
es - episternum

f - frontal pit
fc - fronto-clypeus
fe - femur
fl - flagellum of antenna
fs - furcasternum

ga - galea
gp - gular pit

h - harpe
hp - hypopharynx

jx - juxta

l - labrum
lc - lateral cervical plate (laterocervicale)
lh - left harpe
lp - labial palpus

m - median ossicles or medialia
md - mandibles
me - meron
mn - region of mentum (ligula, palpigera, mentum)
mp -- maxillary palpus
mr - margin of harpe
mv - mid-ventral suture

n - notal ossicle or notale
ni - notal incision

occ - occiput
ocd - occipital condyle
oes - oesophagus
of - occipital foramen
op - "ovipositor"
ov - oviduct

p - pedicel
pa - parafrontals
pes - preepisternum
pfr - pilifer
pg - phragma
pge - postgena
ph - pharynx
pm - pronotum
pn - presternum
po - parocciput
pr - precoxale
pra - prealar sclerite or prealare
ps - penis sheath
psc - prescutum
psl - postscutellum
pt - patagium
ptg - parategula

r - marsupium or basosinus
rec - rectum
rh - right harpe

s - sternite
sa - sacculus
sal - subalare
sc - scutum
sd - salivary duct
se - scape
sh - subcostal head
sl - scutellum
sn - sense hairs
sp - spiracle

spl - sternopleurite
spt - sensory pit
spu - tibial spur
ss - spinasternum
st - sub-tegula
stp - stipes
su - saccus
sur - suralar sclerite or suralare

t - tergite
teg - tegula
ten - tendon
tg - tegumen
ti - tibia
tin - tegular incision
tnt - tentorium
tr - trochanter

un - uncus
ung - ungues or claws

v - vinculum
vg - vagina
vx - vertex

2nd A - second anal
3rd A - third anal
Cu_1 - 1st branch of cubitus
Cu_2 - 2nd branch of cubitus
m - medial cross vein
M_1 - 1st branch of media
M_2 - 2nd branch of media
M_3 - 3rd branch of media
m-cu - medio-cubital cross-vein
R_1 - 1st branch of radius
R_2 - 2nd branch of radius
R_3 - 3rd branch of radius
R_{4+5} - 4th 5th branches of radius
Rs - radial sector
r-m - radio-medial cross-vein
Sc - subcosta

EXPLANATION OF PLATES

PLATE I

Fig. 1 - Anterior view of head (proboscis folded backward)
Fig. 2 - Posterior view of head
Fig. 3 - Cross-section of head
Fig. 4 - Mesothoracic leg
Fig. 5 - Metathoracic leg
Fig. 6 - Antenna
Fig. 7 - Distitarsus
Fig. 8 - Lateral view of the thorax

PLATE II

Fig. 9 - Dorsal view of the thorax
Fig. 10 - Fore wing
Fig. 11 - Hind wing
Fig. 12 - Prothoracic leg
Fig. 13 - Ventral view of the prothorax and mesothorax

PLATE III

Fig. 14 - Lateral view of the abdomen
Fig. 15 - Lateral view of the male genitalia, right harpe detached
Fig. 16 - Posterior view of the male genitalia
Fig. 17 - Dorsal view of the male genitalia
Fig. 18 - Lateral view of female genitalia
Fig. 19 - Posterior view of female genitalia
Fig. 20 - Hypopharynx with associated structures

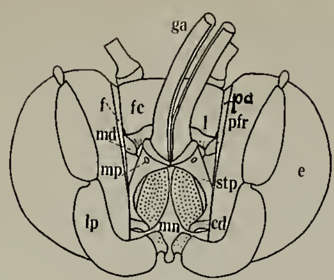
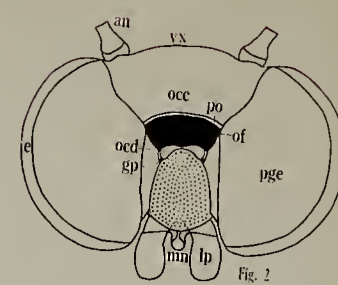


