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# THE LARVAE AND PUPAE OF THE NORTH CHINA SPECIES OF ANOPHELES; THEIR STRUC- TURE AND BREEDING HABITS

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## THE LARVÆ AND PUPÆ OF THE NORTH CHINA SPECIES OF ANOPHELES; THEIR STRUC- TURE AND BREEDING HABITS

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During surveys of malaria or of mosquitoes much time and labour has often been wasted in waiting for the hatching out of adult mosquitoes from their larvæ. Therefore recently we have paid more attention to the morphological characters of the Anopheline larvæ so as to enable immediate specific diagnosis to be made in this stage. This has the further advantage of enabling itinerant collectors, who have only a short time at their disposal, to collect larvæ, preserve them and examine them afterwards at leisure.

In North China there are at present three known species of Anopheles, namely, *Anopheles lindesæi* var. *japonicus*, *A. myzomyia pattoni* and *A. hyrcanus* var. *sinensis*. The first two species have so far been reported only from North China but the latter is found all over this country. *A. lindesæi* var. *japonicus*, a comparatively rare species, occurs only in high altitudes and its relationship to human diseases is unknown. The adults of the other two species, especially of *A. pattoni*, have been shown experimentally by Hindle and Feng (1929) to be malaria carriers, and *A. hyrcanus* var. *sinensis* has been observed to be an efficient intermediate host for *Wuchereria bancrofti* in Central China (Feng 1931).

The larvæ of *A. lindesæi* (type species) and *A. hyrcanus* var. *sinensis* have been described by many workers in other parts of the world notably by Strickland (1925), Joyeux (1918) and Stanton (1915), but in most instances the descriptions are incomplete and are useful only for differentiating them from the larvæ of the other species found in the locality in which they were studied. The larva of *Anopheles myzomyia pattoni* has not yet been described, for the adult has been

known only since 1926 when Christophers described it using specimens from Shantung Province. It seems, therefore, advisable to give here a detailed description of the larvæ and pupæ of all the three North China species together with some notes on their breeding habits, in the hope that workers in other parts of China may find them useful for comparison with the structure and habits of the larvæ of other Chinese species.

ANOPHELES MYZOMYIA PATTONI CHRISTOPHERS 1926

I. *Fourth Stage Larva*

1. *General appearance.* The full grown fourth stage larva measures on an average about 5 mm long. In the living state it is more or less uniformly dark brown or nearly black in color. It never has any light colored spots which vary with the various conditions of its breeding places as in the case of the larva of *A. hyrcanus* var. *sinensis*. (vide infra). The hibernating larvæ are always black.

2. *Head* (pl. I, fig. 14). The head is dark brown, and both the dorsal and ventral surfaces are pigmented with dark spots. Those on the dorsal surface form a more or less definite pattern as shown in the figure. Mouth brushes are short. The arrangement of the clypeal bristles is typical of the subgenus myzomyia or division "B" of Puri (1928). The bases of the inner clypeal bristles are far apart, the distance between them being about one-third of their length. The interval between the inner and the outer clypeal bristles is only about half as wide as that between the former bristles. Both the inner and outer clypeal bristles are finely branched and not simple as figured by Meleney (1928). The branches are so delicate and their number so variable that unless searched for under a high power lens they might be easily overlooked. Each of the inner bristles has five to fifteen branches while the outer bristles which are about half the length of the inner ones have only two to five branches. The branches of the outer bristles are as a rule larger than those of the inner ones. The basal fourth of the bristles is smooth.

(a) *Frontal bristles.* The anterior frontal bristles or posterior clypeal hairs are bare and are about as long as the outer clypeal bristles. Occasionally one of them has two or three small branches at the tip.

The distance between these bristles is as wide as or slightly wider than that between the inner clypeal bristles.

(b) *Middle frontal bristles*. Three are to be seen on each side of the middle line. The innermost bristle is the longest reaching about to the anterior edge of the clypeus, the outermost is the shortest and the middle is intermediate in length. Each of these bristles has about an equal number of branches varying from nineteen to twenty-four and the outermost though the shortest, may even have a few branches more than the longer ones.

(c) *Posterior frontal bristles*, or inner occipital hairs, are simple and short. *Vertical bristles* or outer occipital hairs are short, feathered each with four to seven branches. *Ocular bristles* are small, simple or bifid.

(d) *Antennæ*. The antenna is straight and comparatively slender and bears at its tip two digits of equal length between which there is a hair with three to five branches. The shaft of the antenna has strong spines on its inner surface. The antennal hair is simple and short, not longer than the widest portion of the shaft, and is situated on its outer side at one-third to two-fifths from the base and occasionally half way up. The subantennal or basal hair is long and profusely branched.

(e) *Maxillary palp*. Recently Puri (1929) has noted that at the tip of the maxillary palp of the larvæ of the Indian Anopheles are three broad leaf-like pieces, a pair of finger-like processes, a single finger-shaped piece and a long cone-shaped piece. The relative sizes of the last two of these vary in different species but the rest remain more or less constant. In *A. pattoni* the single finger-like piece is about two-thirds the length of the cone-shaped piece, and slightly shorter than the paired finger-like processes.

(f) *Mental plate* (pl. I, fig. 9). The mental plate is comparatively wide having one large central tooth, flanked by three equally large teeth and one small one. The tips of the teeth are round and blunt. The distance between the tips of the smallest tooth and the one next to it is about twice the distance that separates equally the rest of the teeth.

3. *Neck hair*. The hair on the ventro-lateral side of the neck (No. 14 of Root) is small and has four to five small simple branches.

#### 4. *Thorax.*

(a) *Dorsal surface.* There are three submedian bristles on each side. The innermost of these is smaller than the intermediate one. Both are profusely feathered with about twelve branches on the former and nineteen on the latter. The outermost bristle is short and simple (pl. I, fig. 7). There is no definite palmate hair on the metathorax but there is a hair (No. 4 of Root) having a rod-shaped base with two to four long flat leaf-like structures.

