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# DESCRIPTION OF THE IMMATURE STAGES OF *BITTACUS PLANUS* CHENG (MECOPTERA: BITTACIDAE) WITH NOTES ON ITS BIOLOGY

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*Abstract.*—The immature stages of *Bittacus planus* Cheng, 1949, including egg, four larval instars, and pupa, are described and illustrated for the first time. The egg is spherical, with two types of micropyles. The larva is eruciform and peripneustic, bearing eight pairs of prolegs on the abdomen. A pair of compound eyes and a median ocellus are present on the head. Each segment of the abdomen has rows of protuberances bearing setiferous clavate setae. The pupa is exarate and decticous. The species is univoltine, overwintering as diapausing eggs on the ground. Larval duration, including a prepupa of 10 days, lasts about 30 days. Pupation occurs in a soil cell, ranging from 10 to 15 days. The roles of larval compound eyes and the ocellus in the phylogeny of Holometabola are briefly discussed.

*Key Words:* egg, larva, pupa, morphology

Bittacidae is the second largest mecopteran family, containing about 180 species in 17 extant genera. Their biology and immature stages are poorly known (Byers and Thornhill 1983), and the immature stages of only a few species have been described briefly or in some detail (Brauer 1871; Currie 1932; Setty 1931, 1939, 1940, 1941; Applegarth 1939; Suzuki 1990; Hua and Tan 2007).

*Bittacus planus* Cheng, 1949, a common hangingfly species in the Qinling Mountains, central China (Hua and Chou 1998), was reported for its hunting, feeding, mating, and oviposition behavior as an adult (Tan and Hua 2006), but nothing is known of its immature stages. From 2004 to 2005, we investigated its life cycle and biology. All immature stages of *B. planus*, including egg, larva, and pupa, were successfully obtained through rearing, and each stage is described morphologically.

## MATERIAL AND METHODS

Adults of *B. planus* were captured and reared in Baiyunshan National Forest Park, Songxian County, Henan Province from mid-July to late August in 2004. Adults were kept in transparent jars 15 cm in height and 7 cm in diameter and provided with fresh twigs to serve as perches for the insects' suspending. Each jar contained a piece of moist filter paper about the same size as the bottom of the jar for humidity. Living insects, including houseflies, leafhoppers and caterpillars, were provided as prey. From September 2004 to June 2005, the immature stages were reared in the laboratory. The temperature was generally kept at around 20°C and relative humidity about

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75%. Eggs, larvae, and pupae were reared in plastic jars with dampened pads of paper tissues. Larvae were fed freshly killed maggots.

All specimens for morphological studies were preserved in 70% alcohol. Observations and illustrations were made under a Nikon Stereoscopic Zoom Microscope SMZ1500, and photographs were taken with Nikon CoolPix5000 Digital Camera.

For scanning electron microscopy (SEM), eggs were fixed for 6 h in 4% glutaraldehyde in phosphate buffered saline (PBS, pH 6.8). Surface granules of the chorion were removed using a 5–10% sodium hypochlorite solution. Eggs were then subjected to a graded ethanol series with the ethanol ultimately replaced through two 30 min baths of isoamyl acetate. Eggs were then dried in a $CO_2$ critical-point-dryer, sputter-coated with gold palladium, and observed with JEOL6360 scanning electron microscope.

Voucher specimens are deposited in the Entomological Museum, Northwest A&F University, Yangling, Shaanxi, China (NWAU).

## Results

### *Bittacus planus* Cheng, 1949

Adult.—For easy identification and comparison, we provide a picture of a male adult (Fig. 1). Wingspan 40 mm. Wings yellowish without distinct markings. Epandrial appendages in male V-shaped from above, with series of short black spines on their inner sides; gonostylus broad basally, very narrow and slender distally, with large inner process medially. Aedaegal lobe broad and long with apex rounded and curved.

Egg (Figs. 2–7).—Spherical, 0.7–0.8 mm in diameter; pale yellow when newly laid but turning dark brown in several hours. Exochorion tough and thick, covered with numerous granules, with honeycombed meshwork and each grid of network roughly hexagonal (Figs. 2–3). Two types of micropyles: one with 3–4 micropylar channels (Figs. 4–5), and another with more channels in special shape as in Fig. 6. Numerous aeropyles unequal in size; some of them arranged to be roughly hexagonal (Fig. 7).

Larva (Figs. 42–45).—Eruciform and peripneustic. Body cylindrical, generally grayish white with mandibles reddish brown. Head hypognathous, with pair of short antennae, two conspicuous compound eyes and large median ocellus (Figs. 8–10). Thoracic legs long, 3-segmented. Prolegs smaller, located on first 8 abdominal segments. Body segments each with 6 rows of branched protuberances except prothorax, each protuberance terminating in distinct clavate seta with numerous hairs. Dorsal protuberances of abdominal segments 8 and 9 four-branched, each with long, finger-like, annulated seta. Last abdominal segment with conspicuous annulated seta on mid-dorsum and terminating in protusile sucker. Spiracles: 9 pairs, on prothorax and first 8 abdominal segments.

