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A DESCRIPTION OF LARVAE AND REDESCRIPTION OF ADULTS OF THE FIREFLY *PTEROPTYX VALIDA* OLIVIER IN SELANGOR, MALAYSIA (COLEOPTERA: LAMPYRIDAE: LUCIOLINAE), WITH NOTES ON LUCIOLINAE LARVAE

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ABSTRACT. - The successful *ex situ* rearing of *Pteroptyx valida* Olivier permits description of final instar larvae, distinction of the four larval instars, brief characterisation of adults, and a reappraisal of literature concerning Luciolinae larvae in the Australasian region from a morphological perspective.

KEY WORDS. - *Pteroptyx valida,* Lampyridae, Luciolinae, larvae, adults, instars, descriptions.

INTRODUCTION

Pteroptyx valida Olivier is a flashing firefly known to use a copulation clamp during mating (review in Ballantyne, 2001b). Consequently, much is known about the behaviour, light patterns and biology of adults of this species, but little about the larval morphology, a common situation in the Lampyridae.

The dearth of information about the immature stages of North American fireflies was noted by Archangelsky & Branham (1998). The situation is no better in the Australasian region and the Luciolinae in particular, where lack of knowledge of larval morphology hinders phylogenetic analysis (Ballantyne & Lambkin, 2000), and prevents correct larval identification. Apart from Bugnion's (1922) extensive treatment of the European species *Luciola lusitanica,* publications addressing larvae (see discussion) often describe external morphology so briefly, if at all, that subsequent identification is virtually impossible. Few of these publications deal with identified larvae (i.e. associated by rearing), and for many, the focus was other than larval morphology.

Reliable associations between adults and larvae can only be established by rearing, but this is often very difficult (Archangelsky & Branham, 1998). If successful rearing confirms the associations, as happened here, the problem then becomes one of substantiating the association. Lloyd & Walker (1967) lamented the situation where biologists who name their experimental material fail nevertheless to properly identify it. They advocated the use of vouchered specimens, to overcome the problem of erroneous or questionable species identification. All material examined here fulfils the criteria for vouchered specimens and is deposited as such.

The external morphology of *Pteroptyx valida* final instar larvae from Selangor Malaysia is described (and all the instars distinguished for the first time), and a consistent terminology of the ventral abdominal plates developed. Within this more complete framework for description of Luciolinae larvae the pertinent literature is readdressed. The associated reared adults are briefly characterised to confirm this association and our identifications. The ethanol preserved adults were killed soon after emergence, and certain features of the

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Table 1. Character scoring for *Pteroptyx valida.*

1,1	2,1	3,1	4,1	5,1	6,0	7,0	8,2	9,0	10,0	11,1	12, ?	13,0	14,2	15,0	16,0	17,0	18,1	19,0	20,0	21,1	22,1	23,0	24,0	25,0
26,0	27,0	28,0	29,1	30,0	31,0	32,0	33,0	34,0	35,0	36,0	37,0	38,0	39,0	40,0	41,1	42,0	43,0	44,0	45,0	46,1	47,2	48,1		
49,0	50,1	51,1	52,0	53,0	54,0	55,0	56,0	57,?	58,?	59,1	60,0	61,0	62,0	63,0	64,0,,65,4	66,0	67,0	68,0	69,0	70,0	71,0			
72,1	73,0	74,2	75,0	76,0	77,2	78,1	79,2	80,0	81,0	82,0	83,1	84,0	85,0	86,0	87,0	88,1	89,0	90,0	91,1	92,0	93,1	94,1		
95,0	96,0	97,0	98,0	99,0	100,0	101,0	102,0	103,0	104,0.															

Characters with'?' were not identified in Ballantyne & Lambkin's (2000) matrix and are not scored here.

elytral apex and extent of colour patterns were easier to interpret, and Ballantyne's (2001b) redescription of the species is expanded.

