Comparative anotomy of the internal organs of the calyptrate mucoid flies.IV.the malpighian tubulesof adult flies

COMPARATIVE ANATOMY OF THE INTERNAL ORGANS OF THE CALYPTRATE MUSCOID FLIES IV. THE MALPIGHIAN TUBULES OF ADULT FLIES

By

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Introduction

There are some general, but fragmental, researches concerning the morphology of the Malpighian tubules of the calyptrate muscoid flies (Dufour, 1851 ; Lowne, 1893-95 ; Tulloch, 1906 ; Giles, 1906 ; Hewitt, 1907, 1914 ; Eastham, 1925 ; Graham-Smith, 1934 ; West, 1951). Most of the works that have been done only concern the species which have econnmic or medical importance. Thus the knowlege of the Malpighian tubules of the calyptrate muscoid flies is very scanty.

In the present article a survey is presented of the Malpighian tubules of 82 Japanese species of the calyptrate muscoid flies, studied from the viewpoint of comparative anatomy.

The auther should like to express his sincere thanks to Prof. M. Katō for his cordial guidance and encouragement during the course of this work. The author's cordial thanks are also due to Dr. Y. Umebachi for his kind suggestions upon the pigments of the Malpighian tubules.

Material and Method

The material here examined are all the same as describeid in the third part of this series. The vivisection was done in physiological saline with the aid of a dissecting binocular microscope. Drawings of general anatomy were made free-hand and the resultant figures illustrated in this article are semi-diagramatic. The measurments of the tubules were carried out in saline with a $^1/_{10}$mm micrometer. The specimens used in the present paper, unless otherwise stated, are all male. In this paper the biochemical investigation of the pigments of the Malpighian tubules was not done because of the intention of studying the systematic relations among the different groups of the calyptrate muscoid flies. The description of the organs of each species and the list of the species of the calyptrate muscoid flies dealt with in this paper are omitted here.

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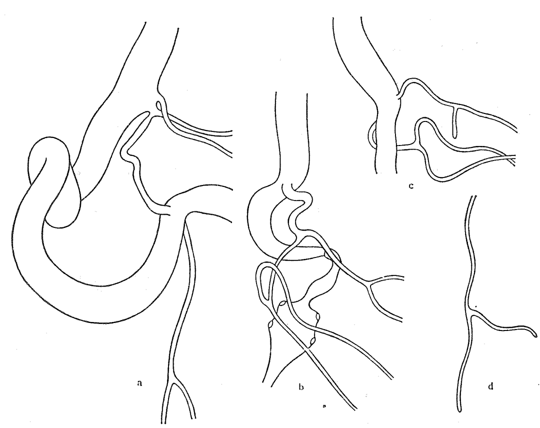
Results and Discussion

A. Arrangement of the Malpighian tubules

The Malpighian tubules are mainly excretory in function and are almost universally present in insects. The number of the Malpighian tubules is subject to great variation in different insects, occuring usually in pairs. Their number reaches upwards of 100 (Imms, 1951). The prevalent number of the organs in question of the Diptera is only 4, but there are exceptions, such as *Culex*, *Aëdes* and *Psychoda* with 5 (Dufour, 1851 ; Graber, 1889 ; Wheeler, 1893 ; Christophers, 1960). According to Wheeler (1893) and others, in the Diptera the primitive number of the tubules is 6, and numbers 4 and 5 are derived from a hexanephric condition by the suppression of the tubules.

The Malpighian tubules of the 82 species that came under the author's observation are all 4 in number. The two Malpighian tubules on each side unite to form a short common duct which opens into the terminal portion of the mid-gut along the right and left mid-lateral line respectively immediately above the anterior end of the hind-gut. Some individual ones, however, which are abnomal in the shape of the Malpighian tubules as illustrated in Text-fig. 1, are observed in this study.

The two tubules or anterior pair arising from one stalk on the right mid-lateral side of the gut run forwards, taking a more or less convoluted course according to the species, parallel to the straight region of the proximal intestine as far as the anterior extremity of the abdomen. The arrangement the tubules take subsequent to this portion varies according to the species as shown in Table 1.



Text-fig. 1. Abnormal forms of the Malpighian tubules.
a, *Calliphora grahami* (♂) ; b–d, *Musca domestica vicina* (♂).

a. Y-shaped

In this type the two tubules run forwards, on each side of the gut, with a simple course, along the straight region of the anterior portion of the abdominal cavity. The four tachinids that came under the author's observation all belong to this type. In the Phasiidae and Dexiidae the anterior tubules are somewhat longer than in this type, and each tubule has a short folded portion apically. This indicates that they are the transitional type to the M-shaped (Figs. 13 14, 15).

Table1. Arrangement of the Malpighian tubules of 82 species of the calyptrate muscoid flies

Species	Arrangement						
	Anterior tubules				Posterior tubules		
	Y–shaped	Inter–Mediate	M–shaped	Fused	Once–looped	Twice–looped	Thrice–looped
Scopeuma stercorarium			+		+	+	
S. mellipes			+			+	
Ophyra leucostoma			+				+
O. chalcogaster			+				+
O. nigra			+				+
Fannia scalaris			+		+		
F. canicularis			+		+		
F. sp.			+		+		
Anthomyia illocata			+			+	
Hydrophoria ruralis			+			+	
Pegomyia virginea			+			+	
Hylemyia antiqua			+			+	
Lispe orientalis			+		+		
Orthellia latipalpis			+			+	
Musca domestica vicina			+		+		
M. sorbens			+		+		
M. hervei			+		+		
M. convexifrons			+		+		
Graphomyia maculata				+			+
Muscina stabulans			+		+	+	
M. angustifrons			+		+	+	
M. pabulorum			+		+		
Dasyphora cyanella			+			+	
Pyrellia cadaverina			+			+	
Morellia hortorum			+		+	+	
Myiospila meditabunda			+		+		
Stomoxys calcitrans			+				+
Lyperosia exigua			+		+		
Strongyloneura prasina			+				+
Stomorhina discolor			+				+
Phormia regina			+				+
Protophormia terrae–novae			+				+
Chrysomya megacephala			+				+
C. pinguis			+				+
Melinda pusilla			+		+		
Calliphora vomitoria			+				+
C. grahami			+				+
Triceratopyga calliphoroides			+				+
Hemipyrellia ligurriens			+		+		
Lucilia illustris			+				+
L. caesar			+				+
L. ampullacea			+				+