First instar (Fig. 42): Length 3.3–6.0 mm; width 0.6–0.88 mm; width of head capsule 0.65 mm; length of mesothoracic dorsal protuberance (DP) 0.33 mm.

*Head* (Figs. 8–10): Vertex (Vx), genae, and postgenae fused into single large piece. Ecdysial line inverted Y-shaped. Frons (Fr) roughly triangular. Median ocellus large, located close to upper corner of frons (Fig. 8). Small, black, triangular projection, egg burster (Bu), situated at center of frons. Clypeus (Clp) approximately rectangular, with strip of conjunctiva. Eyes dark brown, with 7 ommatidia annularly borne on oval hillock (Fig. 13), located caudodorsad of each antenna (Fig. 9). Antenna 3-segmented, scape narrow, pedicel elon-

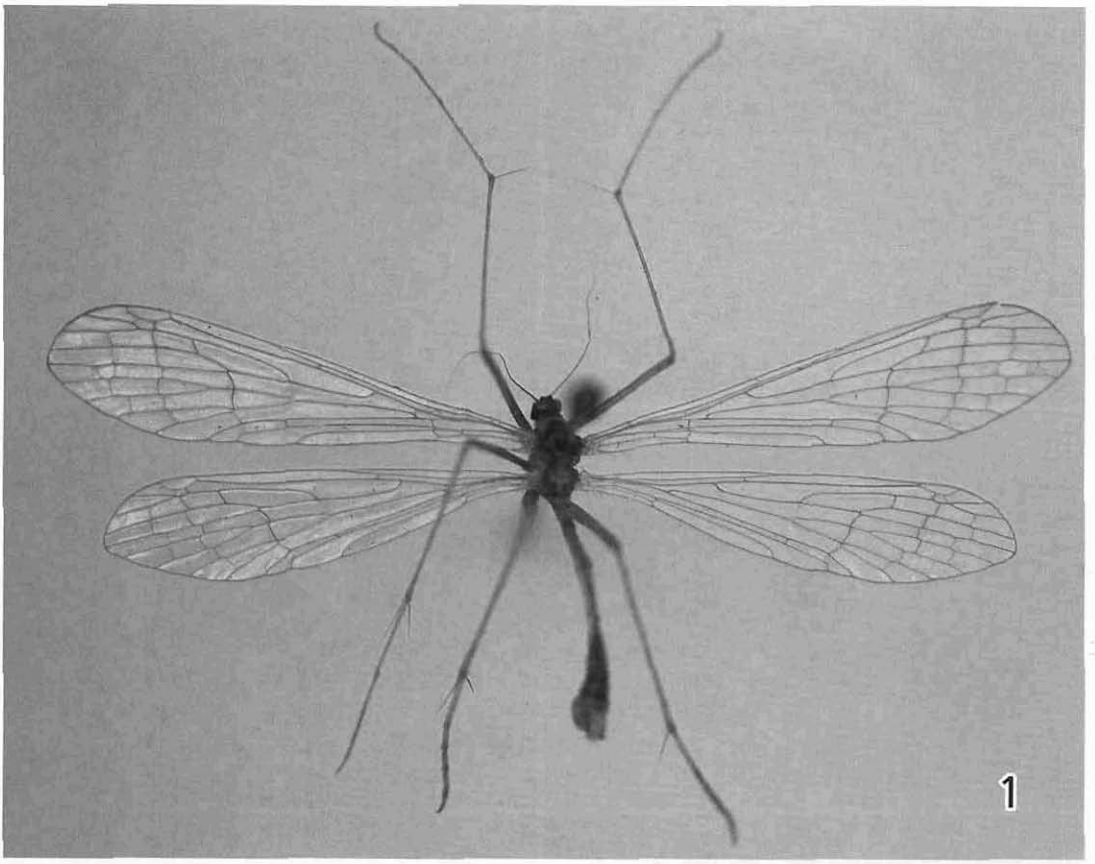
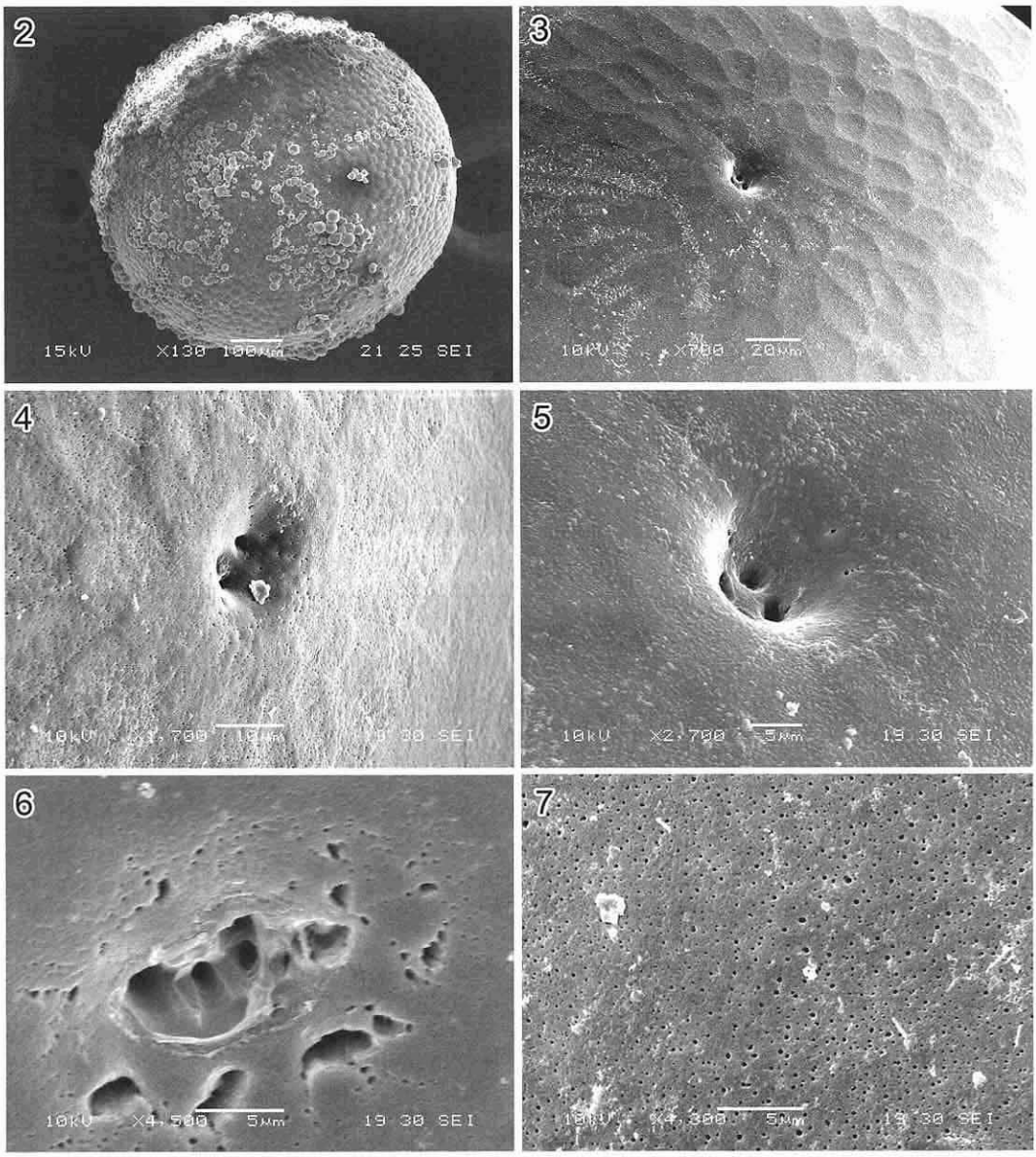