Fig. 1



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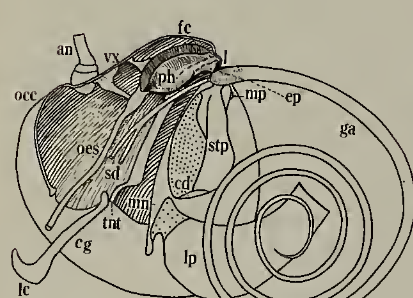

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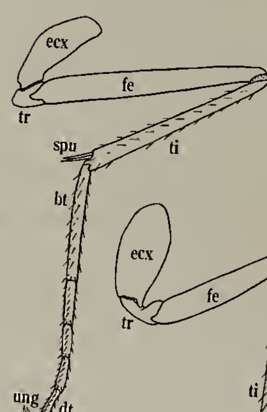


Fig. 4

Fig. 5

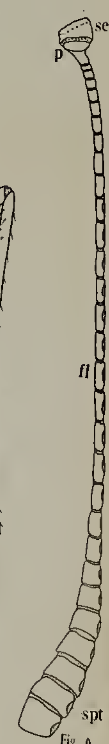


Fig. 6

Fig. 7

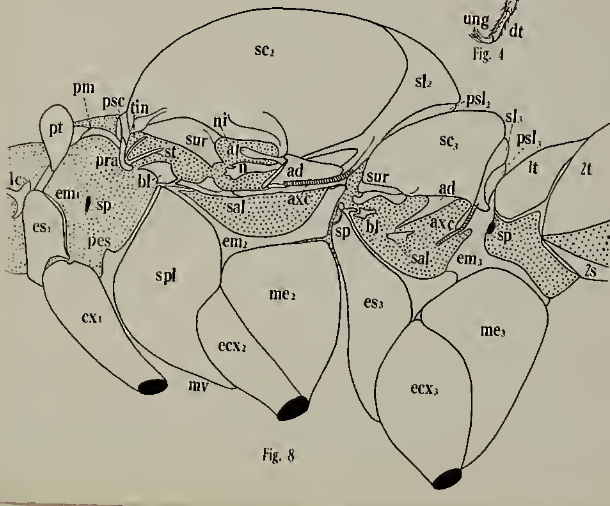
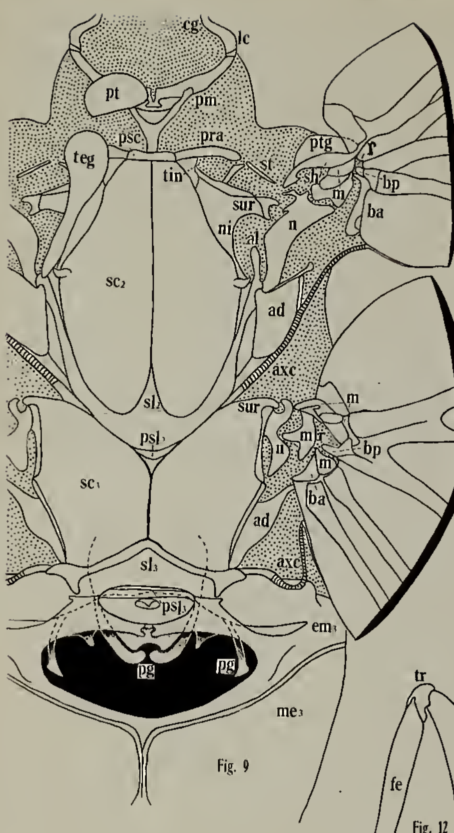


