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Lieut.-Col. I.M.S. (Retd.)

[Reprinted from the "Journal of Tropical Medicine," June 15, 1903]

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ON PRE-PUPAL CHANGES IN THE LARVÆ OF THE CULICIDÆ.

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Perhaps no other of the curiosities of development are so striking, alike to the popular and scientific imagination, as the changes that take place during the pupal stage of insect life, whereby the worm-like larva is transformed into the complete insect; and this is especially the case where the change, as in the case of the *Culicidæ*, is accomplished to all appearance in what appears a most inadequate allowance of time.

We have always been accustomed to regard the *Culicidæ* as insects undergoing a "complete metamorphosis," that is to say, that the changes which transform the larva into the adult are not spread gradually over the period of growth, with its various changes of skin, but are all effected during one and the last ecdysis, viz., that of pupal life; during which insects cease to eat, and are often reduced to a more or less motionless bundle, which no longer grows, but rearranges the nutritive materials which it has collected as a larva into the shape of the widely different anatomy of the adult. In the *Culicidæ*, however, the pupa, though incapable of feeding, is never quite motionless and helpless; and so far from the sum total of the changes that transform the larva into the imago being compressed into the three or four days of pupal existence, most of the adult appendages are, as we shall see, well advanced in development within, at any rate, the last larval skin. It is never practically possible to be sure of the age of a larva with any exactitude, as to its stage of ecdysis, as, like the adults, they vary much in size;

certain full-grown larvæ just ready to enter upon their last, or pupal, change of skin being quite frequently less in actual dimensions than others that may be junior to them by one or two larval ecdyses; and on this account, although many larvæ be examined, it is quite a matter of chance that one obtains for examination a specimen which has actually fully completed its stage of larval life.

In the accompanying plate I have placed, for comparison, in the middle of the page a drawing of the transverse section of the pupa of *Anopheles Rossii* through the mesothorax at the level of the roots of the wings, and have grouped round it four drawings of transverse sections of a full-grown larva at various levels.

Taking first the key section of the pupa (fig. 1), we find that, like that of the adult, at the same level, the body consists essentially of a solid mass of the muscles which for the most part actuate the somewhat complex movement of the wings above and the legs below. Almost in the middle of the section is the œsophagus with, immediately below it, the rudiment of the pneumatic vesicles. Grouped round these are four glandular cords, the shrinking remains of the hepatic crypts of the larva; and, immediately above the upper pair of these are cut across the two great main longitudinal air-vessels. Further below, on the middle line, imbedded between the two sets of muscles that are to actuate the coxæ of the middle pair of legs, is seen the section of the thoracic mass of ganglia.

So far, save in the incomplete development of the pneumatic vesicles and in the presence of the still recognisable remnants of the hepatic crypts, there is really very little to distinguish the section from one cut across an adult; but it will be observed that this forms only the middle portion of the section, and, except in its dorsal aspect, has no share in forming its outer boundaries; their ventral aspect and sides being enveloped in a thick sac, separated from the body by

a large air space, which, as will be seen, imparts to the pupa the necessary buoyancy to keep it afloat.

The walls of this sac are double, and completely separated from the true body of the pupa, except at the points where the budding extremities take their origin; and between its walls lie the developing appendages of the adult, which are sometimes cut across more than once, on account of their being folded on themselves.

In the middle line below are seen the upper and lower lips, with the hypopharynx between them, and just outside these the mandibular and maxillary styles.

Immediately outside these are seen sections of the palpi, followed by six sections of the three folded pairs of legs; and still further out a couple of sections of the also folded antennæ. Uppermost and outermost of all are seen sections of the limp, crumpled wings.

If we now compare with this fig. 2, a section of a full-grown larva at the same level, we find that the essential difference lies in the fact that the great air space is entirely wanting, and that the larva is flattened from dorsum to venter, instead of being, like the pupa, compressed from side to side. The great masses of muscles are as yet wanting, and represented only by soft nuclear tissue. But apart from this, the two sections are completely comparable, the appendages, as well as the viscera, being already more or less completely represented. Taken as it is, at the level of the origin of the wings, the section divides the intestinal canal exactly at the point of entry into it of the four pairs of hepatic crypts, which are thus here represented by four semilunes.