Fig. 1. *Bittacus planus*, male.

gate and flagellum small (Fig. 11). Pedicel large, cone-shaped with an oval sensory pit area near its apex, under high magnification each pit appearing surrounded by hexagon of minute circles (Fig. 12). Cervical sclerites (cvpl) with two small setae near upper margin of sclerite (Fig. 9).

*Mouthparts* (Figs. 14–20): Typically mandibulate. Labrum trapezoidal (Fig. 14), with apical area membranous, ventral margin slightly notched medially. Prominent median sclerite connecting labrum with clypeus on base of epipharynx. Mandibles densely sclerotized, with two long and one short seta on outer surface. Incisor region with two conspicuous and four smaller teeth; molar region small with tuft of stiff hairs (Figs. 15–16). Maxilla with stipes seeming to merge with cardo; lacinia wanting; galea with two setae at distal end and numerous stiff hairs along base of mesal edge. Maxillary palp long, 4-segmented (Figs. 17–18). Hypopharynx broad basally with numerous sensory hairs and tapering distally (Fig. 19). Labium with pair of short 2-segmented palpi (Fig. 20) located between paired cardos of maxillae; lingula absent; opening of salivary duct situated at base of labium.

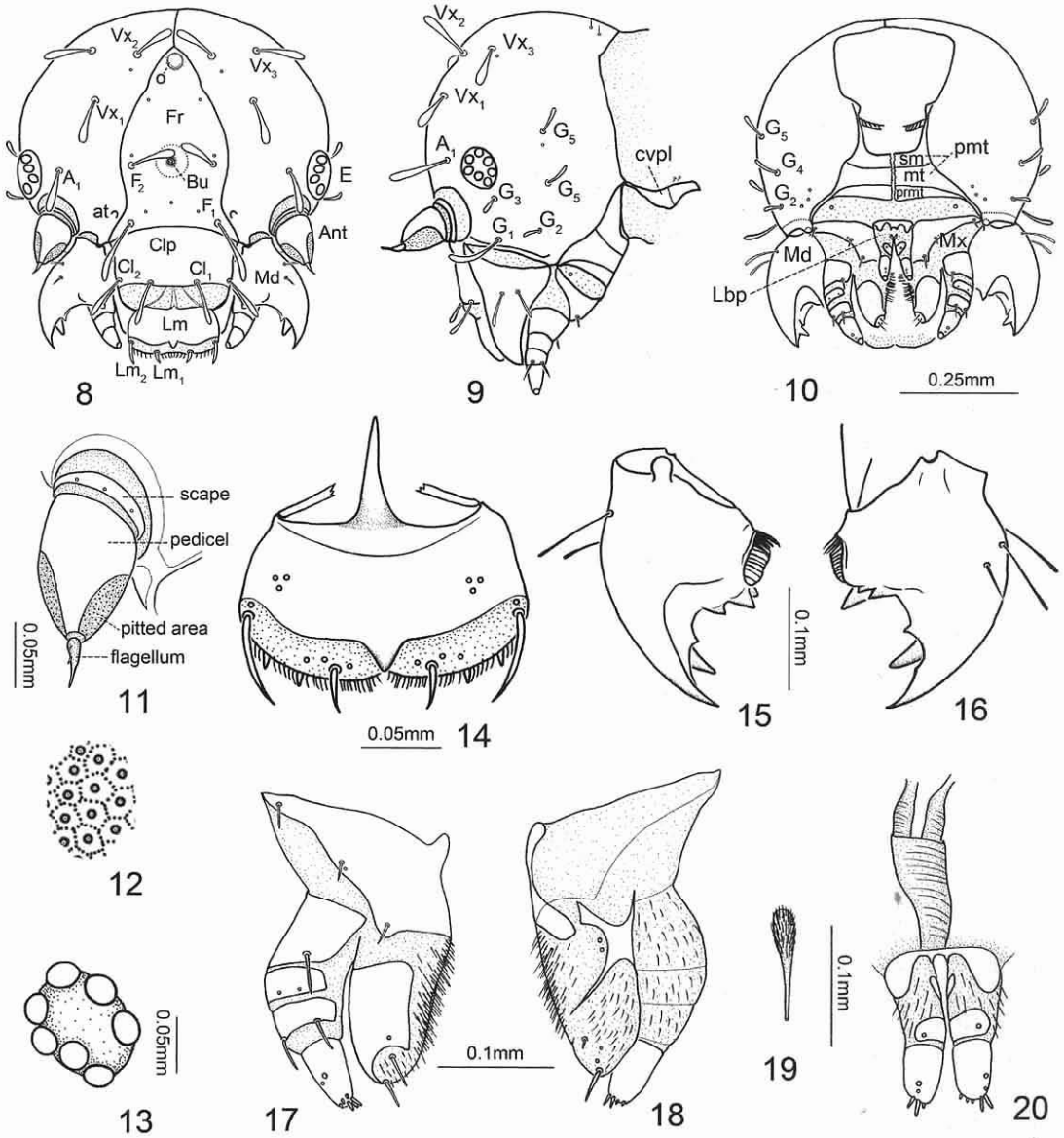
*Chaetotaxy of head:* Head bearing 15 pairs of setae (Figs. 8–10), most distinctly clavate and furnished with fine hairs. Anterior setae ($A_1$) situated between frons and eyes but very close to eyes. Frontal setae ($F_1$ and $F_2$): $F_1$ near ends of frontal suture; $F_2$ approximately at level of $A_1$. Clypeal setae ($Cl_1$ and $Cl_2$)




Figs. 2–7. Egg of *Bittacus planus* (SEM). 2, Surface granules of exochorion. 3, Surface granules of exochorion removed. 4, Micropyle with three channels showing some aeropyles in hexagonal form. 5, Micropyle with four channels. 6, Micropyle with several channels. 7, Aeropyles.

near distal border of sclerotized portion. Labral setae ($Lm_1$ and $Lm_2$) on distal margin of labrum. Vertical setae ($Vx_1$, $Vx_2$ and $Vx_3$) arranged in triangle on each side. Genal setae ($G_{1-5}$) roughly arranged at three levels. Some microscopic pores visible on head.