(b) *Ventral surface.* On the ventro-lateral surface of each of the three thoracic segments is a group of four bristles which as Puri (1928) pointed out is of great importance in the classification as well as in the specific diagnosis of the larvæ of the closely allied Indian species of *Anopheles*. Each group arises from a strong, chitinized, spinous process. The bristles in each group are arranged in anterior and posterior pairs, the members of each of which occupy a dorsal and a ventral position. These are the pleural bristles. In the larva of *A. pattoni* they are characterized as follows (pl. II, fig. 1): (i) *Prothoracic pleural bristles.* The dorsal bristle of the anterior pair is long, stout and feathered, and its ventral fellow though longer is slender and simple. In the posterior pair, the dorsal bristle is about one-third the length of the ventral bristle of the same pair and has four to five branches which arise irregularly from the stem while the ventral bristle, like its neighbor of the anterior pair, is slender and simple; (ii) *Mesothoracic pleural bristles.* The dorsal bristle of the anterior pair is long, stout and feathered while the ventral bristle which is about one fourth longer, is slender and simple. The dorsal bristle of the posterior pair is minute and simple, and the ventral bristle of the same pair is longer, delicate and bifid; (iii) *Metathoracic pleural bristles.* Though both the dorsal and ventral bristles of the anterior pair are stout, long and feathered, the ventral bristle has fewer and shorter branches, especially toward the distal portion of the bristle. The dorsal bristle of the posterior pair is, like its mesothoracic corresponding member, very small and simple and the ventral hair is longer with three to five branches.

#### 5. *Abdomen.*

(a) *Palmate hairs* are present from segments I to VII. That on abdominal segment I has only about six to seven long blade-like

leaflets with undifferentiated filaments (pl. I, fig. 5). Those on segments II to VII are well developed (pl. I, fig. 2). The palmate hair of segment II is small having thirteen to sixteen leaflets which are short, narrow, notched and armed with short filaments. It is usually very poorly pigmented. The palmate hairs of segments III to VII are of about the same size, with eighteen to twenty-two leaflets which are broad, and steepled with four to six sharp notches ending in a long, sharp filament. The distal portion of the leaflets including the filament is darkly pigmented. (See pl. IV, fig. 2.)

(b) *Dorsal plaques* are present on the dorsum of all the abdominal segments from the first to the eighth. That on the eighth segment is the largest, the one on the second the smallest, and the rest are of about the same size.

(c) *Pecten*. There are two pectens on the sides of eighth abdominal segment, each with some ten to thirteen teeth of irregular size. On the dorsal side of the basal half of each tooth there are four to eight strong spines. These are also occasionally present on the ventral side of some of the long teeth (pl. II, fig. 5).

(d) *Side hairs or bristles*. There are two plumose long bristles on each side of segments I and II and one on segment III. The side hairs on segments IV to VI are short with four to six long branches which arise irregularly from the stem. The tips of the *external anal gill bristles* are strongly hooked.

## II. Pupa of *A. pattoni*

1. *The trumpets* (pl. II, fig. 8). The opening of the trumpets is wide, triangular in shape, and without folds. The basal tubular portion is about half the length of the whole trumpet.

2. *Setæ* (pl. II, fig. 12). Seta A is simple, and on segment IV, is long and pointed. On segments V to VII, these setæ are very long, each measuring about half the length of its respective abdominal segments. Seta A on segment VIII is a brush of hair with five to ten long branches, arising irregularly from the stem. Seta B on segments II to VII has three to five branches and is about half the length of its respective segments. Seta C on segments III and IV has two to five branches which are slender. On segments V to VIII these setæ are simple and long, having almost the same length as the individual segments.

3. *Terminal paddle hair*. The terminal paddle hair is long, slender, curly and about half the length of the paddle. The hair on the blade of the paddle has from two to three branches. The edge of the paddles is armed externally with minute spines which terminate abruptly in a long filament.

### III. *Breeding Habits*

The larvæ of *A. pattoni* are usually to be found together with the larvæ of *C. bitæniorhynchus* in hill streams or in pools in the bed of such streams where filamentous algæ abound. They frequently breed in rain pools in hilly regions, together with *A. hyrcanus* var. *sinensis*. In high altitudes they have also been observed in pools together with larvæ of *A. lindesaii* var. *japonicus*. They have, however, never been found in the plains in ponds which are ideal breeding places for *A. sinensis*. Larvæ of *A. pattoni* have been collected by the present author from Tai An, Tsinan, Chüf u, Linchü and Tsingtao in Shantung Province. They have been recorded from the Western Hills near Peiping by Meloney (1927), and have also been found in Fengtai and Peitaiho in Hopei. Generally speaking, this is the most common species of Anopheles in hilly areas throughout North China. In the Peiping area the larvæ are not seen till about the middle of July, gradually increasing in number until about the end of November when they reach the maximum. From October onwards, however, they are retarded in development. They pass the winter in the second and third larval stages in water under the ice, until about March when they begin to grow again and hatch out around the middle of April. The adults keep on breeding for the rest of the year.

#### *Hibernation of A. pattoni*

(pl. III, fig. 2)

That several species of Anopheles larvæ can stand a certain amount of cold has been observed in various cold regions of the earth. In North America, for instance, Balfour (1928) has shown that the larvæ of *A. quadrimaculatus*, *A. punctipennis* and *A. crucians* resisted successfully for a period of ten days a mean temperature of  $-4^{\circ}$  C with a minimum temperature of  $-11^{\circ}$  C in January. In Hamburg,

Germany, as noted by Martini (1923) the larvæ of *A. maculipennis* can live temporarily in water under the ice in early larval stages. In a recent communication to Dr. Hœppli, Prof. Martini stated that *A. bifurcatus* can hibernate in that region in larval and evidently also in egg stages. After letting *bifurcatus* larvæ repeatedly freeze in ice, he observed that about half of them survived, the remainder died after the first, second and more freezings. The following observations and experiments made in Peiping, North China, indicate that the larvæ of *A. pattoni* hibernate in water under the ice in the winter.