MATERIAL AND METHODS

Ballantyne briefly redescribed the adults from three males and three females, and the larvae from 33 larvae provided by Rasainthiran who reared them ex situ from eggs collected from a gravid female taken at Selangor. These specimens were killed and fixed by immersion in 70% ethanol, in which they are now preserved, and will be deposited in the Australian National Insect Collection in Canberra, except for two fourth instar larvae which are in Rasainthiran's personal collection.

Drawings were prepared of whole specimens using an Olympus stereo microscope with a squared eyepiece graticule, drawn onto graph paper, traced onto architect's tracing paper and inked. Dissections were made under the stereo microscope into glycerine, and material mounted on slides in glycerine was examined with an Olympus CH2 compound microscope and drawings prepared using an Olympus drawing tube.

The adults were scored in a framework of 104 characters described in Ballantyne & Lambkin (2000) and only features which extend the most recent treatments (Ballantyne, 2001b) are included. Methods follow Ballantyne & Rasainthiran (2000). Abdominal segmentation in adults follows Ballantyne & Lambkin (2000).

TAXONOMY

Pteroptyx valida Olivier
(Figs. 6, 7)

See Ballantyne (2001b) for a complete synonymic table.

Type. - Bangkok, holotype male (Paris Museum).

Material examined. - Malaysia, Selangor, three males, three females obtained by rearing.

Brief redescription of Adult Male. - 8 – 9 mm long. Colour: pronotum yellow; fat body closely applied to undersurface, clearly visible through semitransparent cuticle (Fig. 6); retracted along all margins, more widely so along posterior margin, and on disk in slightly pale brown median areas which correspond to the attachment points of underlying dorsoventral muscles; attachment points leave clear impressions and may confuse the interpretation of the colour pattern; elytra very pale yellow, semitransparent, appearing narrowly brown across base because of underlying darker markings on mesothorax, and colour difficult to interpret unless specimen is dried, because of underlying darker hind wings; lateral margins and suture appear white as this area is thicker than rest; one of the three males has fat body in very small clumps in apical fourth of elytron; deflexed apices dark brown in two of the three males, pale with only anterior margin dark in one of the three males; most posterior region of head with very dark brown vertex, top of head between eyes yellow with an underlying layer of fat body, most anterior portion of head between and above antennal sockets for about two to three times antennal socket width is pale yellow, semitransparent, and lacks fat body in two of the three males males; in one of the three males the anterior margin of head just above the labrum and between the antennal sockets is brown; basal abdominal ventrites yellow, cuticle is semitransparent and underlying white fat body shows; posterior margin of ventrite five white, ventrite six very stark white (light organ); ventrite seven stark white in areas of light organ, median area between light organ halves pale, semitransparent, fat body accumulated in posterior two thirds of median posterior projection of ventrite seven (MPP), and posterior margin of ventrite seven and posterolateral corners of MPP yellow; dorsal abdomen yellow, fat body clear through semitransparent cuticle; fat body in tergite eight in lateral areas only. Elytra: with depressed areas on outer margins slightly continuous onto posterior face of elytron so the depression is just

visible from above as a slight kink in the apex (indicated by an arrow in Fig. 7). Abdomen: (Fig. 7); sclerotised portions of ventrite two separated in median line and connected across middle by membrane; posterior margin of ventrite three strongly arched forward, and ventrite three very narrow across middle; anterior margin of ventrite four prolonged and pointed; median posterior projection of ventrite seven having a slender median dorsally emarginate prolongation [Ballantyne's (2001b) Group 2].

Description of Fourth (final) instar larvae. – (Figs. 1–5, 8–14); 12 mm long; elongate, slender, sub-parallel-sided (tapering a little in front and behind), and slightly flattened; lacking laterally explanate margins on terga one – 11; dorsal surface smooth, covered with very short fine hairs which are separated by their length and incline posteriorly parallel to the long axis of the body; dorsal surface heavily pigmented but not strongly sclerotised (Obha & Sim, 1994, Fig. 5), largely dark brown, (not mottled) with irregular small pale depressed areas on all terga; a wide pale median line runs from the anterior margin of the prothorax to the posterior margin of body segment 11, and lateral and posterior margins of those segments are narrowly pale; median line not depressed and margins not elevated; ventral surface largely pale cream with pale mottled brown markings (Fig. 1); with three thoracic and nine obvious abdominal segments (the tenth abdominal segment is very small, and is interpreted here as the narrow ring of dark cuticle immediately following segment nine (Figs. 2, 3).