Fig. 8



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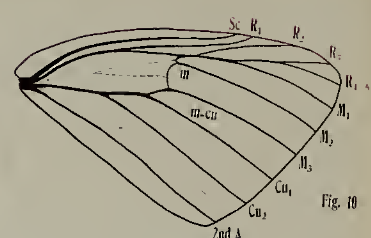
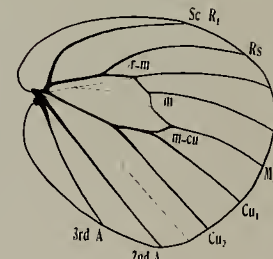


Fig. 10



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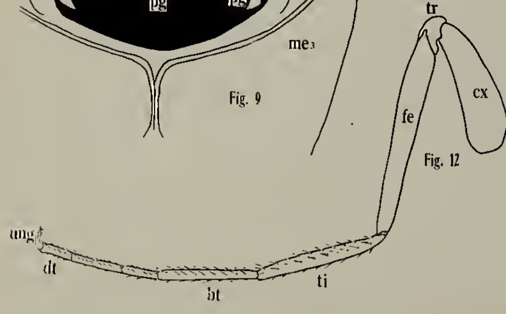

Fig. 12

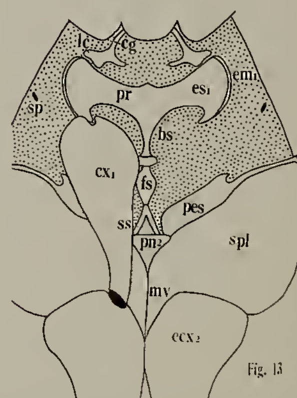

Fig. 13

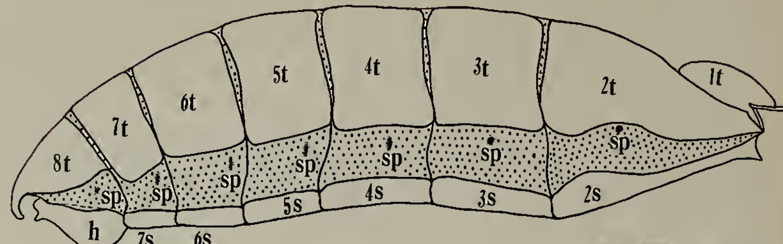

Fig. 14

Fig. 17

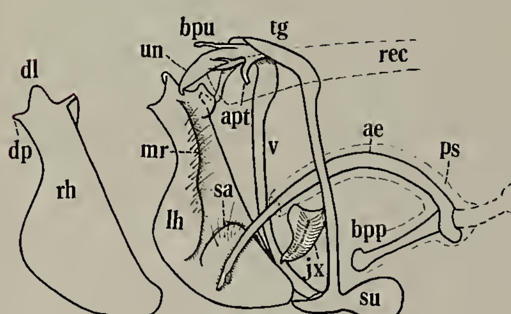

Fig. 15

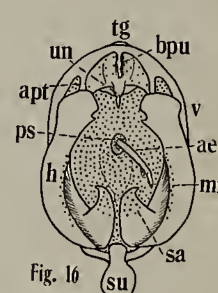

Fig. 16

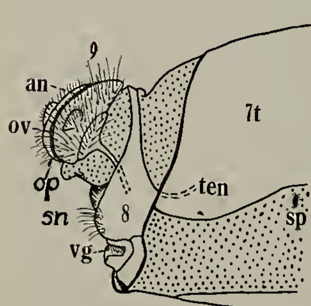

Fig. 18

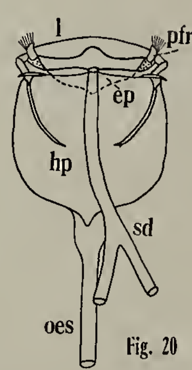

Fig. 20

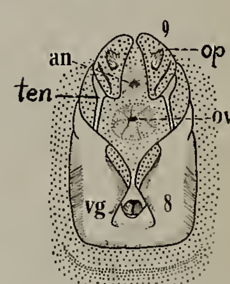

Fig. 19

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[illegible]

Graduate Committee

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