In the summer of 1929, larvæ of *A. pattoni* were collected from pools in the bed of brooks in the Western Hills of Peiping for experimental purposes. Before October, larvæ of all stages, pupæ and some culicine larvæ were included in the collection. Toward the end of October it was noted that the number of larvæ of *A. pattoni* was steadily increasing. However, most of them were in the first and second stages, and only a few fourth stage larvæ were seen. In some pools the small *pattoni* larvæ were so numerous that from one dip with a three-inch spoon one could easily get fifty larvæ. On November 23rd when the outside temperature fell below freezing point at night, the larvæ were found under the thin cover of ice to be as numerous as before and all in the first and second stages. No pupæ or fourth stage larvæ of culicine mosquitoes were present. It was also noted that the larvæ were mostly at the bottom of the water in the morning, came to lie on the surface of the water when it grew warmer in the day, and sank again to the bottom in the evening. By so doing they not only escaped the cold but also the danger of being incorporated in the ice. On December 15th there was a heavy snowfall and the atmospheric temperature in the following three days went down to  $-10^{\circ}$  to  $-14^{\circ}$  C at night and registered  $-2^{\circ}$  to  $-5^{\circ}$  C during the day. These pools were visited again on the 18th. It was found that, under the ice which was about an inch thick, there were still numerous larvæ of the same stage as before, while full grown larvæ or pupæ were absent. After these dates although no record of temperature was noted the weather remained cold for a period of twenty-three days up to January 10, 1930 when another visit was made. All these pools were found frozen. In one of them, the ice was eighteen inches thick, but there was still water underneath. In this water, ladled out through

a hole made in the ice, several hundreds of first and second stage larvæ of *A. pattoni* were obtained. Careful search for larvæ was made in the ice itself but none was found actually in it (see pl. III, fig. 2).

In Tsinan and Linchü in Shantung Province in the latter part of January the same stage of larvæ of *A. pattoni* had also been found under similar conditions in pools in the dry river-beds.

Hibernating with the larvæ of *A. pattoni* were also larvæ of *Chironomus* and *Cyclops*, as well as large masses of filamentous algæ. The latter seem to be very important for the life of the hibernating larvæ which they help to keep submerged under the water and also to give a constant supply of oxygen: an important factor when the water is separated from the air by a thick layer of ice. Furthermore, when the water is shallow so that the whole depth tends to be frozen over, these algæ liberate oxygen (or gas) in the form of bubbles with a film of water in the ice in which the larvæ lodge and so escape being frozen to death. This is clearly demonstrated by the following experiments.

On January 10, 1930, two bottles, each containing an equal amount of water and ten second stage *pattoni* larvæ, were prepared. In addition in one of them some filamentous algæ were placed. Both bottles were put outside the laboratory window. Next morning the water in both bottles was frozen, but it was noted that the bottle containing the algæ had many air-bubbles and some water in the center of the ice mass in which all the larvæ were confined. In the other bottle the water was frozen to solidity and the larvæ were found scattered, four at the surface, and six at the sides of the vessel. On allowing both bottles to thaw at room temperature in the laboratory, it was found that only one larva in the bottle with algæ had died whereas all the larvæ in the other bottle perished.

The same experiment was repeated, two bowls being used, each containing five larvæ. In this instance also the larvæ in the bowl containing water only were killed whereas those in the bowl containing algæ also escaped. Another big bottle containing some algæ and fifty larvæ collected on the 10th of January was put outside the laboratory window from that date until the end of April. Altogether twenty-eight successfully passed the winter and hatched out as adults. The first came out on April the 7th and the last on the 28th of the same month.

The pools where *pattoni* larvæ had been found in the previous winter were again visited on April 12th, and twenty-four fourth stage larvæ of the same species were collected. There were no small larvæ of any species found. This suggests that these were larvæ which had successfully passed the winter.

The average atmospheric temperature was obtained daily by means of a self recording thermometer placed outside of the laboratory window. The average maximum, minimum and absolute minimum temperatures for the latter part of December 1929 and January 1930 were 1.4° C, -6° C and -14° C respectively. The average maximum and minimum temperature for February were 6° C and -2° C; for March: 11° C and 4° C and for April: 19° C and 11° C. No observation has been made to see whether or not the eggs of this species of Anopheles could resist the wintry weather, but it does not seem probable, seeing that only the large number of early stage larvæ have been observed hibernating in the winter. Cazeneuve (1910), however, believed that the Anopheles (species not given) in Chingwangtao near the coast, a place about the same latitude as Peiping, pass the winter in the egg stage. His conclusion was based on the fact that in April he got eight Anopheles larvæ from water melted from ice taken from the marshes a month and a half previously: six of them died and two developed into adults afterwards. The water, thawed from this sample of ice, was kept at a temperature of 6° C with the maximum of 20-23° C. As he did not state whether he looked for the larvæ in the sample or not after the thawing, they might have been there all the time. In that case, it is most probable that he was dealing with *Anopheles pattoni* larvæ which were lodged in the sample of ice taken from the marshes.

*ANOPHELES LINDESALII* VAR. *JAPONICUS* YAMADA

I. *Fourth Stage Larva*

The larva of the type species of *lindsalii* has been redescribed by Strickland (1925) but that of the present variety so far as my knowledge goes has not yet been described. This species also occurs in Japan from where it was first reported.

1. *General appearance of the larva.* The full grown larva measuring about 6 mm is yellowish brown in color, and if disturbed it sinks

down to the bottom of the water and assumes a more or less S-shaped appearance.

2. *Head* (pl. I, fig. 12). This is yellowish brown and has pigmented patterns shaped like an anchor, similar to those of the larva of *A. pattoni*.