Species	Arrangement						
	Anterior tubules				Posterior tubules		
	Y-shaped	Inter-Mediate	M-shaped	Fused	Once-looped	Twice-looped	Thrice-looped
L. porphyrina			+				+
L. papuensis			+				+
L. sericata			+				+
L· cuprina			+				+
Metopia leucocephala			+		+		
Sarcophila cinerea			+				+
Blaesoxipha japonensis			+		+		
B. laticornis			+		+		
Sarcophaga melanura			+				+
S. sp.			+				+
S. ugamskii			+				+
S. caudagalli			+				+
S. erecta			+				+
S. basalis			+				+
S. josephi			+				+
S. kagaensis			+				+
S. jezensis			+				+
S. albiceps			+				+
S. tsushimae			+				+
S. brevicornis			+				+
S. misera			+				+
S. harpax			+				+
S. similis			+				+
S. kawayuensis			+				+
S. crassipalpis			+				+
S. peregrina			+				+
S. septentrionalis			+				+
S. schützei			+				+
S. antilope			+				+
S. kinoshitai			+				+
S. hozawai			+				+
S. hakusana			+				+
S. kobayashii			+				+
S. hokurikuensis			+				+
Ectophasia sinensis		+			+		
Succingulum transvittatum		+				+	
Prosena siberita		+				+	
Servillia jakovlewii	+					+	
Echinomya micado	+					+	
Chrysosoma aurata	+				+	+	
Sturmia sericariae	+				+	+	

b. M-shaped

In this type the two tubules are quite long, turning back from the anterior portion of the abdomen with their ending lyings separately on the rectal pouch. The Scatophagidae, Ansomyiidae, Calliphoridae, Sarcophagidae and most Muscidae belong to this type. In most of the flies here examined the folded portions of the anterior pair bear no peculiar structure. In only *Graphomyia maculata* the folded portions of the anterior pair are distinctly differentiated and bear a peculiar process (Figs. 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12).

c. Looped

In this type the two endings of the anterior pair fuse together, after a long course of winding, to make a loop on the rectal pouch. Only the *Graphomyia maculata* belongs to this type (Fig. 8). A similar loop formation of the Malpighian tubules, as is shown in the *Graphomyia maculata*, occurs in the Drosophilidae (Eastham, 1925 ; Okada, 1935), and also in some others.

The Malpighian tubules in the Diptera pass without any actual atrophy into those of the imagos (Wigglesworth, 1950). The author considers, therefore, that the Y-shaped type of the tubules, in the Tachinidae is the result caused by effects given in the parasitic larval life, and the relationships between the three kinds of the arrangement, including the intermediate type, are diagramatically explained as follows :

Fused ⟵ M-shaped ⟶ (Intermediate type) ⟶ Y-shaped

The arrangement taken by the posterior pair which arises from the ventral side of the gut may be divided into the following three types.

a. One loop

In this type each tubule runs posteriorly, both ending separately at the dorsal surface of the rectal pouch. The genera *Fannia*, *Lispe*, *Musca*, *Myiospila*, *Lyperosia*, *Hemipyrellia*, *Melinda*, *Blaesoxipha*, *Metopia*, and *Ectophasia* belong to this type. Among this type the tubules of the genus *Fannia* and those of the Tachinidae run around the duct of the gonad, while in the others they run straight inside the duct. In some species such as *Muscina*, *Morellia* and *Scopeuma stercorarium*, the tubules take a convoluted course, and they are sometimes folded apically, thus resulting in a transitional type to the twice-looped type (Figs. 1, 3, 7, 9, 11).

This arrangement must surely be regarded as a primitive stage of the differentiation of the posterior tubules.

b. Two loops

In this type the tubules turn forwards from the caudal part, and their free ends lie usually ventrally to the rectal pouch. *Scopeuma mellipes*, *Anthomyia*, *Hydrophoria*, *Pegomyia*, *Hylemia*, *Orthellia*, *Dasyphora*, *Pyrellia*, *Echinomya*, *Servillia*, *Prosena* and *Succingulum* belong to this type (Figs. 4, 5, 6, 14, 15).

c. Three loops

This type is till more advanced than the former, and the tubules bend again dorsally from the ventral portion of the abdominal cavity, extending to the rectal pouch. The genera *Ophyra*, *Graphomyia*, *Stomoxys*, *Calliphora*, *Triceratopyga*, *Lucilia*, *Chrysomya*, *Strongyloneura*, *Stomorhina*, *Sarcophila* and *Sarcophaga* belong to this type (Figs. 2, 8, 10, 12).

The three types of the arrangement of the posterior tubules are also diagramatically considered as follows:

Once-folded ⟶ Twice-folded ⟶ Thrice-folded

B. Colour of the Malpighian tubules

The colours of the Malpighian tubules, in fresh preparations, of the 82 species that came under the author's observation are roughly divided as shown in Table 2.

The common ducts are in every case all white, and show no difference in colour among all the 82 species. The four tubules, when fresh, are yellow in colour, regardless of sex, in most cases, ranging from pale yellow to bright yellow, sometimes with white tips. This yellow series of colour are most frequent, occuring in 81 out of the 82 examined species.

