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The Pupal Characters and Key to Subfamilies and Genera of Pupae of Chinese Mosquitoes* (Diptera: Culicidae)

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The pupal stage is critical in the metamorphosis of mosquitoes, and the study of pupal morphology has important implications for mosquito taxonomy, especially where species determinations, evolution and phylogenetics are concerned. For many years research on mosquito pupae languished. Only within the last two decades has attention been focused on the pupal stage, chiefly by overseas investigators. Belkin (1962), Bram (1967), Huang (1972), Smith (1973), Sirivanakarn (1972, 1976, 1977), Peyton (1977) and others represent the vanguard of those advocating a primary position for pupae in mosquito taxonomy. Though descriptions of mosquito pupae have occasionally appeared in the Chinese literature, no summary report on their taxonomic role has hitherto been published. For just this reason, the authors are launching a series of studies on pupae. The present paper describes taxonomically important

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pupal characters and provides a key to the subfamilies and genera of Chinese Culicidae. Future reports will extend the scope of this work.

Morphological Characters for the Identification of Mosquito Pupae

Culicid pupae are active, swimming by rhythmic expansion and contraction of the abdomen. In lateral view, a mosquito pupa is comma-shaped (Fig. 1.1). The body is conventionally divided into a cephalothorax and abdomen. The fused and enlarged cephalothorax is followed by a long, slender, downwardly curved abdomen that terminates in a pair of flattened paddles.

Some of the principal pupal characters used in mosquito identification are: shape of trumpets; chaetotaxy, especially the number, configuration and form of the abdominal hairs; and shape of paddles.

1. Cephalothorax

The cephalothorax comprises the fused head and thorax (Fig. 1.1, 3), but only the long anterior margin is head--all the rest is thorax.

The mouthpart case, which is shaped like a bird's sternum and situated in the middle of the anterior cephalic margin, contains the developing mouthparts of the adult mosquito. Laterad of the mouthpart case is a pair of compound eyes, which will develop into adult eyes, together with a pair of ocelli, which are the functional eyes of the pupa. Arising just anterior to the compound eyes are the long, slender antennal cases, which extend posteriorly along the lateral surfaces of the thorax, terminating near the distal end of the mouthpart case. Above the bases of the antennal cases are the

paired head shields.

The chief structures of the pupal thorax are: an enlarged scutum extending posteriorly from the head shields and characterized by a middorsal ridge through which the wings of the adult will emerge; three pairs of leg cases located between the antennal cases and the mouthparts case; a pair of respiratory trumpets situated anterolaterally on the scutum; paired wing cases that cover the lateral surfaces of the thorax; a rectangular metanotum posterior to the scutum; and the paired lateral haltere cases.

The respiratory trumpets (Fig. 1.2) connect directly to spiracles. The open distal portion is the pinna, while the tubular proximal portion is the meatus. In turn, the meatus consists of a proximal striated tracheoid and a distal reticulate area. The trumpet index is the ratio of total length to width at midlength. Trumpet length, shape, and degree of tracheoid development vary among species and are therefore important taxonomic characters. In Anopheles the trumpets are short and conical, the pinna enlarged and deeply split; in Culex and Toxorhynchites trumpet shape is variable but the pinna is unsplit; in Ficalbia the pinna is again split but the trumpets are exceedingly long and slender; in Mansonia the trumpets are sharpened distally for penetration of aquatic plant tissues; and in Topomyia and Malaya the inner and outer walls of the trumpets are distinctly separated. Clearly, the respiratory trumpets furnish excellent generic characters.

Chaetotaxy of cephalothorax: The cephalothorax bears a total of 13 pairs of hairs (1-13C), including 4 pairs (10-13C) on the metanotum. In Aedes subgenus Stegomyia and part of Uranotaenia, hairs 13-C are slightly developed but all other pairs are

degenerate, their former positions marked only by sockets. The general configuration of the cephalothoracic hairs is illustrated in Fig. 1.1, 3, 4. Hairs of key importance in taxonomy are 1-3C, 8, 9-C, and 10-12C.