(a) *Clypeal bristles*. These are all simple. The inner clypeal bristles are long with their bases close together. The outer clypeal bristles are about half the length of the inner ones. The distance between the bases of the inner bristles is about half of that between them and the outer bristles.

(b) *Frontal bristles*. These are smaller than those of either *A. pattoni* or *A. sinensis*. i) *Anterior* frontal bristles are simple and are about the same length as the outer clypeal bristles. ii) *Middle* frontal bristles: the *outermost* bristle, having about seventeen to twenty branches, is shorter than the inner two; the inner two bristles are about equal in length, and do not quite reach the anterior edge of the clypeus. Each has only twelve to fifteen branches. iii) The *posterior* frontal and the vertical bristles are about the same size, small and bifid. The ocular bristle is small, simple or bifid.

(c) *The antennæ* are slender with minute spines on the shaft especially on the inner side. The antennal hair is small and has from six to ten short branches. It is situated on the dorsal surface of the shaft about one-sixth from its base. The two long digits at the tip of the antenna are equal and the hair between them has four to six branches. Subantennal or basal hair is long and plumose.

(d) *The maxillary palp*. The single finger-like process is small and is only about half the length of the cone-shaped piece.

(e) *The mental plate* (pl. I, fig. 10) is comparatively long and narrow with one central and four lateral teeth which are more pointed than those of the larva of *A. pattoni*. The distances between the tips of the fourth and the third and the third and the second lateral teeth are equal but are twice as wide as that between the rest of the teeth.

3. *The neck hair* has three to five unequal and often irregular branches.

4. *Thorax*.

(a) *Dorsal surface*. Submedian bristles are similar to those of *A. pattoni*. The outermost bristle is short and simple, the innermost one

long and feathered with eight to twelve branches and the intermediate one is the longest and has ten to fifteen branches.

(b) *The thoracic palmate hair* on the posterior quadrant is well developed and has eighteen to twenty-three long leaflets. Its distal end is finely pointed and filamentous (pl. I, fig. 3).

(c) *The ventral surface.* Pleural bristles (pl. II, fig. 2). *Prothoracic*, both bristles of the anterior pair and the ventral bristle of the posterior pair are long, slender, and simple. The dorsal bristle of the posterior pair is about one-tenth the length of the ventral bristle of the same pair and is also slender and simple. *Mesothoracic.* Both bristles of the anterior pair are long slender and simple. The dorsal bristle of the posterior pair is also simple but longer. *Metathoracic.* The anterior pair is about the same as the same pair of the meso- and prothorax. The dorsal bristle of the posterior pair is minute and the ventral one is long and bifid.

#### 5. *Abdomen.*

(a) *Palmate hairs* (pl. I, fig. 1) are present on segments II to VII. All these hairs are well developed. There is no rudimentary palmate hair on the first segment as in *A. pattoni*. Each palmate hair has from twenty to twenty-five leaflets, which are pigmented at their distal extremities. They are marked on each side with two to four fine sharp notches ending *gradually* in a long, sharp filament.

(b) *Dorsal plaques.* The plaque on the eighth segment is the largest; they become gradually smaller towards the anterior part until the second segment where the smallest plaque is seen; then that on the first abdominal segment again is large.

(c) *The pecten* is well developed and has about twenty long teeth. Each of these teeth is armed on the dorsal surface with five to ten strong spines. The hair on the pecten is small and has about four branches (pl. II, fig. 6).

(d) *Side hairs* of abdominal segments I to III are of the usual type seen in Anopheles larva, those of segments IV to VI are long and have two to four basal branches arising from the same short stem.

## II. Pupa of *A. lindesayi* var. *japonicus*

1. *The trumpets* (pl. II, fig. 9) are short and the widely opened meatus is triangular in form, when the pupa is lying at the surface of

the water. The basal tubular portion is short, about one-third the length of the whole trumpet.

2. *The setæ.*

*Seta A* (pl. II, fig. 11) on segment III is minute and strong, and measures about one-quarter the length of the respective abdominal segment. That on segment VIII consists of a hair with seven to ten long lateral branches.

*Seta B.* On segments III to VII these setæ are about half the length of the abdominal segment, each having four to seven branches.

*Seta C.* On segments III to VII these setæ are slightly longer than seta B and each has two to four branches.

3. *The terminal paddle hair* is simple, straight and pointed, measuring about a quarter of the length of the paddle. The hair on the blade of the paddle is delicate, short and simple. The edge of the paddle is covered nearly all around with fine delicate hairs.

### III. *Breeding Habits*

The larvæ of this variety are to be found in high altitudes. The first specimens of larvæ were collected at a level of two thousand feet by Patton from Taishan in Shantung Province and the emerged adults were identified by Christophers (1926). The present author also collected larvæ from Laoshan (about one thousand feet high) in Tsingtao. Meleney found this species in the Western Hills of Peiping at the level of 320 kilometers. They may also breed in slightly lower hilly streams or pools together with *A. pattoni*. On December 7th, 1930 ten full grown larvæ were collected with numerous second stage larvæ of *A. pattoni* from a pool in the Western Hills. They probably do not hibernate in the larval but in the adult stage, because their larvæ cannot stand a temperature of  $-5^{\circ}$  C which had no effect on the larvæ of *A. pattoni*.

### *ANOPHELES HYRCANUS* VAR. *SINENSIS*

#### I. *Fourth Stage Larva*

1. *General appearance.* The full grown larvæ measure about 6 mm. The color of the dorsum varies, especially in early stages, from grayish brown to green. According to its surroundings, the larvæ may or may not be spotted.

2. *Head* (pl. I, fig. 13). The head is longer than that of the *A. pattoni* larva but is lighter in color. The dorsal surface has four pigmented bands. The first is very narrow and occupies the space between the anterior margin of the clypeus and the anterior frontal bristles (or posterior clypeal hairs). The second is broader and lies between the anterior and the middle frontal bristles. The third band is immediately behind the middle frontal hairs. It is wider than the preceding one. The fourth is the broadest band and extends from the posterior frontal bristles to the posterior margin of the head.