The brown tubules are found only in *Graphomyia maculata*. The anterior tubules of this species are pale brown basally, becoming darker distally, and the upper halves or upper segments are equally fuscous, and the posterior tubules are equally fuscous in colour.

In the three species of the genus *Fannia* the anterior tubules are yellow as in the others, but the posterior pair are white pellucidly.

Graham-Smith (1934), who has studied the morphology of the alimentary canal of the *Calliphora erythrocephala*, finds that in the *Calliphora* a yellow pigment is present in the large cells of the outer basement membrane. The yellow pigments in the Malpighian tubules, which are responsible for the yellow colour of the tubules of insects, are regarded as belonging to two different groups, 3-hydroxy-kynurenine derived from tryptophan, and from riboflavin. Thus the chemical components of the yellow pigments of the Malpighian tubules are different in different insects (Kikkawa, 1955). The Malpighian tubule cells of the *Calliphora* and the common house fly contain a considerable quantity of riboflavin (Kikkawa, 1955). However, the chemical components of the yellow pigments of the tubules of the remaining species of the calyptrate Diptera that came under the present study have not been studied yet. In the *Graphomyia maculata*, the tubules are brown in colour as in the *Tipula* and *Eristalis*, whose tubules are brown in colour and contain ommine (Kikkawa, 1953). This also indicates that *Graphomyia maculata* seems to be a specialized form in the Muscidae.

Table 2. Colour of the Malpighian tubules of 82 species of the calyptrate muscoid flies

Species	Colour				
	Anterior tubules		Posterior tubules		
	Yellow	Fuscous	White	Yellow	Fuscous
Scopeuma stercorarium	+			+	
S. mellipes	+			+	
Ophyra leucostoma	+			+	
O. chalcogaster	+			+	
O. nigra	+			+	
Fannia scalaris	+		+		
F. canicularis	+		+		
F. sp.	+		+		
Anthomyia illocata	+			+	
Hydrophoria ruralis	+			+	
Pegomyia virginea	+			+	
Hylemyia antiqua	+			+	
Lispe orientalis	+			+	
Orthellia latipalpis	+			+	
Musca domestica vicina	+			+	
M. sorbens	+			+	
M. hervei	+			+	
M. convexifrons	+			+	
Graphomyia maculata		+			+
Muscina stabulans	+			+	
M. angustifrons	+			+	
M. pabulorum	+			+	
Dasyphora cyanella	+			+	
Pyrellia cadaverina	+			+	
Morellia hortorum	+			+	
Myiospila meditabunda	+			+	
Stomoxys calcitrans	+			+	
Lyperosia exigua	+			+	
Strongyloneura prasina	+			+	
Stomorhina discolor	+			+	
Phormia regina	+			+	
Protophormia terrae-novae	+			+	
Chrysomya megacephala	+			+	
C. pinguis	+			+	
Melinda pusilla	+			+	
Calliphora vomitoria	+			+	
C. grahami	+			+	
Triceratopyga calliphoroides	+			+	
Hemipyrellia ligurriens	+			+	
Lucilia illustris	+			+	
L. caesar	+			+	
L. ampullacea	+			+	
L. porphyrina	+			+	
L. papuensis	+			+	
L. sericata	+			+	
L. cuprina	+			+	
Metopia leucocephala	+			+	
Sarcophila cinerea	+			+	
Blaesoxipha japonensis	+			+	
B. laticornis	+			+	
Sarcophaga melanura	+			+	
S. sp.	+			+	
S. ugamskii	+			+	
S. caudagalli	+			+	
S. erecta	+			+	
S. basalis	+			+	
S. josephi	+			+	
S. kagaensis	+			+	
S. iezensis	+			+	
S. albiceps	+			+	
S. tsushimae	+			+	
S. brevicornis	+			+	
S. misera	+			+	
S. harpax	+			+	
S. similis	+			+	
S. kawayuensis	+			+	
S. crassipalpis	+			+	
S peregrina	+			+	
S. septentrionalis	+			+	
S. schützei	+			+	
S. antilope	+			+	
S. kinoshitai	+			+	
S. hozawai	+			+	
S. hakusana	+			+	
S. kobayashii	+			+	
S. hokurikuensis	+			+	
Ectophasia sinensis	+			+	
Succingulum transvittatum	+			+	
Prosena siberita	+			+	
Servillia jakovlewii	+			+	
Echinomya micado	+			+	
Chrysosoma aurata	+			+	
Sturmia sericariae	+			+	

The yellow colours of the tubules sometimes vary both intra- and interspecifically from pale yellow to bright yellow. In saline, too, the yellow colour of the tubules inclines readily to fade into white.

In this study the writer has also observed abnormal individuals of the *Calliphora grahami*, *Lucilia illustris* and *Lucilia sericata* whose tubules were partially bluish green in colour and also one example of *Sarcophaga crassipalpis* and two examples of *Lispe orientalis* with partial red colour.

C. Length of the Malpighian tubules

In most of the calyptrate Diptera the Malpighian tubules are so long and so entangled with the coils of the intestine that it is very difficult to unravel them completely. The anterior tubules are usually somewhat longer than the posterior tubules (see Table 3), but the two tubules of each pair are usually of about equal length.