The wings themselves, already far developed, are on account of their less horny consistency distinctly thicker, if less in area than in the adult. Following the periphery of the section, we find on either side of its ventral aspect a compartment containing sections of the rudiments of the three legs, and in the middle line a small mass of tissue, as yet not distinctly differen-

tiated, but which obviously represents the commencement of the unpaired structures of the mouth to be found in the corresponding position in the pupa.

If we now pass to the examination of a section (fig. 3) carried across this mature larva at the anterior part of the mesonotum, we find that between the sections of the rudimentary legs and the now separate median structure lie a pair of developing masses, which probably represent the commencement of the paired mouth organs.

The intestinal canal is lined with a plain endothelium of quadrangular cells, and on either side lie the salivary glands.

Coming still further forward to the examination of fig. 4, a section taken at the level of the pronotum, we find, springing from the dorsal aspect of the section, the already far-developed respiratory horns of the pupa, and outside these the anterior parts of the wings; while the ventral part of the periphery of the section is occupied by sections of the rudiments of the three legs.

The median mass has disappeared, and it is evident from this circumstance that the area of tissue so placed really corresponds, not to the thorax, but to the parts of the head of the adult insect, placed though it be, to all superficial appearance, under the very middle of the thorax. It is further worthy of notice that the lining of the intestinal canal is no longer glandular but chitinous; in other words, that the section is in advance of the midgut.

The other structures cut across are the salivary ducts and two large longitudinal air-vessels.

It remains only to examine a section carried across the metanotum, as in fig. 5. In this we find, surrounding the intestinal canal, the four great hepatic crypts of the larva. Springing from the side of the dorsum is the rudiment of the ballancer, which already contains an obvious ganglionic mass, which is to be afterwards developed into what we believe to be an organ of hearing. Next to this we find, cut across, the hinder ends

of the wing; and quite ventrally, a mass representing the hindmost pair of legs.

I have sectionised a considerable number of larvæ, but this is the only instance in which the specimen selected has chanced to represent the larva in its last and most advanced ecdysis; and it is evident that the change from larva to imago is by no means as abrupt as we have been accustomed to think, but is spread not merely over one, but at least two changes of skin.

The position of the masses representing the mouth-parts is at first rather difficult to explain, but is sufficiently easily understood when similar sections of larva and pupa are compared, though it opens up a distinct doubt as to whether the structures of the proboscis are really entirely referable to the head, as it seems perhaps possible that, though attached to and in front of the head in the imago, they may really partly appertain to the ventral aspect of the thoracic segments; though, of course, the fact of their appearing in the same transverse section by no means necessarily implies this, as it is quite possible that the germinal masses representing these median prolongations of the adult head may be bent round so as to lie between but on the same level as truly thoracic structures; and it is needless to remark that this explanation is the easier to believe, even though it be the less easy to understand, when one is confronted with actual sections.

EXPLANATION OF ILLUSTRATION.

FIG. 1.—Transverse section of thorax of pupa, at the level of the origin of the wing (for comparison with the other sections).

FIG. 2.—Transverse section of a mature larva at the same level.

FIG. 3.—Transverse section of thorax of mature larva somewhat in front of preceding, showing the body of the salivary gland and rudiments of proboscis and limbs.

FIG. 4.—Transverse section of thorax of mature larva at the level of the origin of the respiratory syphons, in front of body of salivary gland, the duct of which now appears.

FIG. 5.—Transverse section of thorax of mature larva at the level of the origin of the ballancers.

In the above figures—*a*, thoracic muscles; *at*, respiratory horn of future pupa; *b*, ballancer; *d*, dorsal vessel; *e*, œsophagus; *f*, air cavity or float between body and appendages of pupa; *h*, hepatic tubules; *k*, hypopharynx; *l*, legs; *lbr*, labrum; *lm*, labium; *mb*, mandible; *mx*, maxilla; *n*, ventral nerve cord; *p*, rudiment of pneumatic vesicle; *pr*, proboscis; *s*, salivary gland or duct; *t*, main trachea; *w*, wings.