(a) *The clypeal bristles*. The inner clypeal bristles are simple, long and their bases are close together. The outer clypeal bristles are dendritic and placed at the outer corners of the clypeus.

(b) *The frontal bristles*. The *anterior* frontal bristles, have two to four branches, are short and do not extend beyond the anterior margin of the clypeus. The *middle* frontal bristles are well developed and feathered. The innermost and the intermediate bristles are long, reaching anteriorly beyond the margin of the clypeus and have from fifteen to twenty branches. The outermost ones are slightly shorter and have twenty to twenty-five branches. The posterior frontal bristles are feathered each with seven to eleven branches. Vertical bristles are slightly smaller with five to ten branches.

(c) *The antennæ* are straight, stout and covered with numerous minute spines, those on the inner surface of the antenna being the largest. The shaft is bulbous at the basal portion and somewhat tapering at the distal end. The antennal hair is well developed and is situated at about the middle of the shaft with five to ten long branches reaching to the tip of the shaft. The two long digits at the distal end are equal and the interdigital hair has four to seven branches. The basal hair or subantennal bristle is plumose and extends to about one-sixth the length of the antenna.

(d) *Mental plate* (pl. I, fig. 11). The arrangement of the teeth is similar to that of *A. lindesaii* var. *japonicus*, but the teeth are smaller and the tips are not so sharp.

(e) *The maxillary palp* is similar to that of *A. lindesaii*.

3. *The neck hair* is fan-shaped, with twelve to fifteen short, strong branches.

4. *Thorax*.

(a) *Dorsal surface.* Submedian bristles (pl. I, fig. 8). The innermost bristle is in most instances branched at the tip with two to four minute branches but sometimes it may be simple. These branches when present are very fine and can be seen only under high magnification. The intermediate bristle is long and feathered with eight to ten branches. The outermost bristle is simple. At the posterior quadrant of the thorax there is on either side of a large palmate hair with twenty to twenty-four long narrow leaflets which differs considerably from that of the larva of *A. lindesaii* var. *japonicus*.

(b) *Ventral surface.* The pleural bristles are typical of the Anopheles group. Prothoracic: The dorsal and ventral bristles of the anterior pair and the ventral bristle of the posterior pair are all long, slender and bare. The dorsal bristle of the posterior pair is of the same thickness but short and has four to six branches arising from the same spot (pl. II, fig. 3). The pleural bristles of the meso- and meta-thorax are similar to those of *A. lindesaii* var. *japonicus*.

5. *Abdomen.* Palmate hairs are present on segments I to VII. Those on the first two segments are not fully developed and are similar to the thoracic palmate hair (pl. I, fig. 6). Palmate hairs (pl. I, fig. 4) on segments III to VII are fully developed; each has eighteen to twenty-five leaflets which are marked distally with *shallow* notches. The *terminal filament* is *blunt* and insignificant. The distal portion of the leaflets is free from pigment while the basal portion is darkly shaded.

(a) *Dorsal plaques.* The plaque on the seventh segment is the largest, and the rest are of about uniform size except for the second which is slightly smaller than the others.

(b) *The pecten* (pl. II, fig. 4). The pecten on each side of the eighth abdominal segment has nine to eleven long teeth intermixed with fifteen to eighteen short ones which are arranged in groups of from one to three. A few of the long teeth at the dorsal end of the pecten have minute spines on both the dorsal and ventral surfaces, but the rest are simple, and all the short teeth are spined at the basal portions. The spines in all cases, however, are very minute so that the teeth appear almost as simple. The pecten bears a hair of seven to nine branches.

(c) *Side hairs* are similar to those of *A. lindesaii* var. *japonicus*.

(d) *Anal gill hairs.* The external anal gill hairs are markedly hooked at the end.

## II. Pupa of *A. hyrcanus* var. *sinensis*

1. *The trumpets* (pl. II, fig. 7) are very short and the openings are large with folded margins.

### 2. *The setæ.*

*Seta A* on segment III is short, stunted and blunt; those on segments IV to VII are slightly longer but are also blunt, strong and stout and are about one-sixth the length of the abdominal segment. *Seta A* on segment VIII is also stout, with eighteen to twenty-two short, delicate, lateral branches.

*Seta B.* On segments III to V these setæ are profusely branched basally with eighteen to thirty branches; those on segments VI and VII have fewer branches of six to fourteen.

*Seta C* is also branched with two to fifteen branches.

Generally speaking, all the setæ, especially those of the anterior segments, have more branches in this species than in the others.

3. *Terminal paddle hair* is stunted and short and has two to three minute terminal branches. It is about one-eighth of the length of the paddle. The hair on the blade of the paddle has two to four branches (pl. II, fig. 13).

## III. *Breeding Habits*

The breeding habits of the larvæ of this species in North and Central China have been studied by Meleney (1927) and by the present writer (1931). They breed in ponds, rainpools, rice fields and marshes in the plains in that order of frequency. They are frequently found together with larvæ of *C. tritæniorhynchus*, *C. bitæniorhynchus*, *C. pipiens* and in hilly regions occasionally with larvæ of *A. pattoni*. As a rule, they breed in nearly stagnant water, in which there is much vegetation of the ceratophyllum and alga of the spirogyra group. They have also been found several times in water kongs (big jars) in the public park in Tsinan, but this is not a natural breeding place, for the larvæ usually die before reaching adulthood. This species as well as *A. lindesæii* var. *japonicus* probably cannot pass the winter in the larval stage but only as adults. Observations made in Peiping showed

that the larvæ disappear toward the end of November. During 1929 when observation was made on larvæ of *A. pattoni* a parallel one was also made on *A. hyrcanus* var. *sinensis* in ponds in Haitien (near Peiping) where many larvæ of every stage were found in August and September. About the first part of October the number became still larger, and the larvæ were mostly in the full grown stage. In the latter part of the same month they became fewer and at the end of November after a light fall of snow even after a long search only a few dead fourth stage larvæ were found. The water at that time was not frozen and the general condition of the pond was practically the same as before. This seems to indicate that they had all hatched out and were hibernating in the adult stage.