Head prognathous, flattened, parallel-sided, smooth and largely hairless except for profusion of hairs around mouthparts (Figs. 8, 9); dark brown with lateral areas around and behind antennal bases pale; retractable within prothorax within an extensible neck membrane which forms a two layered envelope around retracted head; a pair of lateral stemmata occur on the side of the head just behind the base of the antennal articulating membrane; the frontoclypeus is the median dorsal plate, which narrows slightly just behind anterior margin, and is bounded at the sides and behind by the frontal arms of the epicranial suture, which meet behind the frontoclypeus; epicranial stem absent, and posterior margin of head is emarginate almost to the frontoclypeus; labrum is not distinguishable from the anterior head margin which is medially shallowly emarginate; the lateral head plates (parietals) reflex ventrally; mouthparts are retracted and most of the ventral head area is formed of a compound plate formed by the fused maxillae and labium.

Antennae (Figs. 8, 9, 14) three segmented, with an elongate 'articulating' membrane into which the antennae retreat in repose (Mehta, 1932); arising at anterolateral corners of head capsule to the sides of the mandibular bases; basal segment short, smooth and hairless, darker than rest, less than half as long as yellow segment two; second segment elongated, smooth and hairless except for an elongate subapical hair, apex obliquely truncate and bearing at its apex the very short (third) segment which lies adjacent to a small elongate, slender sensorium which is only a little shorter than segment three; segment three with a subapical rosette of four hairs and a single apical hair. Exserted antennal length at least as long as head width.

Mouthparts (Figs. 8-13) well developed (homologies interpreted after Haddon, 1915, and Lawrence et al., 1995); mandibles symmetrical, strongly sclerotized, narrow, tapering to a finely pointed apex, densely covered in fine hair on all but their most apical portion; perforated along most of their length by a fine canal which terminates preapically on the outer edge and arises at the base; articulating with head by two condyles, one just beneath anterolateral corners of frontoclypeus, and second ventrally at the narrowed anterior margin of the reflexed head margin; lacking teeth at base; no setae or spines along length. Maxillae and labium fuse to form most of the ventral head area; maxillae with a short, squat, four segmented palp, the basal segment of which is large and well defined, next two segments very short and diminishing in width towards the apex, apical segment longer, narrower, subconical; the palp may obscure the galea from above; the galea is long, thin, two segmented and bears on its inner margin an elongate, flattened, dense profusion of anteromedially directed hairs which has been attributed to the lacinia; the cardo is narrow, well sclerotised, articulating with the broad and elongate stipes, which is sclerotised around the margins only and bears a narrow, dense, anteriorly directed tuft of hairs on its laterodorsal margin. Labial palpi are minute, two segmented, arising at the anterolateral corners of a small sclerotised heart shaped prementum which lacks a ligula; postmentum elongate, not well sclerotised and colourless, and joined along its sides by membrane to the cardines.

Thorax (Figs. 1, 5) with prothorax longer than wide, anterior margin bluntly rounded, and containing retracted head beneath; lateral margins divergent slightly posteriorly, with a slight expansion in width at posterior half; posterolateral corners rounded; posterior margin biemarginate, with midlateral

longitudinal depressions which project forward for slightly less than half the median pronotal length (Obha & Sim, 1994, Fig. 5); ventral surface little differentiated, with very narrow strips of cuticle above and to the sides of coxae one representing the episterna and epimera of segment one, otherwise coloured as figured (Fig. 1); meso and metathoracic segments shorter than prothorax and roughly rectangular in outline; posterior margins of meso and metathoracic terga biemarginate; ventral surface of meso and metathorax with median sternal elements delimited by an elongate pleural suture from the lateral elements, the laterotergites; this ventral surface is composed of two areas in each segment, an anterior presternum with paired laterotergites bearing well developed (biforous) spiracles in the mesothorax (these spiracles are rudimentary in the metathorax), followed by a median subrectangular sternal area bearing the legs, above the coxae of which the episterna and epimera of the meso and metathorax are visible as thin sclerotised strands, and which is margined laterally by paired laterotergites.

