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MIYAMOTO, SYÔITI
Biological Laboratory, General Education Department, Kyushu University

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BIOLOGY OF *HELOTREPHES FORMOSANUS* ESAKI ET MIYAMOTO, WITH DESCRIPTIONS OF LARVAL STAGES

SYÔITI MIYAMOTO

(Biological Laboratory, General Education Department, Kyushu University)

The present knowledge on the biology of the interesting water-bugs of the Family Helotrephidae is not adequate. Fragmental biological and ecological data on these bugs were given by Esaki and China (1927) on African *Idiocoris lithophilus* Esaki et China and *Paskia minutissima* Esaki et China, Usinger (1937) on Philippine *Hydrotrephes balnearius* Bergroth, and by Takahashi (1941) on *Tiphotrephes indicus* Distant. The habitats of several species were given by Esaki and China (1928), China (1930, 1932, 1935, 1936) and Lundblad (1933). During the year 1941, from February to November, I studied on the biology of *Helotrephes formosanus* Esaki et Miyamoto in Formosa, both afield and in laboratory. Thus, these observations may be of some interest and significance.

Before proceeding further I wish to thank Professor Teiso Esaki of the Kyushu University for his kind guidance and advice, and to Dr. Ryôichi Takahashi for some literature and for the gift of the specimens of *Tiphotrephs indicus*. Thanks are due also to Dr. Keizô Yasumatsu of the Kyushu University, Dr. Yûshirô Miwa and Professor Michio Chûjô of the Kagawa Agricultural College for their encouragement.

Habitat: As tabulated below (Tab. 1), *Helotrephes semiglobosus* Stål, *Hydrotrephes balnearius* Bergroth, *Idiotrephes chinai* Lundblad and *Neotrephes usingeri* China were found in a river or a stream, *Tiphotrephes indicus* Distant, *Limnotrephes campbelli* Esaki et China, *Esakiella* spp., *Idiocoris* and *Paskia* were from a pond or a lake. It may be noteworthy that the Oriental Helotrephid, *Idiotrephes chinai* Lundblad was found in a hot-spring in Sumatra (Lundblad, 1933). R. Takahashi captured the same species also in a hot-spring in Selangor,

Tab. 1. Habitats and time of appearance on Helotrephidae.

	Species	Habitats	Time of appearance											Localities
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Oriental species	*Helotrephes semiglobosus* Stål	Canton River						?							S. China
	Hel. lundbladi China	?						○							E. China (Tygosan Isl.)
	Hel. formosanus E. et Miy.	Hill-stream		◉	◉	◉	◉	◉	○	○	○	○	○		N. Formosa
	Hydrotrephes balnearius Bergr.	River, creek							◉						Philippines (Luzon)
	Hyd. bouvieri Kirkaldy	?						?							Celebes
	Hyd. martini Kirkaldy	?						?							Sumatra
	Hyd. angulatus China	?									○	○			Sumatra
	Hyd. corporaali China	Lake		◉			●				◉	○			Sumatra
	Hyd. kirkaldyi E. et. Ch.	?						?							Ceylon
	Idiotrephes chinai Lundblad	Streem, pool, pond, hot-spring			●	◉	◉	○							Sumatra, Malaya
	Tiphotrephes indicus Distant	Pond				○		◉	◉	◉			○		C. India, Burma, Malaya, Indochina
	Limnotrephes campbelli E. et Ch.	Tank						?							S. India
African species	*Esakiella hungerfordi* E. et Ch.	?											○		Africa (French tropical Africa)
	E. hunger. ugandensis China	Lake Victoria							○						Africa (Uganda)
	E. hancocki China	Lake Victoria						◉							Africa (Uganda)
	E. hutchinsoni China	Torro Crater-Lake											○		Africa (Uganda)
	E. hutch. bunyonica China	Lake Bunyoni						?							Africa (Uganda)
	Idiocoris lithophilus E. et Ch.	Lake Tanganyika											◉		E. Africa (Tanganyika)
	Paskia minutissima E. et Ch.	Lake Tanganyika											○		E Africa (Tanganyika)
Neotropical species	*Neotrephes usingeri* China	Mountain-stream					◉								S. America (Brazil)
	N. plaumanni China	?			○										S. America (Brazil)
	Paratrephes hintoni China	?										○			S. America (French Guiana)

○ indicates imago, ● larva, ◉ imago and larva.

Malaya, on June 27, 1943 and the specimens are now preserved in the Entomological Laboratory of Kyushu University.

Helotrephes formosanus was found not rarely in a hill-stream, flowing into the Shinten River, at Ankô, southern vicinity of Taihoku, and a single young larva was captured in a smaller hill-stream at the foot of Mt. Sôzan, north of Taihoku (Esaki and Miyamoto, 1943). The stream at Ankô is about ten metres in width, and the ordinary amount of water is not much, thus the depth may be estimated about sixty centimetres in spring, and fourty centimetres in summer. The bugs are found at the deepest part. After a heavy rain the stream may attain a depth of more than two metres. The average depth in the rainy season, i. e. in winter and early spring, may be eighty centimetres. The velosity of the flowing water at the middle part is about fifty centimetres per second.

The bottom condition of the stream is gravelly or sandy where the flowing is rapid part, but becomes gradually muddy as approaching to the shore, where abundant rootlets of shrubs are exposed by erosion, partially submerged and partially on the surface or above water. Trees, shrubs and bamboos produce suitable shades along the banks, and various grasses, ferns and herbs cover the ground except for the waterside. The bugs were found only either along the slow-moving margins of the stream or in small still-water embayments along the beach as in *Hydrotrephes balnearius* (Usinger, 1937) and they got the living place among the rootlets.