#### SUMMARY

1. Descriptions are given of the larvæ and pupæ of the three species of Anopheles of North China, namely *A. myzomyia pattoni*, *A. lindesayi* var. *japonicus* and *A. hyrcanus* var. *sinensis*.

2. Larvæ of *A. pattoni* are found in fresh pools or streams in hilly areas of North China, those of *A. lindesayi* var. *japonicus* in the same kind of breeding places but in higher altitudes of about two thousand feet, whereas *A. hyrcanus* var. *sinensis* breed mainly in plains in the ponds, rice fields and rainpools.

3. Larvæ of *A. pattoni* hibernate in the second and third stages in water under ice, as thick as eighteen inches. The larvæ of *A. lindesayi* and of *A. sinensis* cannot endure such cold. They probably hibernate only in the adult state.

4. The larvæ and pupæ of the three species of Anopheles may be distinguished by the characteristics tabulated below:

TABLE 1.

*Larvæ*

	<i>A. myzomyia pattoni</i>	<i>A. lindesatii</i> var. <i>japonicus</i>	<i>A. hyrcanus</i> var. <i>sinensis</i>
Inner clypeal bristles	Far apart and branched	Close together, simple	Close together, simple
Outer clypeal bristles	Finely branched	Simple	Dendriform
Posterior frontal bristles	Simple	Bifid	Feathered
Verticle bristles	Feathered	Bifid	Feathered
Antennal hair	Short, simple, externally	Short, branched dorsally	Long, branched internally
Prothoracic pleural bristles	Dorsal bristle of the posterior pair has 5 branches arising irregularly from one stem. Dorsal bristle of anterior pair feathered. The rest simple	Dorsal bristle of posterior pair simple. The rest long and simple	Dorsal bristle of the posterior pair thick, short having 4-6 branches arising from the stem at the same spot. The rest are long and simple
Thoracic palmate hair	None	Well developed, leaflets ending in fine filaments distally	Well developed blade-like leaflets
Palmate hairs on abdomen	Extremity with deep notches ending abruptly in filament	Extremity with shallow notches ending gradually in long filament	Extremity slightly dentated; filaments inconspicuous
Pecten	10-13 irregular teeth with well developed spines	20-23 long teeth with well developed spines	8-10 long teeth intermixed with 18-20 short ones in groups of 1-3. Spines inconspicuous

TABLE 2.

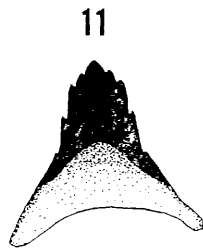
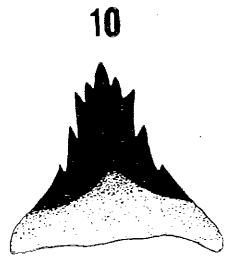
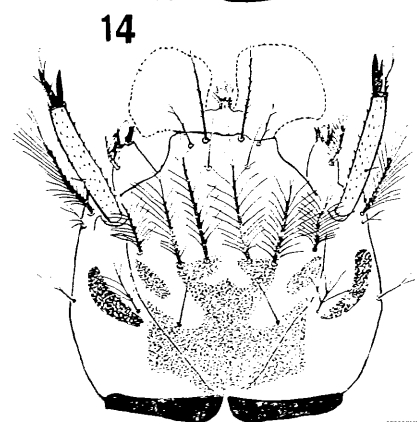
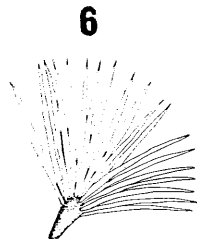
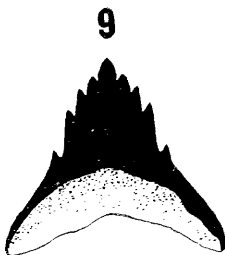
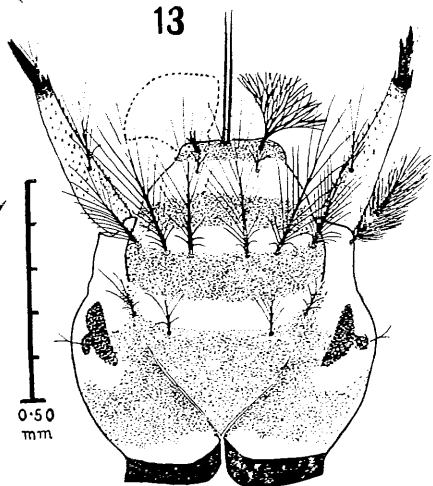
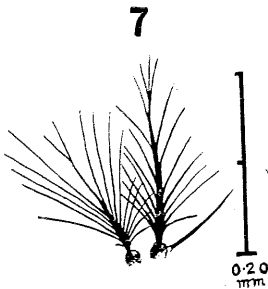
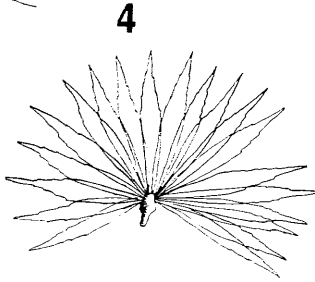
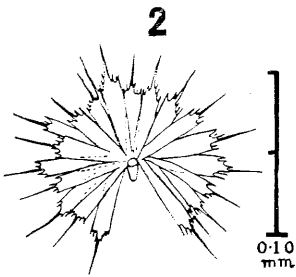
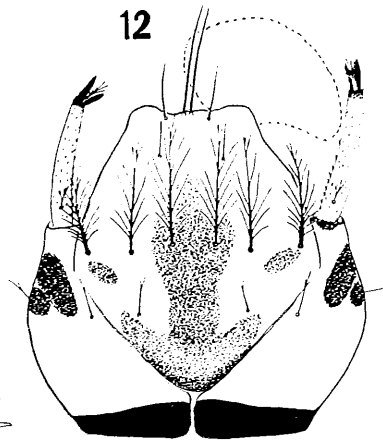
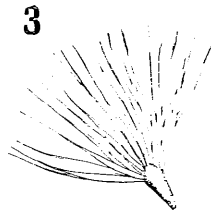
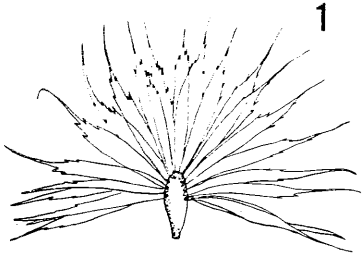
*pupæ*

