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By Millett T. Thompson.

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No. 6.—ALIMENTARY CANAL OF THE MOSQUITO.[1]

BY MILLETT T. THOMPSON.

Introduction.

Literature on the mosquitoes is rather extensive, especially that which deals with the genus Anopheles. Comparatively few articles, however, discuss the internal anatomy of these flies and in many of those papers where details of internal structure are given, these are not cited from morphological motive. The structure of the salivary glands or the alimentary canal may be described, but it is to make clear the life history of the malarial Plasmodium or as a guide in dissecting when studying these parasites, and not from interest in the anatomy itself. In view of the secondary purpose of such descriptions it has not seemed best in this paper to make a complete survey of articles of this class or to comment at length on the interpretations of structure that are presented. Criticism and discussion will be limited to the few researches which deal extensively with the internal anatomy or which discuss this from a morphological view-point.

Of the studies that fall into this last group, several are found which give accounts of Anopheles. Nuttall and Shipley's, "The structure and biology of Anopheles" and Christophers' "The anatomy and histology of the adult female mosquito" are comprehensive and very valuable. Annett and Dutton's "Report" is excellent but more limited in scope. As far as anatomical details are concerned at least, Giles' "Handbook of the gnats or mosquitoes" is unreliable. I have been unable to obtain Grandpré and Charmoy's "Les moustiques." With respect to Culex on the other hand, I know of no single comprehensive work, but scattered descriptions of the various internal organs exist. The external form of the larvae and pupae of mosquitoes has been studied considerably, but the internal anatomy of these stages has been neglected. Raschke gives the best account for the larva in "Die larve von *Culex nemorosus*." Our knowledge of the metamorphosis of the internal organs

[1] From the Biological laboratory, Clark university, and the Laboratory of the U. S. bureau of fisheries, Woods Hole, Mass.

is summed up in two excellent papers by Hurst, "The pupal stage of Culex" and "The post-embryonic development of a gnat," and in details given by Miall and Hammond ('92) from Hurst's unpublished notes.

Three species of Culex as they occurred at different seasons furnished the material on which this paper is based. *C. stimulans* and *C. pipiens* were used for the study of the perfect insect, and a small midsummer form that was not identified gave me larvae and pupae. Comparative notes were made at all stages, but failed to bring out appreciable differences between the three forms at any time. The genus Culex was used instead of the more important Anopheles, because early in the study it became impossible to obtain a sufficient number of specimens of the latter, either larvae or adults. However, enough material was available to enable me to compare the two genera with respect to many structures and to check the descriptions given in the literature dealing exclusively with Anopheles. The specimens of Anopheles at my disposal were representatives of the commonest New England species, *A. punctipennis*.

Technique.

The chitin of the imago of the mosquito is not heavy enough to offer especial obstacles to research, except as it interferes with the penetration of the killing fluids. This was overcome without injury to important structures by cutting off the dorsum of the thorax while the insect was immersed in the reagent. Of all killing fluids that were tried, Gilson's mercuric nitrate proved most valuable, and in the end was exclusively used. In order to remove air from the scales, the mosquito was dipped for a moment in alcohol before it was plunged into the warm fluid. I made Gilson's fluid according to the following formula: —

70 % alcohol	10	parts.
Distilled water	86	"
Corrosive sublimate (crystals)	2	"
Glacial acetic acid	½	"
Nitric acid (80 %)	1½	"

Dissection is of primary importance in a study of the thoracic and abdominal portions of the alimentary canal of the mosquito. But it must be constantly controlled and supplemented by sections. Knowledge of the structures within the head of the insect on the other hand, has to be derived almost wholly from sections. Reconstruction proved of slight value. I used serial sections cut in the three planes usually employed and depended on careful study of these, adding to and controlling the interpretations by study of dissections and of material cleared with caustic. Excellent thick sections — 30 μ or over — for control and demonstration were prepared by killing in Flemming's fluid and allowing the specimens to blacken somewhat. Material treated thus may be imbedded in paraffin, sectioned, and the sections mounted without staining. The discoloration produced by the killing fluid gives sufficient character to the structures.

With the larva of the mosquito, study of the living animal or of fresh dissections is of paramount importance. Sections of the head especially are not readily interpretable taken alone. Fortunately for research, the wriggler of Culex has a large, transparent head, so that the contained structures can easily be made out in the living animal or in whole mounts of the head. In the light of knowledge obtained in this way, sections become interpretable and through these in turn we are enabled to understand sections of the Anopheles wriggler, where the head is small and opaque. An excellent method for mounting the whole head is to stain with picro-carmine and then clear through Weigert's fluid. Fine preparations may also be obtained by staining with haematoxylin, but this method is slower and less uniformly successful than the picro-carmine stain.