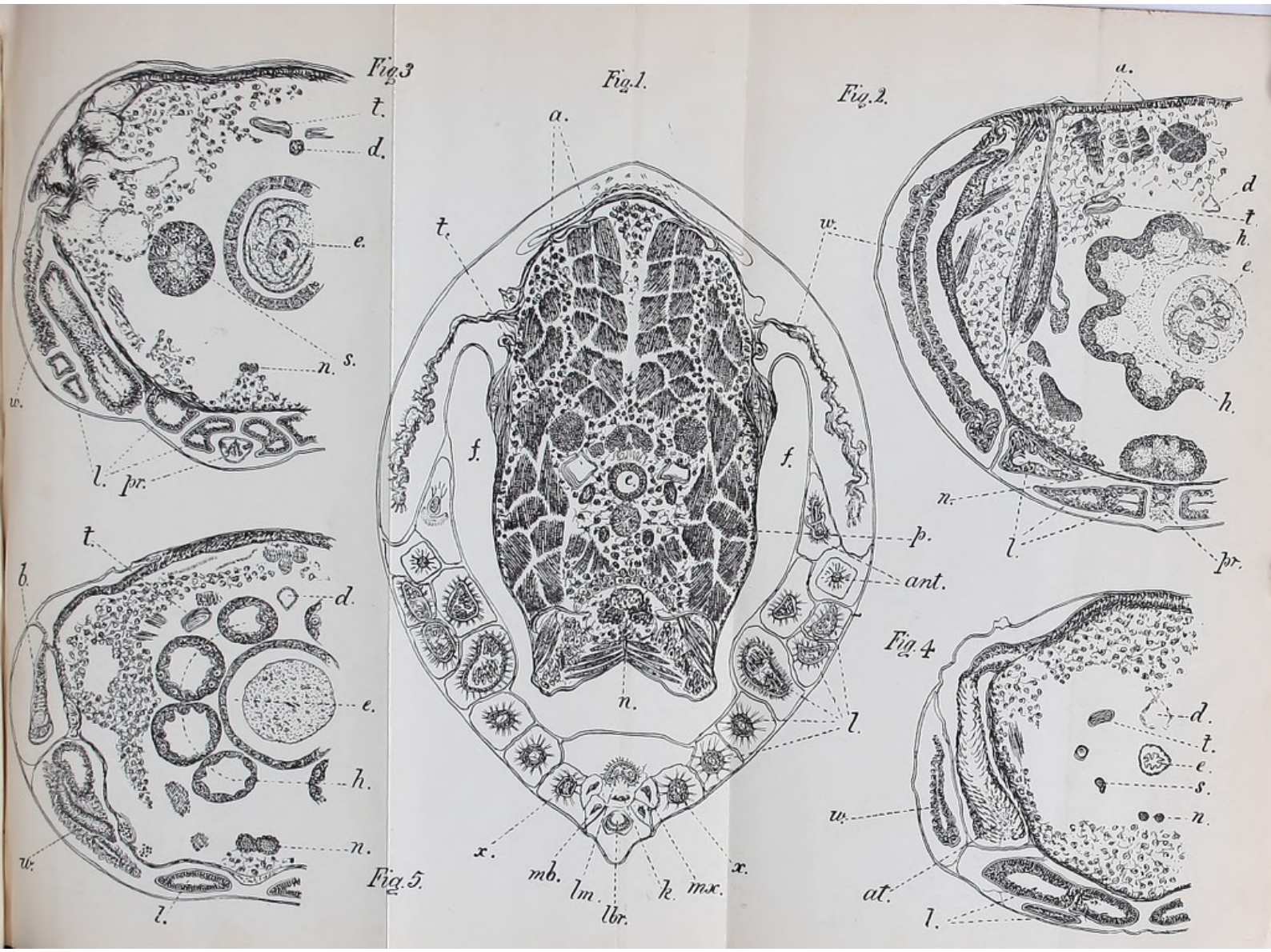
Fig. 3
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Fig. 4
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Fig. 5.
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