Table 3. Malpighian index of 82 species of the calyptrate muscoid flies

Species	Number of specimens examined	Malpighian index			
		Anterior tubules		Posterior tubules	
		Average	Range	Average	Range
Scopeuma stercorarinm	4	1.5	1.4–1.6	1.1	0.8–1.6
S. mellipes	2	1.6	—	1.0	1.0–1.1
Ophyra leucostoma	4	1.5	1.2–1.6	1.4	1.3–1.5
O. chlacogaster	4	1.4	1.1–1.6	1.4	0.9–1.6
O. nigra	1	1.5	—	1.3	—
Fannia scalaris	9	1.5	1.3–1.8	0.4	0.4–0.5
F. canicularis	9	1.5	1.3–1.9	0.4	0.4–0.5
F. sp.	3	1.7	1.5–1.8	0.4	—
Anthomyia illocata	3	1.7	1.6–1.7	1.3	1.1–1.4
Hydrophoria ruralis	3	1.8	1.7–2.0	1.6	1.5–1.7
Pegomyia virginea	3	1.6	—	1.1	1.0–1.2
Hylemyia antiqua	1	2.3	—	1.4	—
Lispe orientalis	2	2.4	2.2–2.5	2.0	1.7–2.2
Orthellia latipalpis	4	3.5	3.2–3.6	3.1	2.8–3.2
Musca domestica vicina	50	2.3	1.5–3.0	1.6	1.3–1.9
M. sorbens	5	2.3	2.0–2.5	1.4	1.3–1.6
M. hervei	6	3.1	1.7–4.2	1.7	1.3–2.2
M. convexifrons	2	3.0	2.9–3.0	1.6	1.4–1.8
Graphomyia maculata	3	2.7	2.5–2.9	2.6	2.2–2.8
Muscina stabulans	3	2.5	2.1–2.8	1.8	1.6–2.1
M. angustifrons	6	2.8	2.4–3.2	2.4	2.0–3.1
M. pabulorum	2	3.9	3.8–3.9	3.8	—
Dasyphora cyanella	2	3.0	2.8–3.2	2.1	2.0–2.1
Pyrellia cadaverina	3	2.3	—	1.9	1.8–2.0

Species	Number of specimens examined	Malpighian index			
		Anterior tubules		Posterior tubules	
		Average	Range	Average	Range
Morellia hortorum	4	3.0	2.2–3.8	1.7	1.4–2–0
Myiospila meditabunda	1	1.8	—	1.1	—
Stomoxys calcitrans	6	2.0	1.7–2.2	1.7	1.4–2.0
Lyperosia exigua	3	2.1	2.0–2.2	1.5	1.4–1.6
Strongyloneura prasina	5	1.6	1.4–1.8	1.6	1.4–1.8
Stomorhina discolor	4	2.4	2.3–2.6	2.0	1.8–2.1
Phormia regina	2	2.6	2.5–2.7	2.5	2.4–2.5
Protophormia terrae-novae	3	2.5	2.0–2.8	2.4	1.9–2.6
Chrysomya megacephala	4	3.2	2.7–3.5	2.7	1.7–3.3
C. pinguis	5	3.4	2.5–4.3	2.8	2.0–3.2
Melinda pusilla	1	1.0	—	0.6	—
Calliphora vomitoria	5	3.0	2.3–3.4	2.5	2.1–3.1
C. grahami	4	3.0	2.6–3.7	2.6	2.3–3.1
Triceratopyga calliphoroides	6	3.1	2.4–4.0	2.3	1.5–3.1
Hemipyrellia ligurriens	9	3.0	2.4–3.4	2.7	2.1–3.3
Lucilia illustris	5	2.8	2.4–3.3	2.8	2.4–3.3
L. caesar	7	3.2	2.2–4.2	2.9	2.2–3.9
L. ampullacea	2	3.6	3.5–3.6	3.6	3.5–3.6
L. porphyrina	2	2.8	2.5–3.0	2.0	—
L. papuensis	4	3.5	2.8–3.8	2.6	2.0–3.0
L. sericata	4	2.8	2.4–3.0	2.5	2.0–2.7
L. cuprina	6	2.2	1.9–2.6	2.1	1.9–2.3
Metopia leucocephala	2	1.0	0.8–1.2	0.9	0.8–1.0
Sarcophila cinerea	3	1.8	1.7–1.9	1.4	1.3–1.6
Blaesoxipha iaponensis	5	0.9	0.8–1.1	0.9	0.8–1.1
B. laticornis	2	0.9	0.8–0.9	0.8	0.7–0.8
Sarcophaga melanura	2	1.5	1.2–1.8	1.5	1.2–1.8
S. sp.	2	2.0	1.7–2.2	1.9	1.6–2.2
S. ugamskii	2	1.2	1.0–1.3	1.2	1.0–1.3
S. caudagalli	4	1.7	1.2–1.9	1.7	1.1–1.9
S. erecta	1	1.5	—	1.1	—
S. basalis	3	2.7	2.6–2.9	2.8	2.4–2.9
S. josephi	3	2.2	2.0–2.3	2.2	2.0–2.3
S. kagaensis	4	2.1	1.7–2.3	2.2	1.5–2.6
S. jezensis	3	1.3	1.2–1.3	1.2	1.1–1.2
S. albiceps	3	2.2	—	2.0	1.9–2.0
S. tsushimae	4	2.1	2.0–2.3	1.9	1.4–2.3
S. brevicornis	5	1.9	1.7–2.1	1.8	1.5–2.0
S. misera	6	2.2	1.7–2.8	2.1	1.2–2.8
S. harpax	2	2.3	2.0–2.5	2.3	2.0–2.5
S. similis	5	2.8	2.3–3.3	2.2	1.9–2.4
S. kawayuensis	2	2.0	1.9–2.0	1.6	1.4–1.8
S. crassipalpis	4	2.1	1.8–2.4	2.1	1.8–2.4
S. peregrina	7	2.3	1.8–2.9	2.2	1.9–2.9