	<i>A. myzomyia pattoni</i>	<i>A. lindesatii</i> var. <i>japonicus</i>	<i>A. hyrcanus</i> var. <i>sinensis</i>
Trumpets	Opening triangular	Opening triangular	Opening with folds
Seta A on segments VI and VII	Pointed, $\frac{1}{2}$ the length of abdominal segments	Pointed, $\frac{1}{4}$ the length of abdominal segments	Short and blunt, $\frac{1}{6}$ the length of abdominal segments
Seta C on abdominal segments VI-VII	As long as the abdominal segment and simple	$\frac{1}{2}$ the length of abdominal segment with 2-3 branches	$\frac{1}{2}$ the length of abdominal segments with 2-8 branches
Terminal paddle hair	Simple and straight, $\frac{1}{4}$ the length of the paddle	Simple and curly, $\frac{1}{2}$ the length of the paddle	Short stout about $\frac{1}{8}$ the length of the paddle, with 2-4 branches at the tip

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Plate I.



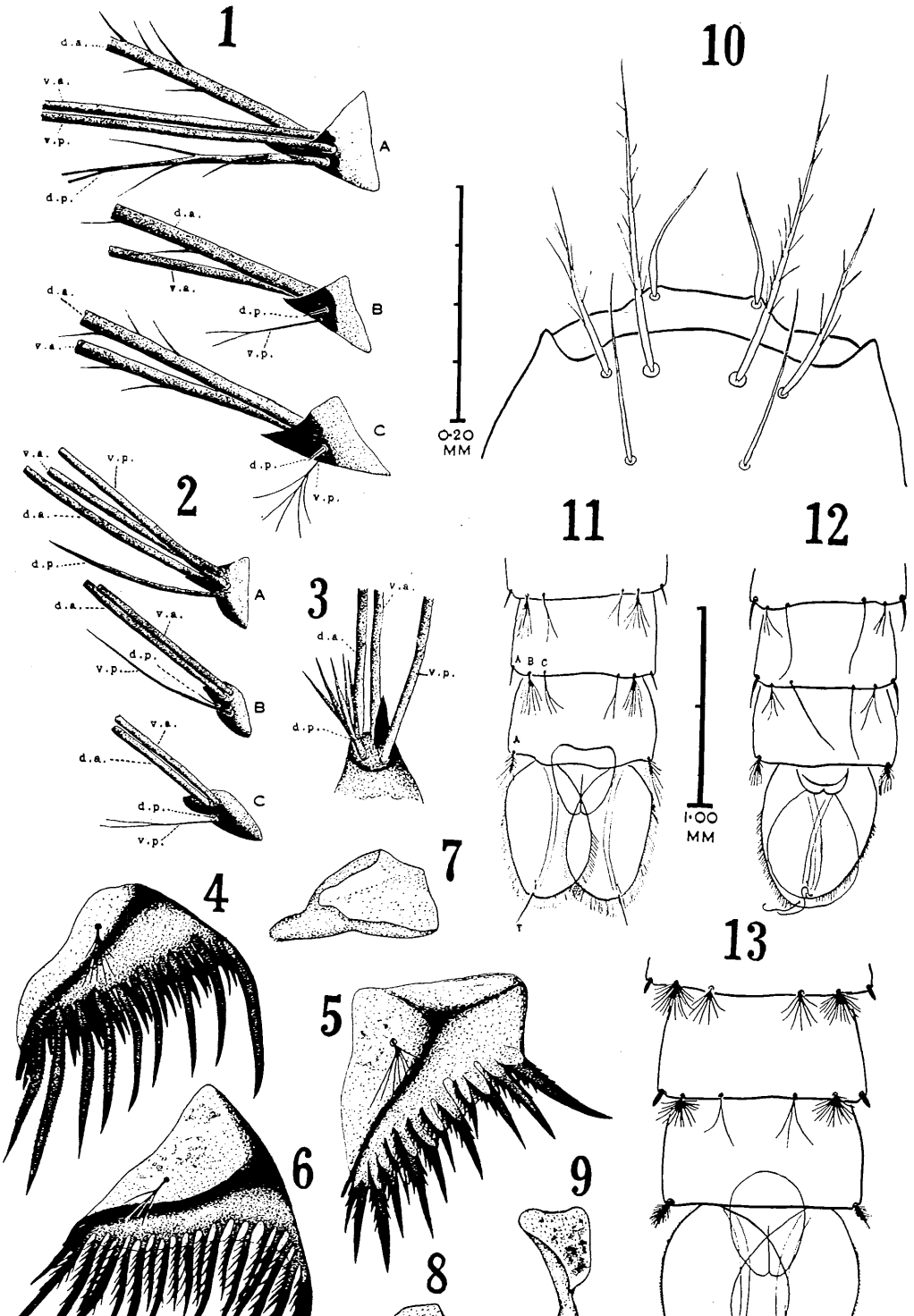




Fig. 1.



Fig. 2.



Fig. 1.