Legs (Fig. 4) short, coxae widely separated at their bases, with apices inclining medially; five segmented, with cylindrical coxae; elongate trochanters, joining obliquely to the femora, which have an elongate fine hair on under side near the base; tibiae covered with short strong setae, and each terminating in a single apical claw the tarsungulus; legs one are shorter than legs two and three.

Abdomen (Figs. 1-3) with terga 3 – 9 subequal in length, tapering in width from tergum six backwards; segments one to eight have single laterotergites at each side with sclerotised plates bearing the spiracles; the ventral area of segments one to seven has a median subrectangular pigmented sternal area with paired pale, depressed areas, which are inwardly inclined; median sternal area margined by elongate, narrow paired pigmented laterosternites, delimited by folds from the laterotergites above and the median sternal plate; ventral area of segment eight has these same areas but the median area is pale; ventral area of segment nine is pale brown, somewhat paler in middle than sides and is a simple plate with no differentiation into areas; the light organ is present beneath the antepenultimate abdominal segment (eight) and Obha & Sim (1994) described it as paired; the abdomen is terminated by a series of eversible filaments (= pygypods, holdfast organ) and each filament, which possesses rows of recurved teeth, is everted by blood pressure and retracted by muscles inserted at their tips (Domagala & Ghiradella, 1984; Archangelsky & Branham, 1998); the filaments function in locomotion and cleaning; a bifurcate sensory hair arises from the ventral surface of segment ten just anterior to the origin of the pygypods.

Differentiation of larval instars. –

Table 2. Larval specimens examined

Instar	Age in days	No.	Length mm
1	1	3	1.7-2.2
1	5	3	2
1	10	3	2 – 2.5
1	15	6	2-2.5
2	20	4	4-4.5
2	25	5	3.5-4
3	35	3	6.5-7.5
4	60	2	12
4	100	4	12