The pupa stage can only be studied from serial sections and to work to best advantage a series of specimens the ages of which are approximately known, is needed. Such a series was obtained for Culex by segregating mature larvae in a dish and each hour removing all pupae to separate containers, in which they could be reared for any desired number of hours. A very complete series ought to be obtained. In the summer our species of Culex spend from 48 to 70 hours as pupae, and I did not find that a set of specimens representing in ages nearly every hour up to the thirtieth of pupal life and then more distant intervals, was too extensive.

Imago.

Head and mouthparts. — An extended description of the external anatomy of the mosquito does not come within the scope of this paper. A few points with respect to the head, however, must be noted. The part of the head that lies in front of the large compound eyes is inflated above to form a rectangular box, which is called the clypeus. This seems to correspond to the "face" of other flies. A vertical furrow is impressed into the anterior face of this box. At the foot of the furrow a boss of chitin for muscle insertion projects into the cavity of the clypeus, while near the roof of the box on either side a short chitinous ala also enters the cavity. Ventrally and at the sides, the pre-ocular region of the head is rounded and forms as it were an imperfect cylinder, at the summit of which the mouthparts arise, nearly at one level. The anterior wall of the clypeus lies forward of this point by one half of the length of the box in the female insect and nearly two thirds of the length in the male. The postocular or epicranial region of the head is extensive in the female but truncate in the male mosquito.

Within, the head is strengthened by a mesial crest which continues from the level of the antennae along the roof of the head to the border of the occipital foramen. It is also braced by two hollow cylindrical struts which pass from the ventral border of the occipital foramen to the cheeks. I shall refer to these struts as tentoria, without intending to imply any necessary morphological connection between them and the analogous internal head braces of other insects. Among the flies, hollow tentoria similar to those of the mosquito are found in Chironomus, Anopheles, and Simulium. They appear to be wanting in many families, as, for example, the Tipulidae, Asilidae, Dolichopodidae, and the Muscidea. The Tabanid flies have solid tentoria with somewhat the same relations as the hollow struts of the mosquito. In the female of Culex the tentoria arise in front of the border of the occipital foramen and ascend at an angle of twenty-five degrees with the floor of the head. Each strut has a short spur near the lower end, to which no obvious function can be assigned, and above as the cheeks are approached, flares out into an irregular funnel-shaped "head." In the male mosquito the struts arise from the border of the occipital foramen, and the differently shaped head makes the angle with the floor measure nearly thirty-five degrees. The struts are provided with the seemingly useless spur near the foot, but above expand suddenly to form the "head" and then the tube narrows again as it meets the cheeks.

The mouthparts (pl. 16, fig. 46–47) of the mosquito need no elaborate description here. The usually accepted nomenclature will be employed for the various stylets. The labrum is horseshoe-shaped in section and forms the whole or the major part of the tube (*pc*) through which the insect sucks blood or other liquid. There is no good reason to retain the name labrum-epipharynx for this dorsal stylet, with the consequent implication that the organ is compound. Becher long ago ('82) pointed out that the separation into two parts under manipulation was an artifact. Morphologically for the imago of Culex (pl. 16, fig. 46–47) and for the imagoes of other flies (Kräpelin, '82, '83) the labrum is a unitary structure. During the metamorphosis of Culex also, the labrum is formed as a simple tube. The canal (*pc*) on its ventral face is moulded by the infolding of the ventral wall. The labrum receives a single muscle which probably serves for a retractor and depressor. This muscle is inserted on the boss of chitin at the base of the labrum and its fibers arise from the dorsal and posterior walls of the clypeus. It may be called the labral muscle (pl. 12, fig. 2). This muscle has been described as "labral muscle" (Annett and Dutton, :01), "elevator of labrum-epipharynx" (Nuttall and Shipley, :01–:03), "retractor of labrum" (Giles, :02), and "retractor partes productae" (Meinert, '81). It corresponds in part to the "pharyngeal muscle" of Dimmock ('81).

The mandibles are wanting in the male mosquito and are slender, delicate lancets in the female. Dimmock ('81) has figured these organs in the cross section of the mouthparts as lying beneath the hypopharynx. Giles (:02) gives a similar arrangement in one figure while in another he shows the mandibles above the hypopharynx at the sides of the labrum. This last is the proper position for the stylets when at rest. The mandibles are morphologically dorsal to the hypopharynx. The other position is due to misplacement during the processes of sectioning. Each mandible is retracted by a mandibular muscle (*mnd m*) which arises on the "head" of the tentorium and is inserted on the base of the stylet. As these muscles approach their insertions short fibers connect them with the