mdcv, middle discocellular vein (in this case, and usually, a portion of media-one).

ldcv, lower discocellular vein (the portion so marked is a portion of the stem of media one-plus-two, but as ordinarily defined the short cross-vein m. would also be considered part of it).

1st A is a concave vein, and when it becomes rudimentary is known as the submedian fold.

The veins, hum., Sc^1, sc-r, r, cu-1st a, 1st-2d a, and 4th a, are lost in almost all higher forms.

i, Intercalated cell (reckoned as part of the discal cell).

acc. c, Accessory cell (reckoned as part of the discal cell in micros- and butterflies, where it is more or less completely fused with it, but not in most moths, where it is perfectly separated, when present).

Fig. 2. Portion of bleached wing-membrane, showing points of attachment of scales and aculeæ.

THE ALIMENTARY CANAL OF A CERCOPID.

By J. C. Kershaw.

The following brief notes refer to *Tomaspis saccharina* Dist., a pest of sugar cane in Trinidad, West Indies, where the nymphs feed on cane roots and the adults on the leaves. In the nymph of this Cercopid the air, which all sucking insects doubtless imbibe in quantity along with the liquid food, appears to pass through the alimentary canal and be utilized in forming the air-bubbles coated with mucinoid which are emitted from the anus and form the froth in which the nymph lives. After examining this Cercopid I am the more inclined to believe that (as stated in a previous paper on Flata in Psyche) the "food-reservoir" in the head of Flata functions in part as an air-separator to rid the liquid food of superabundant air before it passes through the alimentary canal. In the Cercopid nymph, however, the air is directly utilized, as mentioned above. In this Cercopid and in Cicada the diverticulum or pouch of the midgut (forming the "food-reservoir" of the head in Flata and the filter-chamber of the thorax in Cercopid and Cicada) is almost filled up by the zigzag course through it of the posterior part of the midgut and the anterior part of the malpighian tubes. This diverticulum, pouch or filter-chamber is entirely situated in the thorax, as are also the diverticula of Perkinsiella and other Homoptera mentioned in the paper referred to above; only entering the head in Flata, Pyrops and Dictyophoro-

delphax, so far as I have had the opportunity to ascertain, and in these genera the diverticulum does not enclose other portions of the alimentary canal. But although the alimentary canals of these Homoptera are all on the same plan, yet the simple arrangement of Aleyrodes and Psyllid seems to lead up to and culminate in the very complex system of Cercopid and Cicada. On considering the diverticula and zigzags of these two latter one must, I think, conclude that Berlese's theory (of filtration or osmosis in order to get rid more quickly of innutritious liquid) is correct. Dr. Licent's opinion that the anterior portion of the malpighian tubes is producing the froth or spume of the nymph is, in my opinion, certainly correct.

The alimentary canal of the nymph of Tomaspis, when just hatched, is practically like that of the adult, so that the enwrapping of other parts of the midgut by the diverticulum takes place in the embryo. There is a well-marked œsophageal valve, and behind and laterally to this the midgut forms a recurved diverticulum or pouch somewhat U-shaped in transverse section, the external cavity of the pouch enclosing the zigzag ascending anterior portion of the midgut and descending straight portion; also the straight ascending and zigzag descending portions of the malpighian tubes. But the whole pouch and all parts of the alimentary canal are covered by the peritoneal membrane, muscular and connective tissues. Thus the zigzags of the various parts of the gut do not pierce the walls of the pouch in order to enter or leave it, but are merely enclosed between its exterior walls (fig. 1, d′, ex), the peritoneal membrane, muscular and connective tissues sealing up their entrances and exits and the narrow gap or slit-like opening (fig. 1, d′, so) between the exterior walls of the pouch. I thus differ from Dr. Licent in believing that the basement-membrane of the epithelium of the pouch does not separate or split off therefrom and enclose the other portions of the midgut, but that it is the peritoneal membrane which encloses the whole hermetically. The pouch is a diverticulum of the midgut, and the lips of its long, narrow internal aperture leading from the pouch to the sac are bounded by a broad and thick band of fat-cells (fig. 3, f) on each side, which may probably act as a valve to regulate the flow of food from the pouch to the sac; and as the latter is somewhat askew to the large and more or less conical sac of the midgut, the