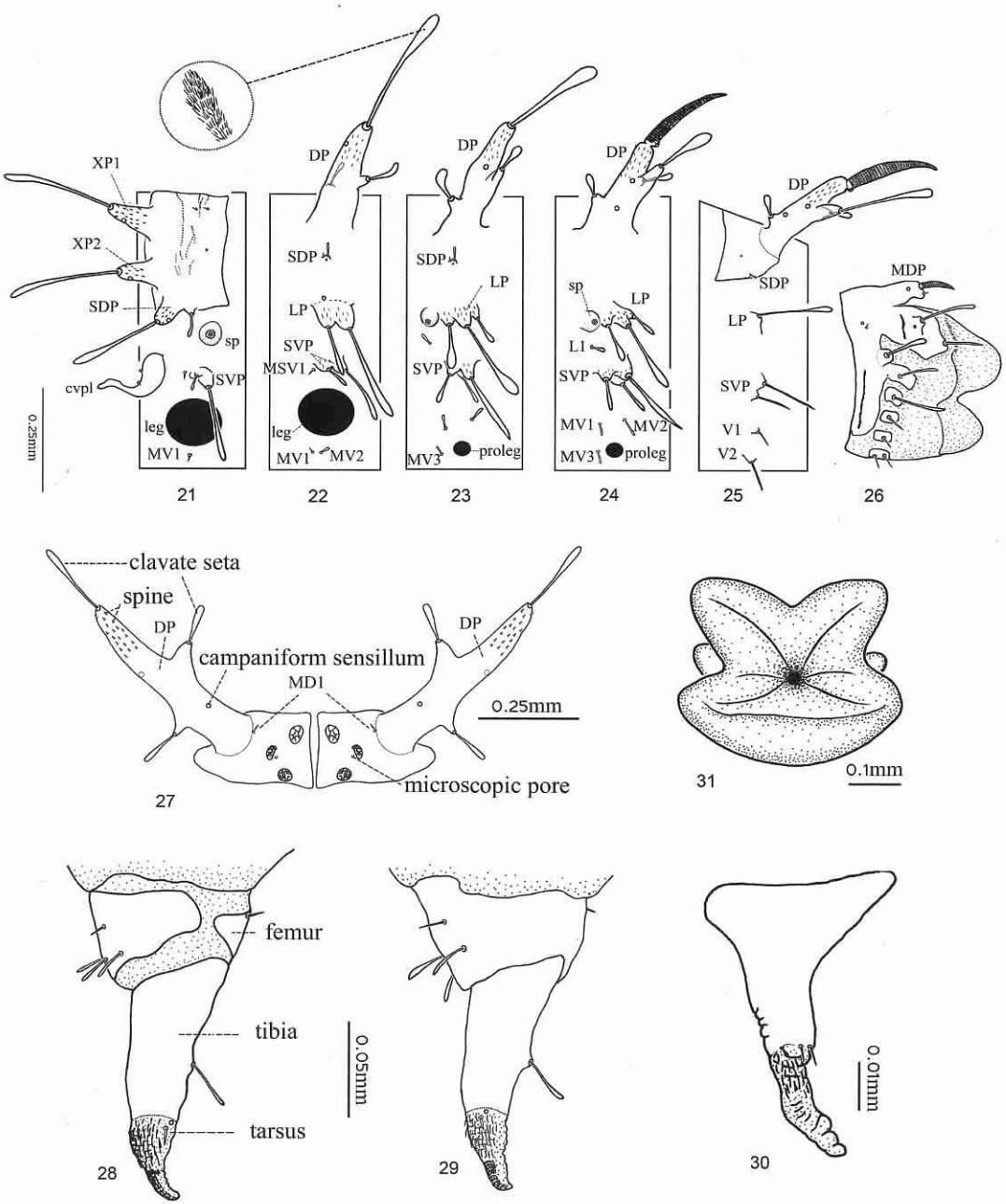
*Prothorax* (Fig. 21): Prothoracic shield large, with 3 pairs of long protuberances (XP1, XP2, SDP), each terminating with long, hairy, clavate seta; subdorsal protuberance (SDP) bearing small branch basally with small seta. Subventral protuberance (SVP) similar




Figs. 8–20. *Bittacus planus*, head of first instar. 8, Frontal view. 9, Lateral view. 10, Caudal view. 11, Antenna, dorsal view. 12, Portion of pitted area of antennal pedicel. 13, Eye. 14, Labrum. 15, Left mandible, frontal view. 16, Left mandible, caudal view. 17, Left maxilla, caudal view. 18, Left maxilla, frontal view. 19, Hypopharynx. 20, Labium, caudal view. Abbreviations: Ant = antenna; at = anterior tentorial pit; Bu = egg burster; Clp = clypeus; cvpl = cervical plate; E = compound eye; Fr = frons; Lm = labrum; Lbp = labial palpus; Md = mandible; mt = mentum; Mx = maxilla; O = ocellus; pmt = postmentum; sm = submentum. Head setae named as $A_1$, $Lm_1$, $Lm_2$, $Cl_1$, $Cl_2$, $F_1$, $F_2$, $Vx_1$, $Vx_2$, $Vx_3$, $G_1$, $G_2$, $G_3$, $G_4$ and $G_5$.

to SDP. One minute subventral seta (MSV1) at each side anterior to SVP. Two minute ventral setae (MV1) mesal to legs. Prothoracic spiracle round with protruding fleshy base, with 10 apertures and round atrial orifice in center.

*Meso- and metathorax* (Fig. 22): Similar to each other in chaetotaxy, with 3




Figs. 21–31. First instar larva of *Bittacus planus*, chaetotaxy of somites. 21, Prothorax. 22, Meso- and metathorax. 23, Abdominal segments 1–7 (A1–7). 24, A8. 25, A9. 26, A10 and telson. 27, Tergum of A1–7. 28, Left mesothoracic leg, lateral view; 29, Right mesothoracic leg, mesal view. 30, Proleg, lateral view. 31, Caudal end of telson showing sucker. Abbreviations: sp = spiracle; XP1, XP2 = anterior dorsal-cephalic protuberances; A = abdominal segment; SDP = subdorsal protuberances; DP = dorsal protuberances; LP = lateral protuberances; SVP = subventral protuberances; MDP = mid-dorsal protuberance; L1 = lateral setae; MV1, MV2 = minute ventral setae; MSV1 = minute subventral setae; MD1 = minute dorsal setae.

pairs of prominent protuberances: dorsal (DP), lateral (LP), and subventral protuberance (SVP). DP thick and long, with one long apical and two shorter clavate setae and two campaniform sensilla each on mesal and lateral sides. LP and SVP 2-branched, each with two clavate setae and campaniform sensillum, but SVP smaller than LP. Minute subventral seta (MSV1) anterior to SVP. Subdorsal protuberance (SDP) very small, with minute seta. Pair of minute ventral setae (MV1, MV2) mesal to coxal cavity.