Species	Number of specimens examined	Malpighian index			
		Anterior tubules		Posterior tubules	
		Average	Range	Average	Range
S. septentrionalis	3	2.8	2.6–3.0	2.8	2.7–3.0
S. schützei	7	1.6	1.4–1.8	1.6	1.4–1.8
S. antilope	4	2.0	1.7–2.2	1.8	1.5–2.2
S. kinoshitai	5	1.9	1.5–2.4	1.7	1.5–2.0
S. hozawai	2	1.9	1.8–2.0	1.9	1.8–1.9
S. hakusana	1	2.4	—	2.4	—
S. kobayashii	7	2.0	1.6–2.2	1.9	1.6–2.2
S. hokurikuensis	3	2.3	1.8–2.6	2.0	1.8–2.4
Ectophasia sinensis	2	1.3	1.2–1.3	1.2	—
Succingulum transvittatum	1	0.8	—	0.7	—
Prosena siberita	2	0.8	0.7–0.9	0.8	0.7–0.8
Servillia jakovlewii	4	1.3	0.9–1.5	1.2	0.9–1.3
Echinomya micado	1	1.0	—	1.0	—
Chrysosoma aurata	3	1.3	1.1–1.4	1.3	1.1–1.4
Sturmia sericariae	2	0.5	—	0.5	—

In order to indicate the length of the tubules, the Malpighian index, which is a ratio between the length of the anterior pair and that of the body, was measured for each of the 82 species (Tabs. 3, 4).

Table 4. Comparison of the Malpighian index of 8 families of the Calyptratae

Family	Number of species examined	Malpighian index			
		Anterior tubules		Posterior tubules	
		Average	Range	Average	Range
Scatophagidae	2	1.6	1.5–1.6	1.1	1.0–1.1
Anthomyiidae	11	1.7	1.4–2.4	1.2	0.4–2.0
Muscidae	15	2.7	1.8–3.9	2.0	1.1–3.8
Calliphoridae	18	2.8	1.0–3.6	2.4	0.6–3.6
Sarcophagidae	30	1.9	0.9–2.8	1.8	0.8–2.8
Phasiidae	1	1.3	—	1.2	—
Dexiidae	2	0.8	—	0.8	0.7–0.8
Tachinidae	4	1.0	0.5–1.3	1.0	0.5–1.3

As is shown in the above tables, the values of the index range from 0.5 to 3.9 in the anterior pair, 0.4 to 3.8 in the posterior pair. This indicates that the values of the index of the calyptrate muscoid Diptera are much larger than those of the nematoceran Diptera where the values vary 0.35 to 1.29 (Okada, 1936).

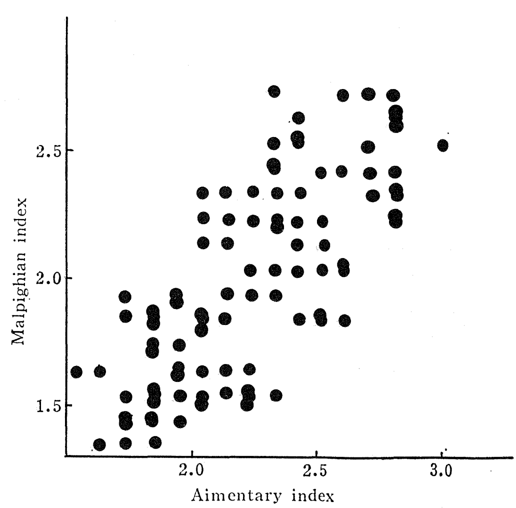
The values of the Malpighian index increase in the following order :

$$\left(\begin{array}{l}\text{Phasiidae}\\\text{Dexiidae}\\\text{Tachinidae}\end{array}\right. \longrightarrow \left(\begin{array}{l}\text{Scatophagidae}\\\text{Anthomyiidae}\end{array}\right. \longrightarrow \text{Sarcophagidae} \longrightarrow \left(\begin{array}{l}\text{Muscidae}\\\text{Calliphoridae}\end{array}\right.$$

In the Anthomyiidae the values of the index are similar in a single genus such as *Ophyra* and *Fannia*, and all the three species of the latter genus have noticeably smaller values for the posterior tubules. In the Muscidae, the genera *Stomoxys* and *Lyperosia*, which belong to the Stomoxydini, have smaller values than those of the Muscini. In the genus *Musca* (*s. lat.*), *domestica vicina* and *sorbens*, which belong to Ch'i-Ho's genus *Eumusca*, and *convexifrons*, which belongs to the genus *Viviparomusca* accordiag to the same author, have larger values. Thus, the values of the genus *Musca* (*s. lat.*) increase in accordance with Ch'i-Ho's system (1938) from the genus *Musca* through *Eumusca* to *Viviparomusca*. In the Calliphoridae, the values of the genera *Melinda* and *Strongyloneura*, which are considered more primitive, are smaller than those of the advanced ones, such as *Calliphora*, *Lucilia* and *Chrysomya*. In the Sarcophagidae, the values of the Metopiini and those of the genus *Blaesoxipha* and some species of the genus *Sarcophaga* such as *ugamskii*, *caudagalli*, *erecta*, *jezensis* and others are smaller than those of the others. The tachinid flies here examined have all smaller values, but the tubules are generally larger in diameter than those of the others. This may be considered as a compensatory development caused by their parasitic larval life.

The relation between the length of the Malpighian tubules and that of the digestive canal was examined. We used 100 specimens of the house-fly, 50 of both sexes, reared in the laboratory (Text-fig. 2).

It is obviously seen from this figure that the length of the Malpighian tubules indicates a high positive linear correlation with that of the digestive tract (coefficient of correlation $r = 0.741 \pm 0.031$). The similar positive linear relation between the length of the Malpighian and that of the digestive tract was also observed for the 82 species examined.



Text-fig. 2. Relation between the alimentary index and the Malpighian index of Musca domestica vicina.

The Malpighian index of the anterior pair increases proportionality with the advance of the arrangement of the Malpighian tubules, namely from the Y-shaped through the M-shaped to the Looped (Tabs. 1,3). In the posterior pair, too, the same relation between the two is observable, though considerable irregularities are also recognized. This indicates that the Malpighian tubules elongate sometimes proportionate with the advance of the arrangement of the tubules, but sometimes independently in each type of the arrangement of the said organ.