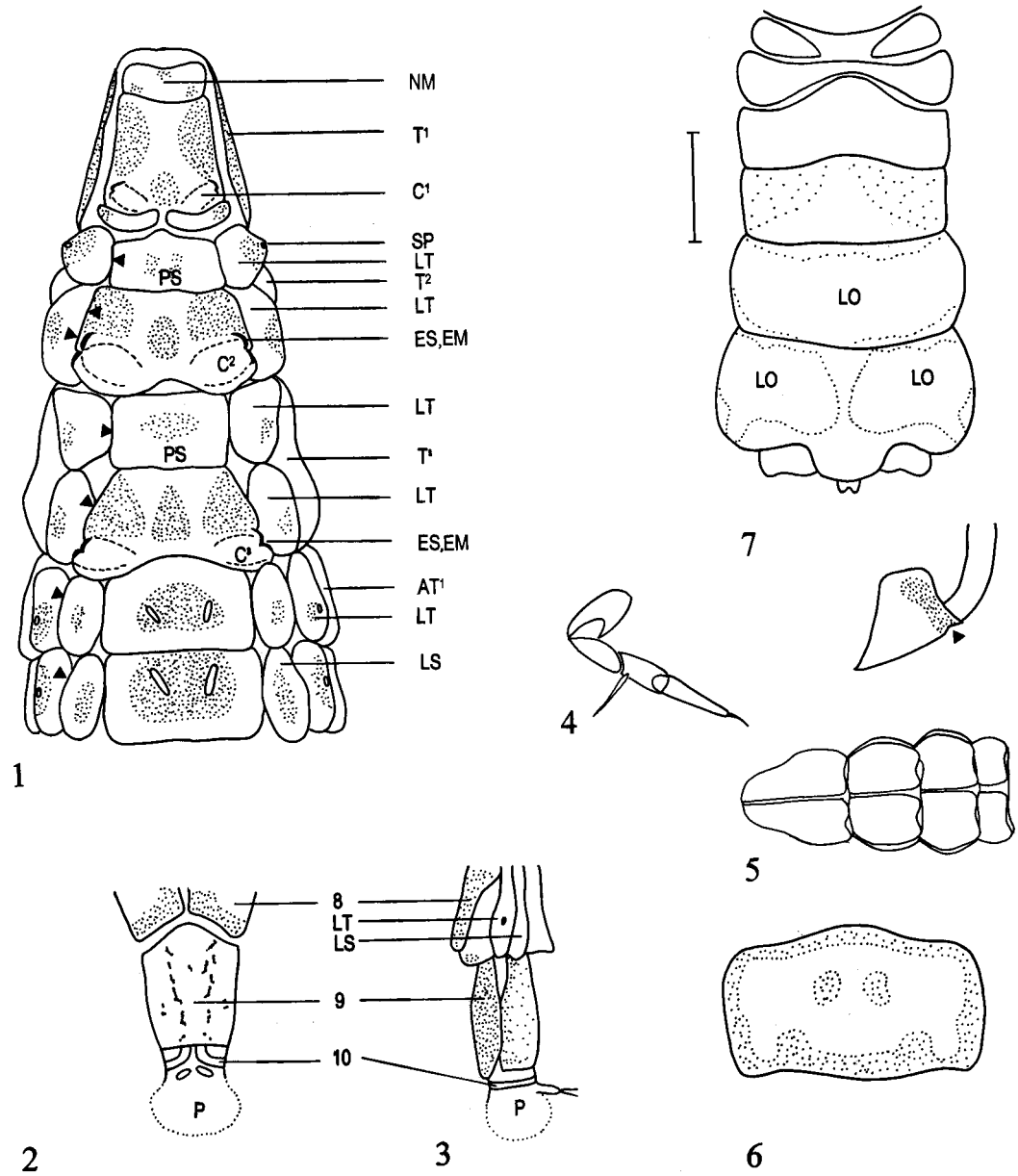
First instar 1.7 – 2.2 mm long; all dorsal plates uniformly mottled brown except for paler non mottled slightly elevated areas at posterolateral corners and to either side of median line on segments one – 11; one day larvae with ventral surface very pale, all coloured areas of final instar defined but very pale except for darker markings on ventral surface of prothorax just anterior to coxae; by day five all ventral plates are a medium mottled brown; ventral surface of light organ segment pale brown; ten day larvae are plumper and the body shows some separation between tergal plates (all larvae were plump at the ten day stage); by 15 days the clear areas along the posterior margins of terga one – 11 are no longer defined. Lacks small pale depressed dorsal areas of fourth instar.

Second instar 3.5 – 4.5 mm long; as for first instar (15 day larvae) except median line broader than preceding stage and separation between terga more obvious.

Third instar 6.5 – 7.5 mm long; light organ segment very pale beneath although no observation of light emission was made at this stage.

DISCUSSION

A more complete framework for the description of Luciolinae larvae is established. As a result larvae can be described and distinguished more easily, certain genera categorised by some larval characters, many older larval references reappraised, and the terminology of the ventral plates reeaddressed.