*Thoracic legs*: Thorax with three pairs of long legs (Figs. 28, 29). Prothoracic legs closer together than other two pairs. Legs 3-segmented, femur, tibia, and tarsus with fleshy base. Femur thickest, sclerotized, with 8 setae, arranged as in Figs. 28–29. Tibia long, thinner than femur, sclerotized, with 2 long clavate setae. Tarsus fleshy, tapering toward apex, transversely wrinkled, with numerous hairs.

*Abdominal segments 1–7* (A1–7) (Fig. 23): Each segment bearing three pairs of prominent protuberances (DP, LP, SVP), a pair of small subdorsal protuberances (SDP), a pair of lateral setae (L1), and three pairs of minute ventral setae (MV1, MV2, MV3). DP of A1 smaller than that of other six segments. DP similar to that of meso- and metathorax but with two minute dorsal setae (MD1). LP three-branched. SVP trifurcated. Abdominal spiracles anterior to LP (Figs. 23, 24), similar to thoracic spiracles in structure but smaller, with six apertures. Prolegs unsegmented, with broad base and pointed apex; variable in length on different segments; distal half transversely wrinkled and partially covered with dense hairs (Fig. 30).

*Abdominal segment 8* (A8) (Fig. 24): Similar to A1–7 but DP with distal, fingerlike annulated seta with short hairs and other 2 small and a long clavate seta. SDP absent.

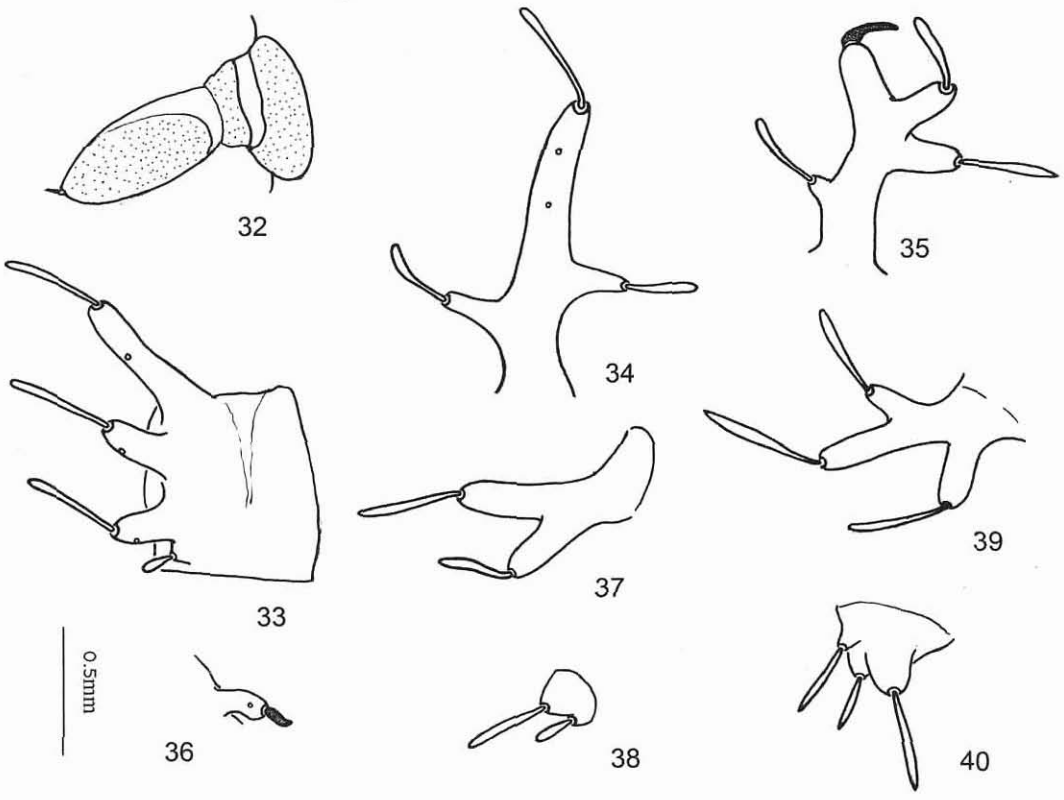
*Abdominal segment 9* (A9) (Fig. 25): Spiracles and prolegs lacking. L1 absent. SDP present. Tergum sclerotized. DP similar to those of A8 but closer to each other. LP simple, with only a long clavate seta. SVP very small, much like two protuberances fused at base. Two ventral setae (V1, V2) each borne on small protuberance.