2. Abdomen

The pupal abdomen is shallowly arcuate. Besides the terminalia, it consists of eight sclerotized segments, each separated by substantial intersegmental membranes that permit freedom of movement. Abdominal segment 1 adjoins the metanotum and bears a pair of well-developed, dendritic float hairs, 1-I, that aid in floating and are absent or undeveloped in Ficalbia and Mansonia. The abdominal venter is largely membranous. Segments II thru VII are similar in shape, the notum and sternum in each case forming a ring that lacks lateral membrane. In addition, segments I-VII each possess a pair of spiracular sensilla.

Essentially, the abdominal hair sequences of mosquito pupae and larvae are similar, but with few exceptions pupae lack hairs 12 and 13; as a result, each abdominal segment possesses only 13 pairs of hairs: 0-11 and 14 (Fig. 1.4). On segments I and II the number of hairs is variable. Hairs decrease greatly in number on segment VIII. The number, configuration and shape of the ventral abdominal hairs could probably be used as taxonomic characters. Ventral hair 9-VIII is especially useful in taxonomy; in Anopheles it assumes a feathery form that is the sole unifying characteristic of this genus. In other genera, this hair is not plumose and its shape, length or position varies not only between genera but between species as well.

Posterior to segment VIII is a crescentic or semicircular

caudal lobe representing abdominal segment IX. Ventrad of this caudal lobe is the genital lobe (Fig. 1.5, 6). In females the genital lobe is short and bears a pair of caudal processes that are more or less vaguely separated from the anterior proctiger (segment X). In males the genital lobe is long and well developed, situated ventrad of the proctiger, and bifurcate distally. Mosquito pupae can generally be sexed by size, especially when all individuals belong to the same population of a given species: female specimens are larger and males are usually smaller, but the morphology of the genital lobe is still the best guide for sex determination. Posterior to segment IX are the paddles, a pair of large dorsolateral appendages, each supported by a sclerotized central midrib. The thickened, sclerotized, basolateral portion of each paddle is called the buttress. The midrib divides the paddle into inner and outer parts that are subequal in length, though the outer part is generally wider. In Toxorhynchites, Ficalbia and some Mansonia the outer part is conspicuously larger. On the other hand, in some Uranotaenia the inner part is longer and the inner margin may be sharply concave basally. All or part of the paddle margin may be smooth (Culex), serrated (Tripteroides, Ficalbia, Mansonia, some Uranotaenia) or fringed (Toxorhynchites, Aedes, Heizmannia, Topomyia, Anopheles, Orthopodomyia, some Ficalbia). Posterior to the midrib there may be one or two paddle hairs (1, 2-P), which vary between genera and species: Anopheles usually possess two paddle hairs, aligned anteroposteriorly; in Culex these hairs may stand side by side or only 1-P may be present; in Aedes, Armigeres, Heizmannia, Ficalbia and Culiseta 1-P stands alone or 2-P is occasionally present. Other mosquito genera lack paddle hairs. The

paddle index or ratio of paddle length to paddle width is another common descriptor in pupal taxonomy.

Key to Subfamilies and Genera of Pupae

of Chinese Mosquitoes

1. Trumpets conical, pinna large and deeply split (Fig. 1 [SIC]: 3, 4); ventral hairs 9-VI-VII modified into stout spines; paddle hairs 1, 2-P arranged linearly (Fig. 2.2) (Anophelinae).....Anopheles

Trumpet shape various, pinna small and usually without deep slit (Fig. 2.5; 3.4, 5; 4.5-7); ventral hairs 9-VI-VII generally setiform; paddle hairs often absent but, if present, either single (1-P) or side by side...2

2(1). Anal hair or hair tuft 1-X conspicuous, either a single stout seta or dendritic; ventral hair 9-VIII simple, slender, small, and unbranched; paddle hairs absent (Fig. 2.1) (Toxorhynchitinae).....Toxorhynchites

Anal hairs absent; ventral hair 9-VIII and paddle hairs not as above (Culicinae).....3