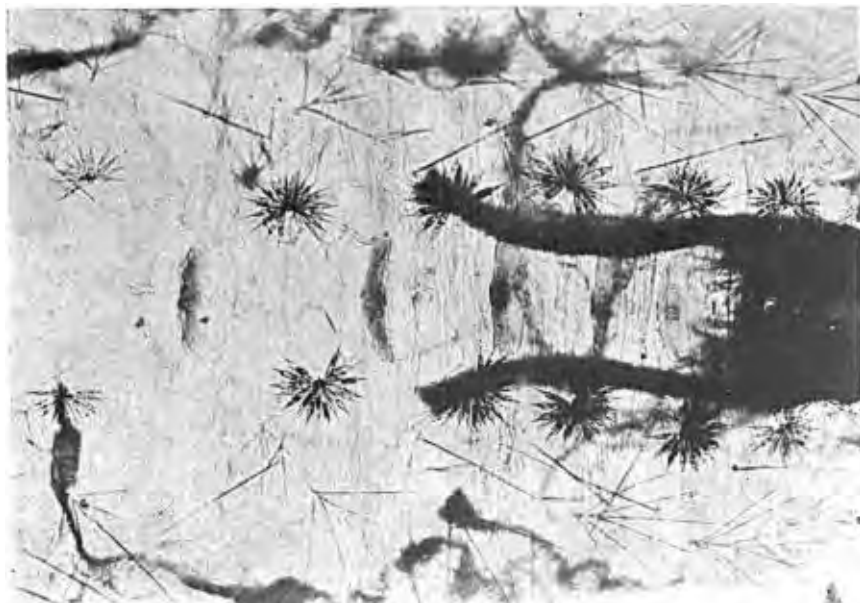


Fig. 2.

## EXPLANATION OF PLATES I, II, III AND IV

*Plate I.*

- Fig. 1. Fully developed palmate hair of the abdomen of the 4th stage larva of *A. lindesaii*.
- Fig. 2. Same of *A. myzomyia pattoni*.
- Fig. 3. Palmate hair of the metathorax of *A. lindesaii* var. *japonicus*.
- Fig. 4. Fully developed palmate hair of the abdomen of the 4th stage larva of *A. hyrcanus* var. *sinensis*.
- Fig. 5. Palmate hair of the 1st abdominal segment of the 4th stage larva of *A. myzomyia pattoni*.
- Fig. 6. Palmate hair of the metathorax of the 4th stage larva of *A. hyrcanus* var. *sinensis*.
- Fig. 7. The right submedian bristles of the prothorax of the 4th stage larva of *A. myzomyia pattoni*.
- Fig. 8. Same of *A. hyrcanus* var. *sinensis*.
- Fig. 9. Mental plate of the 4th stage larva of *A. myzomyia pattoni*.
- Fig. 10. Same of *A. lindesaii* var. *japonicus*.
- Fig. 11. Same of *A. hyrcanus* var. *sinensis*.
- Fig. 12. Head of the 4th stage larva of *A. lindesaii* var. *japonicus* showing the various structures on the dorsal surface.
- Fig. 13. Same of *A. hyrcanus* var. *sinensis*.
- Fig. 14. Same of *A. myzomyia pattoni*.
- SCALE: Figs. 7 and 8 are in the same scale, figs. 12, 13 and 14 are in the same scale and the remaining figures are in the same scale as fig. 2.

*Plate II.*

- Fig. 1. Pleural bristles of the left thorax of the 4th stage larva of *A. myzomyia pattoni*.  
A. prothoracic; B. mesothoracic; C. metathoracic; d.a., dorsal bristle of the anterior pair; v.a., ventral bristle of the anterior pair; d.p., dorsal bristle of the posterior pair; v.p., ventral bristle of the posterior pair.
- Fig. 2. Same of the left thorax of the 4th stage larva of *A. lindesaii* var. *japonicus*. Lettering same as fig. 1.
- Fig. 3. Pleural bristles of the right prothorax of the 4th stage larva of *A. hyrcanus* var. *sinensis*. Lettering same as fig. 1.
- Fig. 4. Pecten of the 4th stage larva of *A. hyrcanus* var. *sinensis*.
- Fig. 5. Same of the 4th stage larva of *A. myzomyia pattoni*.
- Fig. 6. Same of *A. lindesaii* var. *japonicus*.
- Fig. 7. Trumpet of the pupa of *A. hyrcanus* var. *sinensis*.
- Fig. 8. Same of *A. myzomyia pattoni*.
- Fig. 9. Same of *A. lindesaii* var. *sinensis*.

Fig. 10. The anterior part of the head of the 4th stage larva of *A. myzomyia pattoni* showing the structure of the clypeal bristles and the anterior frontal bristles.

Fig. 11. The last part of the abdomen of the pupa of *A. lindesaii* var. *japonicus* showing the various structures. A.B.C., the setæ. T., the terminal paddle hair.

Fig. 12. Same of the pupa of *A. myzomyia pattoni*.

Fig. 13. Same of the pupa of *A. hyrcanus* var. *sinensis*.

SCALE: Figs. 11, 12 and 13 are in the same scale. The remaining figures are in the same scale as fig. 1.

### Plate III.

Fig. 1. Typical breeding place of *A. myzomyia pattoni*. River bed at the foot of the Western Hills, Peiping. In the pools (1, 2 and 3) many larvæ have been found from August to November 1929.

Fig. 2. A frozen pool showing hibernation of the larvæ of *A. myzomyia pattoni*. The thickness of the ice was 18 inches. Through the hole made in the ice several hundreds of *A. pattoni* larvæ were obtained from the water underneath. Photograph taken on January 10, 1929.

### Plate IV.

Fig. 1. Typical breeding place of *A. hyrcanus* var. *sinensis*. A pond in Haitien, west of Peiping. On the edge there is much vegetation (1, 2 and 3) among which many larvæ of this species, *Culex tritaeniorhynchus* and *C. pipiens* have been found.

Fig. 2. The last larval skin of *A. pattoni* showing well developed palmate hairs on abdominal segments II to VII.