*Abdominal segment 10* (A10) *and telson* (Fig. 26): Chaetotaxy and sclerites as in Fig. 26. Dorsum dark brown and extending deeply ventrad, with only single small, median protuberance (MDP) terminating in short, annulated and pilose seta. Telson, also called sucker, used in locomotion, with anal opening in its center; protrusile, with four lobes (Fig. 31).

Second to fourth instars (Figs. 43–45): Second instar (Fig. 43) 6.0–8.8 mm long, 0.88–1.15 mm wide; head capsule 0.92 mm wide; length of mesothoracic DP 0.67 mm. Third instar (Fig. 44) 8.8–13.0 mm long, 1.15–1.36 mm wide; head capsule 1.20 mm wide; length of mesothoracic DP 0.9 mm. Fourth instar (Fig. 45) 13.0–15.0 mm long, 1.36–1.87 mm wide; head capsule 1.40 mm wide; length of mesothoracic DP 1.2 mm. Length of apical long seta of mesothoracic DP all 0.33 mm from first to fourth instar.

Compared with 1st instar, egg burster absent; median ocellus more prominent; pedicel of antenna relatively longer and thinner (Fig. 32); spiracles with more apertures. Protuberances (DP, LP, SVP) more distinctly branched (Figs. 33–40). Annulated setae of abdominal segments 8–10 much shorter compared to protuberances (Fig. 35), especially that of A10 (Fig. 36). On A1–7, DP extending slightly laterocaudad, while distal seta cephalad (Fig. 34).

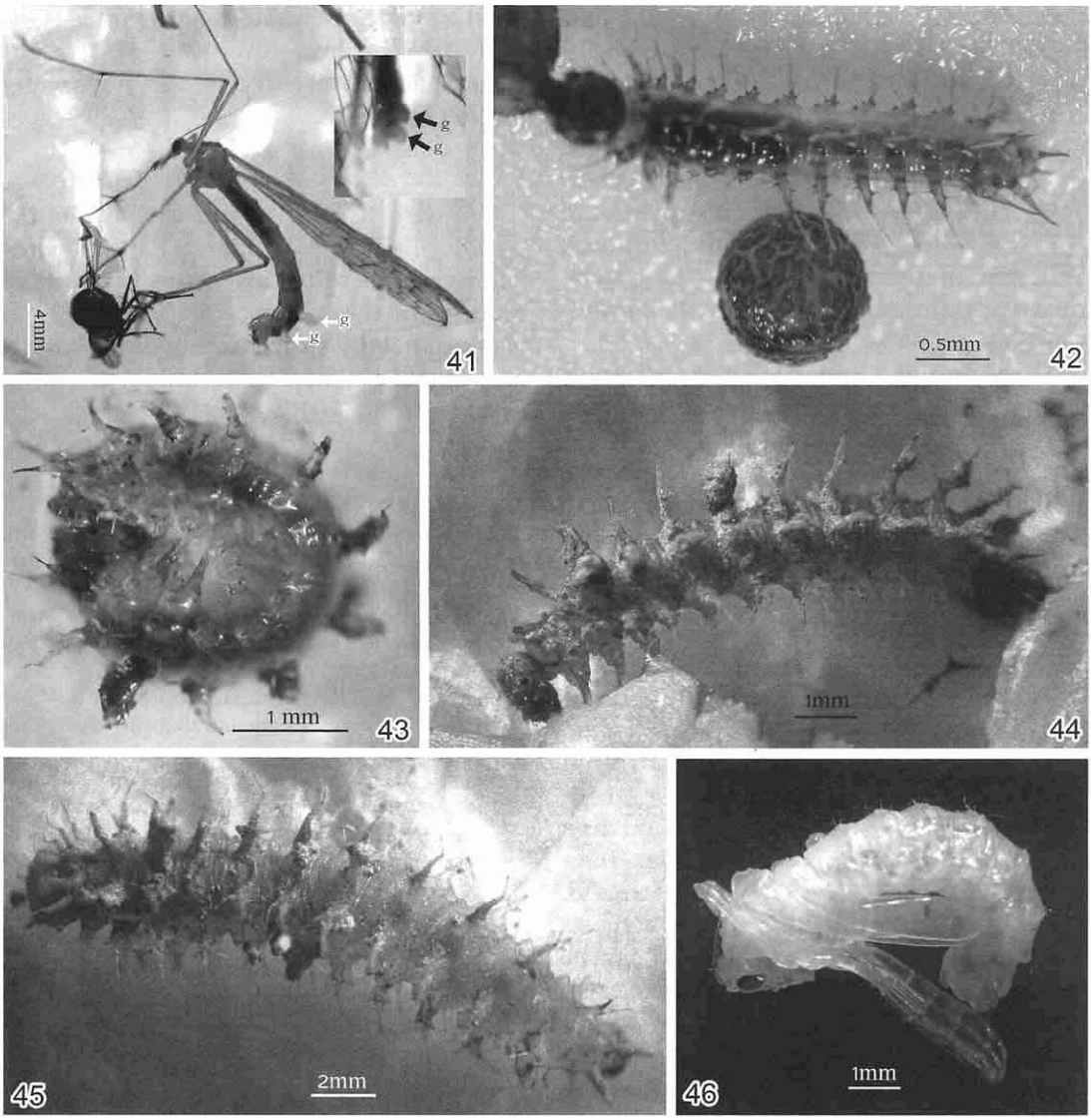
Prepupa.—When full grown, larvae stop feeding and excrete contents of intestine. Body becomes translucent and contracts to two-thirds of its former length.