D. Fusing degree of the Malpighian tubules

The number of the Malpighian tubules of insects vary, occuring in two or multiples of two. Their primitive number is two, according to Pantel (1914), while Wheeler (1893) considered six as the primitive number, each arising separately at the six angles of the proctodaeal wall. Among the Diptera the number of the Malpighian tubules vary from two to six, four being most frequent in the Cyclorrhapha (Okada, 1955). Wheeler (1893) considered that the reduction in number of the tubules and the formation of the common stalk are originated from the hexanephric condition either by the suppression of a single tubules or by the fusion of a pair of tubules into one. Okada (1936), who has studied the digestive system of the Nematoceran Diptera, supported this view of Wheeler's. In some of the Diptera such as the Pupipara (Falcoz, 1926 ; Roberts, 1927) and Syrphidae (Maki, 1935), however, the four tubules enter separately into the gut, while in some others such as the drosophilids, two tubules on each side fuse together to make a common stalk.

Therefore, in order to indicate the fusing degree of the tubules, with the consideration that the Malpighian tubules of the calyptrate Diptera are on the course of fusing the tubules, the fusing index, which is the ratio of the length of the common duct to the total length of the tubules, was calculated for each specimen of the 82 species (Tabs. 5, 6).

This table shows that the fusing index of both the anterior- and posterior pair of the 8 families increases in accordance with increse of the Malpighian indices. The fusing index of the related species is also similar to one another.

Summary

1). The Malpighian tubules of 82 Japanese of the calyptrate muscoid flies belonging to 8 families were studied comparatively.

2). The Malpighian tubules are four in number, two at each side opening by a short common duct into the digestive canal at the junction of the mid- and hind-gut. The anterior tubules proceed forwards, running close to the straight portion of the proximal intsetine, and the posterior tubules run backwards. The arrangement of the anterior pair may be divided into 3 main types : (a) Y-shaped, (b) M-shaped, and (c) looped. The arrangement of the posterior tubules may also be grouped under 3 chief types : (a) once-looped, (b) twice-looped, (c) thrice-looped (Table 1). The relations among these 3 types of arrangement, both in the anterior- and posterior tubules, are here discussed.

Table 5. Fusing degree of the Malpighian tubules of 82 species of the calyptrate muscoid flies

Species	Number of specimens examined	Fusing degree			
		Anterior tubules		Posterior tubules	
		Average %	Range %	Average %	Range %
Scopcuma stercorarium	4	3.2	2.0– 4.0	4.8	3.0– 6.7
S. mellipes	2	3.6	3.5– 3.6	5.5	5.3– 5.7
Ophyra leucostoma	3	5.3	4.5– 5.8	5.9	5.6– 6.2
O. chalcogaster	4	5.9	5.2– 6.5	6.6	5.6– 7.6
O. nigra	1	4.7	—	5.6	—
Fannia scalaris	9	4.1	3.4– 5.1	11.0	8.8–11.7
F. canicularis	9	4.4	3.7– 5.8	10.0	9.0–12.0
F. orientalis	3	3.9	3.4– 4,2	12.4	11.3–13.1
Anthomyia illocata	3	5.6	4.7– 6.0	7.7	6.2– 9.0
Hydrophoria ruralis	3	6.0	5.1– 6.8	6.6	6.0– 7.4
Pegomyia virginea	3	4.3	4.0– 4.7	6.6	6.2– 7.1
Hylemyia antiqua	1	3.2	—	5.6	—
Lispe orientalis	2	4.8	4.5– 5.1	5.8	5.1– 6.5
Orthellia latipalpis	4	6.9	6.2– 8.6	7.6	6.3– 9.0
Musca domestica vicina	50	11.2	9.0–14.5	16.7	13.0–24.0
M. sorbens	5	8.5	7.1–10.2	11.4	13.3–16.7
M. hervei	6	13.8	10.0–23.0	18.9	17.6–20.0
M. convexifrons	2	7.0	6.6– 7.3	11.7	11.4–12.0
Graphomyia maculata	3	7.0	5.6– 8.7	7.0	5.6– 8.7
Muscina stabulans	3	16.7	16.7–20.0	22.2	19.4–24.1
M. angustifrons	6	15.9	11.6–19.0	20.3	17.0–23.5
M. pabulorum	2	12.2	12.0–12.3	12.3	—
Dasyphora cyanella	2	5.2	4.6– 5.7	7.6	7.1– 8.1
Pyrellia cpdaverina	3	6.8	6.7– 6.9	8.4	8.3– 8.4
Morellia hortorum	4	10.2	7.8–12.8	16.6	15.0–18.8
Myiospila meditabunda	1	5.4	—	9.1	—
Stomoxys cplcitrans	6	11.1	10.0–13.0	12.5	10.0–16.6
Lyperosia exigua	3	11.3	10.7–11.8	14.3	13.3–16.0
Strongyloneura prpsina	5	5.8	5.1– 6.2	6.8	5.1– 9.0
Stomorhina discolor	4	5.5	5.0– 6.0	7.0	6.5– 7.5
Phormia regina	2	8.5	8.1– 8.1	8.9	8.7– 9.1
Protophormia terrae-novae	3	7.7	7.4– 8.1	8.2	8.0– 8.3
Chrysomya megacephala	4	9.8	8.0–11.1	11.2	10.7–11.8
C. pinguis	5	8.5	7.6–10.1	10.8	9.9–12.4
Melinda pusilla	1	7.7	—	16.6	—
Calliphora vomitoria	5	7.1	6.2– 8.0	8.2	6.9–10.0
C. grahami	4	9.3	7.5–11.5	10.7	8.8–12.5
Triceratopyga calliphoroides	6	8.3	6.4–10.3	12.4	7.8–17.6
Hemipyrellia ligurriens	9	8.1	5.6–10.3	9.0	5.6–11.1
Lucilia illustris	5	9.6	8.3–10.7	9.6	8.3–10.7
L. caesar	7	10.1	6.8–13.0	10.0	6.8–13.2
L. ampullacea	2	9.0	—	9.0	—