muscle connecting the œsophagus and top of the sac may—by pulling the pouch and sac still more askew—contract the opening further, or by relaxing open it wider. The pouch lies ventrally and medianly within the mesothorax. The sac lies more dorsally and chiefly within the meta-thorax, but projects at times into the abdomen. The œsophagus runs through the pro-thorax. In figures 2 and 3 the anterior end of the pouch is not quite in a natural position, since it is usually more pulled over and downwards to the top of the sac by the large muscle attached to the latter and to the œsophagus. Figures 2 and 3 are slightly diagrammatic to avoid confusion of parts. The lines of the organs in the transverse section if projected to the longitudinal view (fig. 3) would not all agree as they strictly should; for instance the ascending midgut, to agree with the transverse section strictly, should have been dotted in right behind the malpighian tubes, instead of being shown just clearing them, but this would altogether have confused the sketch. The epithelium of the pouch not only tucks in longitudinally between the malpighian tubes, midgut, etc. (fig. 3, trans. sec.), but also—in a plane at right angles to the longitudinal tucks —between the several zigzags of the various tubes (fig. 3, i, k). This is only just indicated for the longitudinal tucks in the transverse section; in reality the epithelium follows all the interspaces of the organs very closely indeed, and more or less adheres to, but does not fuse with, the latter. Thus it presents a very large area for filtration or osmotic action.

The total length of the alimentary canal is about fifty mm., made up as follows:—the œsophagus is about 1 mm.; the pouch and sac together 3 mm.; the tubular part of the midgut from the sac to the constriction or midgut sphincter [1] 10 mm.; from thence to its entrance into the pouch 15 mm.; the zigzag portion within the pouch 11 mm.; from the anterior end of the zigzag to the origin of the malpighian tubes (rectal valve) 1 mm.; thence to the anus 9 mm. The length of the lobulate portion of the malpighian tubes is about 7 mm.; the smooth portion to their entrance into the pouch 3 mm.; the zigzag portion within the pouch 7 mm.; the straight portion to the origin of the tubes 1 mm.; total length about 18 mm. All measurements were taken with the organs straightened out but not unduly stretched.

[1] This constriction is provided with annular muscles.

The appearance and contents of the posterior part of the alimentary canal of the nymph—from the mid-gut sphincter to a little within the pouch—differ from that of the adult in being of an opaque white (due to the contents) and swollen with a great quantity of semi-translucent, colorless or whitish granules varying from one to fifteen microns in diameter, the majority being about five; the contents of two nymphal posterior guts were analyzed at the Trinidad Government Analyst's Laboratory and the granules were found to be amorphous insoluble calcium phosphate and to constitute about 80 per cent. of the contents of the gut; the remaining contents consisted of organic matter (which would be chiefly old, detached cell fragments from the epithelium of the gut) and sodium chloride and potassium phosphate. A quantity of the roots of the grass on which the nymphs chiefly feed was also analyzed by the Government Laboratory; they contained small quantities of calcium salts and phosphates, but there was no evidence of the presence of insoluble forms of calcium phosphate. The Cercopid, very shortly after moulting to adult, voids a quantity of a white substance like plaster-of-paris, which dries on the leaf or other object and takes its impress, afterwards drying and becoming hard and brittle. This is often left under the old froth and moulted skin, as the adult usually remains in the spittle until its integument becomes hard and fully colored. This white substance is chiefly calcium phosphate, and gives canary-yellow crystals when heated with a solution of ammonium molybdate in nitric acid. Thus it seems that the greater part of this phosphate is retained in the posterior part of the gut of the nymph and only evacuated after the final moult. Each insect voids about two milligrams of this substance.[1]

The epithelial cells of the posterior portion of the gut are usually loaded with dark granules (food in process of absorption); those of the anterior part—before the sphincter—are fairly clear and the gut is semi-translucent pale yellowish-brown, as it is throughout in the adult as a rule: rarely an adult also has the posterior portion of the gut white as in the nymph, due to its contents being of the same nature.