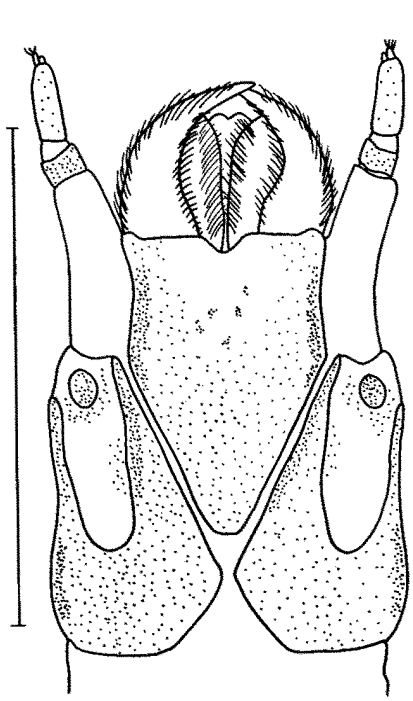
Figs. 1–7, *Pteroptyx valida* (1 – 5 final instar larva, 6 – 7 adult male). 1, ventral aspect thorax and abdominal segments 1 and 2, coxae omitted (arrows indicate pleural suture); 2, dorsal aspect abdominal segments 8 (part only), 9, and 10, with outline of pygypods stippled; 3, right lateral aspect abdominal segments 8 – 10 with outline of pygypods stippled; 4, left metathoracic leg from behind; 5, dorsal thorax and first abdominal segment, head facing left; 6, pronotum; 7, ventral view of abdomen with apex of left elytron (kink in deflexed apex is arrowed).

Scale lines are 1 mm, and all figures share the same scale except Fig. 5 which is not to scale.

Figure legend:

Arrows indicate pleural suture.

AT^{I}	abdominal tergite 1	C^{I-III}	coxae 1 – 3
EM	epimeron	ES	episternum
LO	light organ	LS	laterosternite
LT	laterotergite	NM	neck membrane
P	pygypods	PS	presternum
SP	spiracle	8	tergum 8
T^{I-III}	terga 1 – 3	9	tergum 9
10	abdominal segment 10		



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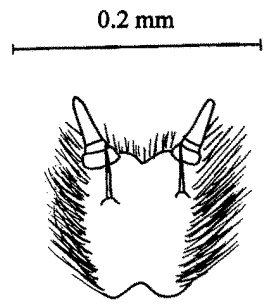

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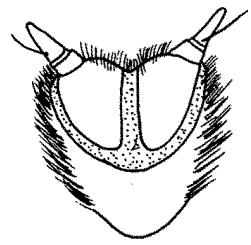

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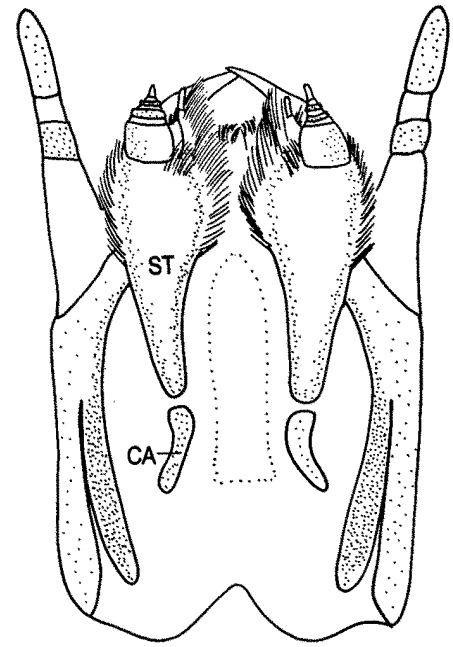

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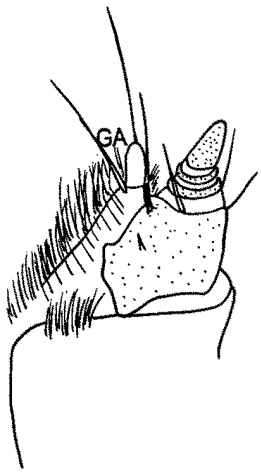

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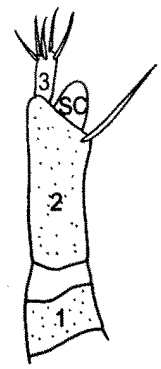

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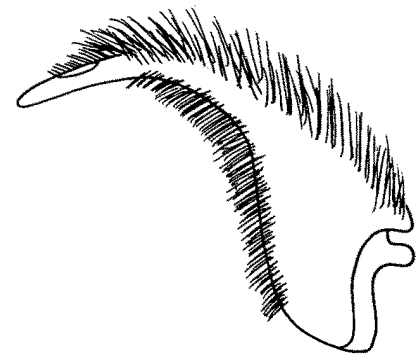

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Figs. 8–14, *Pteroptyx valida* fifth instar larva. 8, 9, dorsal and ventral views of larval head (postmentum outline is stippled in 9); 10, apex of right maxilla ventral view; 11, 12, ventral and dorsal views of prementum; 13, left mandible, ventral; 14, right antenna, ventral.