3(2). Trumpets modified for penetrating plant tissues, sharp and surrounded by membranous sac (Fig. 2.5); head hairs uniformly small; ventral hair 1-I simple (Fig. 2.6).....Mansonia

Trumpets not as above; head hairs better developed; ventral hair 1-I dendritic.....4

4(3). Head hair 6-C developed but single, clearly stouter and longer than 7-C.....5

Head hair 6-C various--undeveloped, single, or branched--clearly thinner and shorter than 7-C.....6

5(4). Trumpets tubular, slender and long, trumpet index >7 (Fig. 3.2); head hair 3-C developed; paddles long and narrow, inner and outer parts subequal (Fig. 3.1); ventral hair 1-IX absent.....Ficalbia

Trumpets conical, short and wide, trumpet index <5; head hair 3-C not developed (Fig. 3.3); paddles short and broad, inner part > outer part, inner margin sharply concave basally (Fig. 3.6); ventral hair 1-IX usually conspicuous.....Uranotaenia

6(4). Paddles small, usually pointed distally; paddle hairs absent.....7

Paddles large, generally rounded distally; paddle hairs 1- and/or 2-P present.....9

7(6). Trumpets rounded and trough-shaped, their inner and outer walls clearly separated (Fig. 3.4, 5).....8

Trumpets conical, their inner and outer walls long and fused (Fig. 3.7).....Tripteroides

8(7). Ventral hair 6-VII small, situated immediately alongside 9-VII (Fig. 3.9).....Topomyia

Ventral hair 6-VII well-developed, situated anterior to and at some distance from 9-VII (Fig. 3.8).....Malaya

9(6). Paddle margins with long fringes (Fig. 4.1, 2).....10

Paddle margins without fringes, or with very short spines or serrations (Fig. 4.3, 4).....12

10(9). Paddles oval in outline, usually pointed distally; ventral hair 5-II long, stout and well-sclerotized or 5-II-VII short and small (Fig. 4.1).....Heizmannia

Without this combination of characters.....11

11(10). Ventral hair 6-VI developed, noticeably stouter and longer than 5-VI; 4-VIII short, branched apically; 9-VI small, lightly sclerotized (Fig. 4.2).....Armigeres

Without this combination of characters....Aedes (in part)

12(9). Paddles somewhat elongate, their outer margins with a fringe of small spines at midlength, otherwise without fringes; ventral hair 9-VIII conspicuously developed, its length equal to or greater than half that of paddle (Fig. 4.4 [SIC].....Orthopodomyia

Without this combination of characters.....13

13(12). Tracheoid of trumpets well-developed; paddle hairs 1, 2-P situated side by side or only small 1-P present (Fig. 4.4).....Culex

Tracheoid of trumpets not well-developed (Fig. 5.3); only paddle hair 1-P present but well-developed (Fig. 5.2, 4) 14

14(13). Head hair 8-C generally situated dorsal to trumpet base and anterior to 9-C (Fig. 5.1).....Aedes (in part)

Head hair 8-C located at level of or posterior to trumpet base and aligned with 9-C (Fig. 5.5).....Culiseta

Legend for Figures

Fig.	1.1	Generalized mosquito pupa, lateral view
	1.2	Trumpet
	1.3	Cephalothorax
	1.4	Abdomen
	1.5	Terminalia of male pupa
	1.6	Terminalia of female pupa

ant. c	antennal case
but	buttress
gn.l	genital lobe
hsh	head shield
l.c	leg case
md.r	midrib
m.r	middorsal ridge
meat	meatus
mtn	metanotum
m.p.c.	mouthparts case
oc	compound eye
pdl	paddle
pin	pinna
prt	proctiger
rtd	reticulate area
sct	scutum
st.l	caudal process
trd	tracheoid
w.c	wing case

5.4 Culiseta niveitaeniata, pupal tail

5.5 Culiseta niveitaeniata, cephalothorax

Translated by Mrs. Fu-meei Yeh Robbins, April 1987.

Note: Eight English-language references and an English summary are included in the original Chinese paper (pp. 89-90) but are not included in this translation.