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[1]9.4 milligrams of this excrement was dried at 100° C. when its weight was 6 mg., and was analyzed by Mr. Shrewsbury of the Trinidad Government Laboratory. "Percentage composition of excrement: organic matter, 20.0; water, 36.0; ash calcium potassium phosphate with minute trace of iron, 44.0. The organic matter was largely ammonium urate. The microscopic appearance of the globular particles of which this excrement was composed was exactly similar to that of urinary calculi."

The froth or spittle of the nymph appears to be a mucin or mucinoid, since it reacts to the usual tests for mucin; it granulates with sub-acetate of lead and stains deeply with methylene blue in glycerine and alcohol; the material taken from the malpighian tubes before it is poured into the gut also gives the xanthoproteic reaction. This mucinous substance is produced by the anterior or smooth portion of the malpighian tubes, which in the nymph is of larger diameter than the lobed part through being swollen with the secretion, whilst in the adult the reverse is usually the case. The nuclei of the smooth part of the tube take Delafields haematoxylin heavily; those of the lobed part mostly stain but faintly. If the smooth part of a nymphal tube is placed in alcohol, the contained mucinoid shrinks and coagulates and can be dissected out as a very pale yellowish, stringy substance. If this coagulated material is then placed in water, it quickly swells and becomes viscid, pale bluish-translucent and just like the untreated material fresh from the tubes. The alcohol and water treatment several times in succession leaves the material practically unaltered after again placing it in water. The secreted froth is a very stubborn material, though it consists merely of air-bubbles coated with an exceedingly thin film of the mucinoid; in this, however, are numbers of crystals; those of calcium oxalate are numerous; uric acid, leucine pellets and urates are also present; also sodium and potassium chlorides. In fact every substance excreted from the anus of the nymph is found in the froth, but it is the mucinoid substance which accounts for the froth retaining its form more or less for three or four days after the nymph has abandoned it. Fragments of shed epithelium from the gut occur in the excrement of both nymph and adult.

I could find but few crystals in the lobed portion of the malpighian tubes; those of uric acid are large and there are numerous urate granules. But some of the œnocytes contain uric acid and calcium oxalate crystals and urates. These cells are exceedingly large, situated in a cluster on either side of the abdomen, and their outer membrane granulated with a claret-red color. They are, as usual, connected intimately to the tracheæ near the spiracles and also to the fat-body, which also contains urates, etc., in some of the cells.

The blood of the nymph differs conspicuously from that of the adult; in the former it is nearly colorless, in the latter of a bright and clear oil-yellow.

The salivary glands are highly developed and differ somewhat in the nymph and adult. The great length of coiled, chitinous duct situated entirely within the upper part of the head acts, I believe, as a salivary-reservoir. At its distal end is a small and irregularly shaped flattened gland, also within the head. Eleven of the tubular glands reach, when straightened out, beyond the end of the abdomen, and, therefore, are somewhat serpentine within the body, or their ends are recurved and lie at the posterior end of the abdomen amongst the fat-body and other organs. The twelfth tube is shorter and thicker and lies partly within the head,being apparently entangled and drawn in by the coil of salivary-reservoir and muscles of the head. The anterior lobes of the glands lie within the pro- and meso-thorax. The secretion of the glands seems to be neutral or very faintly alkaline.

In the nymph of the Cercopid there is a curious arrangement of the spiracles, primarily, no doubt, for the purpose of preventing them from becoming choked with the glutinous froth or spume in which the nymph lives. The tergal plates and pleura of the abdomen are greatly produced and bent around the underside of the abdomen till the opposing ends touch one another. Thus is formed—for the whole length of the abdomen—on the underside of the nymph a large air-chamber or reservoir. The spiracles open into the upper part of this chamber, so that although the whole chamber and spiracles are, of course, integumentary and external, nothing can be seen of them by viewing the nymph on the exterior, unless the ends of the plates closing the chamber are turned up. Apparently the whole sternal surface of the abdomen has been invaginated and has thus drawn inwards the pleural region with the spiracles, and pulled around the ends of the tergal plates, as shown in the diagrammatic sketch. In the adult the tergal and sternal plates with the pleura have returned to a normal position, and consequently there is no air-reservoir. The nymph appears to hermetically seal itself with the froth, but the amount of air contained in the chamber is sufficient to last for a considerable time. I think, however, that from time to time the nymph breaks through the covering of froth—generally with one of the fore legs —and thus admits a fresh supply of air, afterwards resealing the rent with fresh mucinoid. At each moult, also, the nymph usually

but not invariably leaves its old froth and covers itself with fresh spittle on a new rootlet.