Scale lines are 1 mm unless indicated otherwise. These figures share scale lines: 8, 9; 10 – 13.

Figure legend.

CA	cardo	GA	galea
SC	sense cone of antenna	ST	stipes
1 – 3	antennal segments 1 – 3		

Several larval species can now be distinguished from larval characters. Ballantyne & Lambkin (2000) characterised three Australian *Luciola* species by the extent of lateral and posterior tubercles on terga one – 11. Those tubercles are not well developed on larvae of *Pteroptyx valida* which otherwise have the same general form. Obha & Sim (1994) figured unlabelled dorsal and lateral aspects of the larva of *P. valida* but their brief larval description did not otherwise address distinctive features, and therefore in our view, does not permit adequate differentiation from other similar genera and species, given that the larval type of *Colophotia,* many *Luciola,* and *Pteroptyx* appears to be very similar (Ballantyne, 1992; Ballantyne & Lambkin, 2000).

One lucioline genus can be now recognised from larval characters, and others at least partially characterised. *Atyphella* Olliff is distinguished by possession of laterally explanate margins on terga one – 11. Ballantyne & Lambkin (2000) characterised *Atyphella* from several larval features, and described and figured larval features of seven Australian *Atyphella* species, which they keyed. By contrast, larvae of Australian *Luciola* (3 species), New Guinean *Pteroptyx,* Indomalayan *Colophotia* and *Pteroptyx,* and probably also *Pyrophanes,* lack laterally explanate margins and the dorsal plates are not well sclerotised (Ballantyne, 1992; Ballantyne & Lambkin, 2000).

Tentative identifications can be made if larval morphology is considered. Olivier's (1883) distinctively coloured larvae from New Ireland were described as *Luciola australis* F. The laterally explanate tergal margins suggest an *Atyphella* sp., and their colour patterns is consistent with *A. guerini* (Ballantyne, 2001a).

Occasionally larvae may be identified for reasons other than knowledge of their morphology. Armitage (1908) briefly described a larva from Kuranda which he identified as *Luciola flavicollis.* He did however see distinctively coloured adults flying at the same time, the colour pattern of which was inconsistent with *L. flavicollis.* Ballantyne & Lambkin (2000) suggested its correct identity was *Luciola nigra* Olivier. *Luciola trivandrensis* Raj is the only species of *Luciola* described from larval specimens only (the adults are unknown) (Raj, 1941). The distinctiveness of, and differences of certain Indian larvae from *Lamprophorus* (now *Lamprigera*) *tenebrosus* led Raj (1947) to conclude they were probably lucioline, and as the only Indian representative was *Pyrophanes indica,* Raj identified his specimens thus.

Obviously the reliable way to associate larvae and adults is if they have been reared, as we did with *P. valida,* but this is not always possible and sometimes a pragmatic approach can be found. Ballantyne & Lambkin (2000) associated *Atyphella* larvae with adults using locality data, especially where no more than one species was known in the area from which the larvae were collected (as there are no non luminous Australian species this approach worked satisfactorily). Sometimes however, even rearing does not yield unequivocal directions about their morphology. Blair (1927) briefly described a terrestrial *Colophotia brevis* larva that was associated with adults by rearing. These larvae appear to lack the laterally explanate tergal margins of *Atyphella* and have paired 'blunt lobes' at the posterior margin of terga one – 11, but Blair's brief redescription does not permit any further conclusions.

Some larvae are associated by such distinctive features that their identification as different species can be questioned. The very similar *Luciola* species described and figured by Fletcher (1919) from Pusa (*L gorhami*), Mehta (1932) from Lahore (*L gorhami*), and Gardner (1946) from India (*L. dubia*), may have been *L. gorhami, L. dubia* or neither. All larvae had a distinctive shape to the posterior margins of terga one – 11. A study of the ecology and behaviour of *Luciola discicollis* reliably identified the larvae, which possess tergal features similar to those noted above for larvae of the *gorhami – dubia* complex (Kaufmann, 1965).