Species	Number of specimens examined	Fusing degree			
		Anterior tubules		Posterior tubules	
		Average %	Range %	Average %	Range %
L. porphyrina	2	8.0	7.3– 8.7	10.5	—
L. papuensis	4	9.1	7.4–10.2	11.5	10.5–12.5
L. sericata	4	6.8	5.6– 8.1	9.5	8.2–11.1
L. cuprina	6	6.9	5.4– 7.9	8.5	7.6–10.0
Metopia leucocephala	2	6.5	5.6– 7.4	7.1	6.0– 8.2
Sarcophila cinerea	3	7.9	6.8– 9.0	9.9	9.0–10.8
Blaesoxipha japonensis	5	10.4	7.6–13.4	11.1	10.0–13.4
B. laticornis	2	7.6	7.4– 7.7	8.7	8.3– 9.1
Sarcophaga melanura	2	5.3	4.5– 6.1	5.7	5.1– 6.4
S. sp.	2	6.6	6.0– 7.1	6.8	6.0– 7.5
S. ugamskii	2	8.6	7.1–10.1	11.1	10.0–12.1
S. caudagalli	4	7.0	6.6– 8.1	7.7	6.0– 8.6
S. erecta	1	8.3	—	8.3	—
S. basalis	3	7.1	5.8– 8.5	7.5	6.2– 8.5
S. josephi	3	10.0	7.1–11.5	10.0	7.1–11.5
S. kagacnsis	4	7.0	4.7–10.7	7.2	4.6–10.7
S. jezensis	3	5.6	5.1– 6.5	6.2	5.7– 7.2
S. albiceps	3	5.6	3.7– 6.6	5.9	3.8– 7.3
S. tsushimae	4	9.8	8.1–10.9	10.6	10.0–11.1
S. brevicornis	5	9.7	7.6–12.7	7.9	6.5– 9.5
S. misera	6	6.5	5.1– 7.9	7.7	5.1–10.1
S. harpax	2	11.7	11.1–12.3	11.7	11.1–12.3
S. similis	5	6.1	3.9– 8.6	7.8	3.7–10.4
S. kawayuensis	2	7.3	7.1– 7.5	8.9	8.0– 9.7
S. crassipalpls	4	7.2	6.2– 8.3	7.2	6.2– 8.3
S. peregrina	7	7.3	5.7– 8.6	7.8	6.5–10.4
S. septentrionalis	3	10.4	9.6–10.8	10.3	9.6–10.8
S. schützei	7	7.7	5.2– 9.0	7.7	5.0– 9.0
S. antilope	4	5.5	5.0– 5.9	6.1	5.0– 6.6
S. kinoshitai	5	8.0	3.0–10.0	8.5	5.2–10.0
S. hozawai	2	10.8	9.5–12.0	10.3	10.0–10.6
S. hakusana	1	9.0	—	9.0	—
S. kobayashii	7	6.7	5.2– 9.4	7.1	6.0– 9.4
S. hokurikueusis	3	6.6	3.4– 8.6	6.9	5.0– 8.2
Ectophasia sinensis	2	9.1	—	9.6	9.1–10.0
Succingulum transvittatum	1	13.3	—	15.8	—
Prosena siberita	2	6.2	5.8– 6.6	7.1	6.6– 7.6
Servillia jakovlewii	4	8.0	5.3–11.6	9.2	5.9–12.6
Echinomya micado	1	11.5	—	11.5	—
Chrysosoma aurata	3	11.1	10.0–11.8	11.1	11.1–16.7
Sturmia sericariae	2	8.1	—	7.8	7.4– 8.1

Table 6. Comparison of the fusing degree of the Malpighian tubules of 8 families of the Calyptratae

Family	Number of species examined	Fusing degree			
		Anterior tubules		Posterior tubules	
		Average	Range	Average	Range
Scatophagidae	2	3.4	3.2– 3.6	5.2	4.8– 5.5
Anthomyiidae	11	4.7	3.2– 6.0	7.6	5.6–12.4
Muscidae	15	9.9	5.2–16.7	13.1	7.0–22.2
Calliphoridae	18	8.1	5.5–10.1	9.9	6.8–16.6
Sarcophagidae	30	7.8	5.3–11.7	8.3	5.7–11.7
Phasiidae	1	9.1	—	9.6	—
Dexiidae	2	9.8	6.2–13.3	11.5	7.1–15.8
Tachinidae	4	9.7	8.0–11.5	9.9	7.8–11.5

3) The colour of the tubules are yellow in 81 species out of 82 examined species, while only in *Graphomyja maculata* are they fuscous in colour (Table 2).

4). The Malpighian index for each species was calculated (Tabs. 3, 4). The values of the index of the calyptrate muscoid flies are larger than those of the nematoceran Diptera. In the calyptrate muscoid flies, with the exception of the Tachinidae whose larval life is parasitic, they increase in the following order:

$$\left(\begin{array}{l}\text{Scatophagidae}\\ \text{Anthomyiidae}\end{array}\right. \longrightarrow \text{Sarcophagidae} \longrightarrow \left(\begin{array}{l}\text{Muscidae}\\ \text{Calliphoridae}\end{array}\right.$$

In a single systematic group the index may increase from the primitive to the advanced.

5). The length of the Malpighian tubules increase with the elongation of the digestive canal.

6). The fusing index for each species was calculated (Tabs. 5, 6). The values increase conciding with the traditional classification of the group.

References

CHRISTOPHERS, S. R. (1960). *Aëdes aegypti* (L.), the yellow fever mosquito. Cambridge, England.