The total length of an adult *Tomaspis saccharina* is 7—8 mm., or a full quarter-of-an-inch, from the head to the tips of the tegmina.

In Cicada (a moderate-sized species common in Trinidad was examined) instead of the rectum descending from the posterior end of the diverticulum, it descends from the anterior. The malpighian tubes, also, descend from the anterior part of the diverticulum to the rectal valve without any return portion within the pouch, as there is in Cercopid; so that on the whole, perhaps, the alimentary system of Cercopid is slightly more complicated than that of Cicada. The malpighian tubes of Cicada fork very near their point of origin, as shown in fig. 5.

In the Psyllid (*Freysuila dugesii* Aleman, also common in Trinidad on the so-called Cedar) the arrangement of the alimentary canal is as simple as in Aleyrodes, but there are four malpighian tubes; these originate from the rectum at a great distance apart from one another.[1] The two middle tubes were much shorter than the end ones in the specimens dissected.

I send these notes to PSYCHE chiefly because the figures form a continuation of a former paper therein on the alimentary canal of various Homoptera, and owing to pressure of economic work on this Cercopid in Trinidad I shall probably be unable to add much to them. Unfortunately I have neither a copy of Licent's paper nor of my own previous paper in PSYCHE, in which, however, Dr. Licent's paper is referred to. In conclusion it must be added that I am greatly indebted to Prof. P. Carmody, Director of Agriculture, Trinidad, who very kindly had the foregoing analyses made in the Government Laboratory, and, moreover, gave valuable suggestions and assistance in the chemistry of this Cercopid. I have also to thank Mr. H. S. Shrewsbury, who made the analyses.

EXPLANATION OF FIGURES.

1.

a, diagrammatic longitudinal section of diverticulum or pouch.

b, diagrammatic transverse section of diverticulum or pouch.

c, external diagrammatic lateral view.

d, diagrammatic transverse section of pouch, much simplified.

2.

d, exterior view of alimentary canal of adult *Tomaspis*.

e, exterior view looking on anterior end.

[1] "Text-book of Entomology," Packard, 1903, p. 320.

f, exterior view of midgut at sphincter; and cells of epithelium. More enlarged. Dark portion posterior, light portion anterior gut.

g, part of malpighian tube of nymph, junction of smooth and lobed parts.

h, the same, more enlarged.

3.

Longitudinal section through pouch and part of œsophagus and sac. Only two malpighian tubes shown fully. Transverse section through pouch; both sections are slightly diagrammatic.

i, ventral view of part of zigzag of midgut.

k, lateral view of part of a malpighian tube.

4.

To left, adult salivary glands; to right, nymphal glands.

5.

Alimentary canal of Cicada.

6.

Alimentary canal of Psyllid.