Some very abbreviated descriptions do not permit even suggestions about the proper species identity of the larvae examined. Annandale (1900) described the form and colour of an aquatic glowworm from 'Siam', and (1906) a very similar larva from Calcutta he identified as *Luciola vespertina,* but he did not identify any distinctive morphology. Two larval specimens associated with a collection of *Luciola picea* from Sumatra were described and identified as that species (Olivier, 1900). No attempt was made to identify larvae from over 20 locations in Ceylon, nor figures or photos of two 'Lampyrid" larvae which appear to be lucioline (Bertrand, 1973).

As fully aquatic lucioline larvae have lateral abdominal gills they present a distinctive dorsal aspect if the gills are not retracted. Blair (1914, 1927) figured the dorsum of an aquatic larva he supposed to be *Pyrophanes* sp., which appears to lack laterally explanate tergal margins. Okada's (1928) brief treatment of two Japanese larvae (*Luciola cruciata* and *L. lateralis*) highlighted abdominal gills, and dorsal plates which were divided but not laterally

produced. Bertrand (1972) presented a key to two genera, *Luciola* and *Pyrophanes,* the latter based on its one, unreliably associated, aquatic representative. Obha et al. (1994) addressed a new aquatic species *Luciola owadai* from several perspectives, figured, but did not label, the larval head and a dorsal habitus, but could not distinguish this larva from that of *Luciola cruciata.*

The only two attempts to date at a phylogenetic analysis of the Luciolinae (Ballantyne & Lambkin 2000, and in press) were hampered by missing larval data in 28 of the 43 species considered.

The terminology of the ventral plates of lucioline larvae is readdressed. Stehr (1987) indicated the confused nomenclature regarding the ventral sclerites of larval beetles. Only some Australian and New Guinean luciolines belonging to *Atyphella* and *Luciola* have thus far had the ventral plates described and named (Ballantyne, 1988, 1992, 2001a; Ballantyne & Buck, 1979; Ballantyne & Lambkin, 2000). They differ from *Pyractomena* and *Lucidota* in the subdivision of the thoracic and abdominal ventral plates (Archangelsky & Branham, 1998; Branham & Archangelsky, 2000). Böving & Craighead (1931) considered that ventrolateral sutures delimit lateral areas on all but segment nine and termed "epipleurum" the lateral area of the body immediately above the ventrolateral suture and below the tergal (alar) area. It is not now considered that pleural elements exist in these larvae (advice of John Lawrence) and the term epipleurum is no longer used. A lateral pleural suture delimits laterotergites in the thorax and abdomen. In the thorax Martin (1916) had considered the transverse subdivisions described here in the meso and metathorax to be 'complementary segments' and attributed each to the segment in front i.e. the prothorax was followed by a complementary segment which was covered by the mesotergum, and the mesothorax followed by another segment which was covered by the metatergum. These terms are no longer used. The transverse subdivisions seen in the meso and metathoracic sternal regions are assigned to the sternum, and paired laterotergites (the anterior pair bearing the spiracles) exist at the sides of both meso and metathorax. This interpretation can now be applied to the larval descriptions in Ballantyne (1988, 1992, 2001a), Ballantyne & Lambkin (2000) and Ballantyne & Buck (1979) where the terms epipleurum and complementary segment were used consistently.

Problems outlined here of inadequate larval descriptions etc. can only be overcome by a threefold approach, viz. reliable association of larvae with adults via rearing experiments, appropriate deposition of certain vouchered specimens in museum collections, and then adequate description of the larval morphology. Additionally if rearing methods are published for larvae of varying habitats (e.g. aquatic, terrestrial, subterranean, arboreal), more Lampyrid species can, in turn, be reared, thereby contributing greatly to our knowledge and understanding of this family.

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