DUFOUR, L. (1851). Recherches anatomiques et physiologiques sur les diptères, accompagnées de considérations relatives a l'histoire naturelle de ces insectes. Mem. prés. a l'Acad. Sci. math. et. phys., 11: 171–360.

EASTHAM, L. (1925). Peristalsis in the Malpighian tubules of Diptera, preliminary account: with a note on the elimination of calcium carbonate from the Malpighian tubules of *Drosophila funebris*. Quart. Jour. Micros. Sci., 69: 385–398.

FALCOZ, L. (1926). Diptères Pupipares, in Faune de France, 14. Paris.

Giles G. M. (1906). The anatomy of the biting flies of the genera *Stomoxys* and *Glossina*. Jour. Trop. Med., 9: 99–236.

Graber, V., (1889), Vergleichende Studien über die Embryologie der Iusekten und insbesondere der Musciden. Denkschrift, K. Akad. Math. Naturwiss. Cl. Wien., 56: 37–38 (fide Wheeler, 1893).

Graham-Smith, G. S. (1934). The alimentary canal of *Calliphora erythrocephala* L., with special reference to its masculature and to the proventriculus, rectal valve and rectal papillae. Parasitol., 26: 176–248.

Hewitt, C. G. (1907). The structure, development and bionomics of the house-fly, *Musca domestica* Linn. Quart. Jour. Micros. Sci., 51: 395–448.

——. (1941). The house-fly, Musca *domestica* Linn. Its structure, habits, development, relation to diease and control. Cambridge, England.

Ho, Ch'i. (1938). The significance of the female terminalia of house flies as a grouping character. Ann. Trop. Med and. Parasitol., 32: 287–312.

Hori, K. (1956). Comparative morphology of the Malpighian tubes of the calyptrate muscoid Diptera. Sanit. Zool., 7:150–151 (in Japanese).

——. (1960). Comparative anatomy of the internal organs of the calyptrate muscoid flies, 1. Male internal sexual organs of the adult flies. Sci. Rep. Kanazawa Univ., 7(1) : 23–83.

——. (1961). Comparative anatomy of the internal organs of the calyptrate muscoid flies, 2. Female internal sexual organs of the adult flies. Sci. Rep. Kanazawa Univ., 7(2) : 61–101.

——. (1962). Comparative anatomy of the internal organs of the calyptrate muscoid flies, 3. Alimentary canal of the adult flies. Sci. Rep. Kanazawa Univ., 8(1) :

Imms, A. D. (1951). A general textbook of entomology. 8th ed., London.

Kikkawa, H. (1953). Biochemical genetics of *Bombyx mori* (silkworm). Advance in Genetics, 5 : 107–140.

——. (1955). Biochemical genetics of insects : tryptophan metabolism and its physiological significance, in Ashida, J., Egami, F., and Kikkawa, H. : Seimeigensho no Kagaku (Chemistry of life), pp. 786–836 (in Japanese).

Lowne, B. T. (1893–95). The anatomy, physiology, morphology and development of the blow-fly (*Calliphora exythrocephala*). Vol. II, London.

Maki, T. (1935). Anatomical studies of alimentary canals and their appendages in syrphid flies. Trans. Nat. Hist. Soc. Formosa. 25 : 379–391.

Minchin, E. A. (1905). Report on the anatomy of the tsetse fly (*Glossina palpalis*). Proc. Roy. Soc. London, (B). 76 : 531–547.

Okada, T. (1936). Digestive system of the Nematoeran Diptera. Botany and Zoology, 4: 1531–1540. (in Japanese).

——. (1955). Comparative morphology of the drosophilid flies, VII. The Malpighian tubes of the adult flies. Zool. Mag., 64 : 108–112. (in Japanese with English summary).

Pantel, F. (1914). Signification des "glandes annexes" intestinales des larves des Ptychopteridae et observation sur les tubes de Malpighi de ces Nematoceras (larves et adultes). La Cellule., 29 : 393–429.

Patton, W. S. and Cragg, F. W. (1913). A text book of medical entomology. London, Madras and Calcutta.

Roberts, J. I· (1927). The anatomy and morphology of *Hyppobosca equina*. Ann. Trop. Med. and Parasitol., 21: 11–22.

SCHINDLER, E. (1878). Beiträge zur Kenntniss der Malpighischen Gefässe der Insekten. Zeitschr. Wiss. Zool., 30 : 587–660 ; Taf. XXXVIII–XL.

SNODGRASS, R. E. (1935). Principles of insect morphology, New York and London

TULLOCH, F. (1906). The internal anatomy of *Stomoxys*. Proc. Soc. London, (B), 77: 523–531.

WEST, L. S. (1951). The Housefly. New York.

WHEELER, W. M. (1893). The primitive number of Malpighian tubes in insects. Psyche, 6 : 457–460, 485–486, 497–498, 509–510, 539–541, 545–547, 561–564.

WIGGLESWORTH, V. B. (1950). The principle of insect physiology, revised ed., London.

Explanation of Plate I

Fig. 1. *Scopeuma stercorarium* (Linné)
Fig. 2. *Ophyra chalcogaster* (Wiedemann)
Fig. 3. *Fannia canicularis* (Linné)
Fig. 4. *Anthomyia illocata* Walker
Fig. 5. *Hydrophoria rularis* Meigen
Fig. 6. *Pegomyia virginea* Meigen
Fig. 7. *Lispe orientalis* Wiedemann
Fig. 8. *Graphomyia maculata* (Scopoli)
Fig. 9. *Musca domestica vicina* (Macquart)
Fig. 10. *Lucilia sericata* (Meigen)
Fig. 11. *Blaesoxipha japonensis* Hori
Fig. 12. *Sarcophaga peregrina* Robineau-Desvoidy
Fig. 13. *Sturmia sericariae* Cornalia
Fig' 14. *Prosena siberita* Fabricius
Fig. 15. *Succingulum transvitattum* Pandellé

Plate I