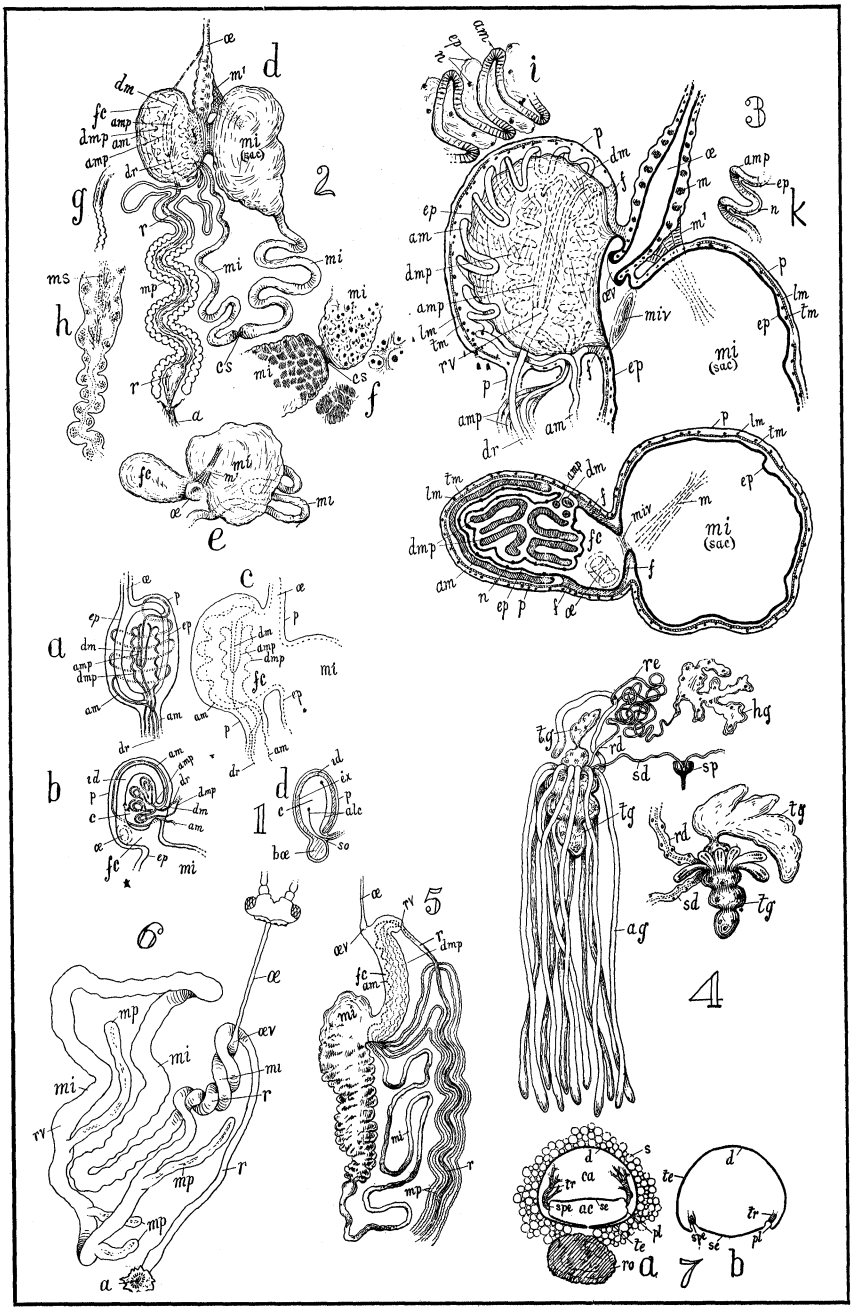
7.

a, diagrammatic transverse section of nymph of Cercopid feeding on rootlet.

b, diagrammatic transverse section of adult abdomen.

LETTERING OF FIGURES.

a = anus.
ac = air-chamber.
ag = abdominal salivary gland.
alc = parts of midgut enclosed in pouch.
am = ascending midgut.
amp = ascending malpighian tube.
boe = base of œsophagus and upper part of sac.
c = exterior cavity of pouch or diverticulum of midgut.
ca = cavity of abdomen.
cs = constriction of midgut sphincter.
d = dorsal part of abdomen.
dm = descending midgut.
dmp = descending malpighian tube.
dr = descending rectum.
ep = epithelium of pouch.
ex = external wall of pouch.
f = fat-cells bounding aperture between pouch and sac.
fc = filter-chamber or diverticulum or pouch.
hg = gland of salivary reservoir in head.
id = interior cavity of pouch.
lm = longitudinal muscles.
m = muscle connecting œsophagus and sac.
mi = midgut.
miv = midgut valve or aperture between pouch and sac.
mp = malpighian tubes.
ms = mucinoid secretion.
n = nucleus.
œ = œsophagus.
œv = œsophageal valve.
p = peritoneal membrane.
pl = pleurum.
r = rectum.
rd = salivary reservoir duct.
re = salivary reservoir.
ro = rootlet of plant.
rv = rectal valve.
s = spume or froth of nymph.
sd = salivary gland duct.
se = sternite.
so = slitlike opening to exterior cavity of pouch.
sp = salivary syringe or pump.
spe = spiracle.
tę = tergite.
tg = thoracic salivary gland.
tm = transverse muscles.
tr = trachea.



Kershaw—Alimentary Canal of a Cercopid