Figs. 32–40. Fourth instar larva of *Bittacus planus*. 32, Antenna, lateral view. 33, Pronotum, lateral view. 34, Dorsal protuberance (DP) of abdominal segment 3 (A3). 35, DP of A8. 36, Mid-dorsal protuberance (MDP) of A10. 37, Lateral protuberance (LP) of meso- and metathorax. 38, Subventral protuberance (SVP) of thorax. 39, LP of A3. 40, SVP of A3.

Pupa (Fig. 46).—Pupa exarate and decticous, creamy white, 8.7 mm long and 3.5 mm wide. Ocellar triangle and tips of mandibles yellowish brown. Eyes reddish brown. Body setae light brown, acerate. A few long setae borne at front part of basal antennal segment, vertex, caudal margin of eyes, and dorsum of each abdominal segment. Wing pads extending to abdominal segment 6. Terminal segments distinctly differing between sexes, similar to those in adults.

Biology (Figs. 41–46).—As the dominant hangingfly species in the Qinling Mountains, 105 adult individuals of *B. planus* were captured and reared from mid-July to late August in 2004. About 1500 eggs were obtained. The larvae hatched from early March to late May in 2005 in the laboratory, and the resultant larvae and pupae were observed for their morphology and biology. *Bittacus planus* is univoltine, completing one generation per year and overwintering as a diapausing egg on the ground. The duration of the egg stage is about 250 days. Prior to hatching, the egg absorbs water and swells to double its original size for the developing embryo. A few eggs were observed to diapause for two years before hatching. Duration of the larval stage is about 30 days, including four instars. The first instar (Fig. 42) lasts five days, second instar (Fig. 43) three days, third instar (Fig. 44) three days, and fourth instar (Fig. 45)




Figs. 41–46. Stages of *Bittacus planus*. 41, Male showing bilobed sex gland (g). 42, Egg and first instar larva. 43, Second instar showing thanatosis. 44, Third instar. 45, Fourth instar. 46, Pupa.

eight days. After the larval stage, there was a prepupal stage lasting 10 days. The mature larva makes a pupation cell in the soil. The pupal stage varies among individuals from 10 to 15 days. The carnivorous adults fly mainly from late June to mid-August in the field, exhibiting slight phototaxy. Females simply drop eggs singly and randomly to the ground. Their fecundity varies from 60 to 80 eggs per female. The larva is saprophagus, feeding on other dead or dying insects. It usually covers its body surface with mud, especially the dorsum of the thorax. The larva also exhibits thanatosis whenever disturbed.

## Discussion

Hinton (1981) reported that the eggs of *Bittacus pilicornis* Westwood had four micropyles on the anterior pole. Ando (1973) mentioned micropyles on the

posterior pole in *Bittacus mastrillii* Navas. Two to five micropyles were observed on both poles of the egg of *Bittacus laevipes* Navas (Suzuki, 1990). One micropyle was described on the eggs in *Bittacus choui* Hua and Tan, 2007. In *B. planus*, two types of micropyles are first reported in the genus *Bittacus*. Whether these are located on the anterior or posterior pole needs further investigation.

Even though the larva of *B. planus* is similar to that of *B. choui* in appearance, we can distinguish it readily from the latter by its grayish color and the fingerlike annulated setae on A8–10. The annulated setae of *B. planus* are longer, distinctly tapering distally, and with numerous short hairs; those of *B. choui* are shorter, slightly clavate, and with long hairs. The clavate setae at the distal ends of most dorsal protuberance are thinner in *B. planus* than in *B. choui*.

In *B. planus* the seta Vx2 is borne at the level of the upper corner of the frons, and Vx1 is clearly under the median ocellus; both are distinctly lower than those of *B. pilicornis* (Setty 1940) and *B. choui* (Tan and Hua 2008). This suggests that relative locations of setae Vx can be used as traits to differentiate species in *Bittacus*.

The dorsal intersegmental membrane has a series of dark brown hairs forming a transverse band in *B. choui*, while these hairs are absent in *B. planus*.

Holometabolous larvae generally have only lateral simple eyes, or stemmata, but several families of Mecoptera, including Panorpidae, Choristidae, and Bittacidae, have compound eyes in their larval stage (Byers and Thornhill 1983), suggesting that Mecoptera may be a relatively deep node in the phylogeny of Holometabola. Furthermore, larval Bittacidae exclusively have a frontal median ocellus, a putatively ancestral characteristic. Ocelli are absent from all the other holometabolous larvae but are present in most nonholometabolous nymphs (Gilbert 1994) suggesting that species of Bittacidae arose early in the phylogeny of Mecoptera.

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