Animal community at the habitat: In the water *Planaria* and crabs are few but shrimps (3 spp.) and *Thiara* are very abundant. Ephemerid-, Perlid- and Trichopterid-larvae are common, though the latter two groups are restricted in the rapid portions of the stream, *Micronecta* is numerous in the still portions; Dryopid-larvae and imagines are also common; Sialid-larvae are rare, but Tipulid-larvae are not rare.

On the water surface various waterstriders of the Gerridae (*Metrocoris, Amemboa, Rhyacobates* and *Strongylovelia*) and Veliidae (*Microvelia* and *Xiphovelia*) as well as Gyrinid beetles (*Orectochilus*) are found.

Locomotion: A film of air, or plastron, covers the venter (Pl. 1, A and B) when the bugs live in water as in most water-bugs. The bugs float under water surface upside-down and usually they swim also upside-down, but often dorsum uppermost as Usinger observed in

Hydrotrephes. Takahashi wrote that *Tiphotrephes indicus* always swimmed about upside-down as in *Paraplea* sp. For swimming the front and middle legs are not functional, the former are stretched out

Tab. 2. Air- and water-temperature at Ankô, in 1941:

Date	Time	Air-temp.	Water-temp.	Weather
Feb. 16th	15.00	27.5°C	21.8°C	fine
Mar. 2nd	15.00	14.6°	17.2°	rainy
„ 23rd	13.30	30.5°	25 0°	fine
Apr. 6th	12.00	12.8°	17.5°	occasionally rainy
„ 20th	13.00	30.0°	24.5°	fine
May 25th	—	—	—	fine
July 6th	—	—	—	fine
Aug. 10th	12.00	35.0°	30.8—31.4°	feebly cloudy

forwards and the latter are attached to the body. They walk about on the surfaces of objects under water by using all legs as Pleids do.

The bugs rest on the shore or among the rootlets under water near the edge of the stream and sometimes above water by exposing themselves. The orientation of the body axis at rest indefinite but it is often observed that the head is directed downwards.

When they are grasped and taken out of water, they feign death, although it is not distinctly observed in water. When suddenly disturbed in water, however, they stop moving with all legs retracted to body for a short time.

Stridulation organ: The stridulation organ is similar to that of *Plea* in structure, but it is more closely situated to the lateral margin of the body, exterior to the second thoracic spiracles, whereas in *Plea* it is found interior to the spiracles and the plectrum is longer and narrower than in *Plea* (Pl. 3, F and G).

I failed to hear any sound of stridulation in field or in captivity.

Foods and feeding habits: I could not observe their feeding habits in nature but it was observed in the laboratory that the bugs fed on the tissue fluids of various aquatic insects. I reared them with larvae of mosquitoes, Chironomids, Tipulids, Dryopids, Ephemerids and Perlids, and used mainly aquatic Dipterous and Dryopid-larvae as

foods.* The bugs attacked younger larvae of the same species at hunger as in other carnivorous insects (Pl. 1, C).

Only when, even in hunger, the front legs get in touch with the prey the bugs seize and hold them with front and middle legs. They hold the prey of small size at the tip of rostrum with the aid of mandibular teeth as in Gerrids, but, when the prey moves actively, they use all legs. Often they swim about in the water, holding their foods either with the middle legs or with the rostrum, and in that case the front legs are stretched out forwards. Hind legs are occassionally vibrated in order to adjust the body orientation during they feed. When feeding on Dryopid-larvae (Pl. 1, D), they attack always at the venter but on Dipterous larvae they pierce the rostrum at any portion of the body of the victim.

Copulation: Prelude of copulation — The holding of the mate is chiefly by the middle legs and the front legs are only touching the frontal edge of her eyes by the tarsi (Pl. 1, E) or they even are apart from her body. The hind legs are never used for precopulatory union but vibrated at times.

Copulation—The male holds the hinder part of the right elytron of female with the right-hand hind leg and by bending the leg, he retracts the body downwards to the postero-dextral part of her (Pl. 1, F and G). Then his genital segments are stretched out and copulation is performed. During copulation position of the male is on the right side and slightly dorsal to the body of the mate as in *Hydrotrephes* (Usinger), clinging with the middle legs, of which the right one on the venter and the left one on the left scutello-elytral suture of her (Pl. 1, F and G). The female swims and walks bearing the mate on her back as in *Hydrotrephes* (Usinger) and *Plea*. Duration of the copulation lasts from ten minutes to about two hours.

The right elytral margin of the female serves as the hold for seizing the female by the male. The presence of the costal lobe on right elytron in female in some Helotrephids (e. g. *Idiocoris*, *Neotrephes*, *Hydrotrephes martini*, *Hyd. balnearius* and *Esakiella* spp. etc.) may be of significance in relation to this fact.

* Mosquitoe- and Chironomid-larvae were scarcely found in the habitats of the bugs but abundantly occurred in Taihoku.

Three species of aquatic Mollusca, *Thiara*, *Lymnaea* and *Gyraulus*, were also given to them as foods but they were not accepted. In only one case *Lymnaea* was attacked on the foot and enfeebled, but the bug was captured by mucus and killed.

Copulation was observed only in the spring, from March to May.

Oviposition: The eggs are laid separately on the surfaces of submerged vegetable matter such as the shrub-rootlets under water at Ankô. Few eggs were obtained in captivity on the surfaces of water plants in a vial in the middle of April but they were so loosely attached to the plants that they fell off when shaked.

Molting: The molting is, as in other allied insects, proceeded at first by the rapture of the dorsal side of the thorax along the median longitudinal line, then followed by the same along the cephalopronotal suture and along the inner margin of eyes. Newly moulted insects rest for a short time on the exuvia.

The insect immediately after molting is entirely pure white but the markings appear gradually on the surface of body in silvery coloration under water, or silvery grey in air, then they grow into pitchy-brown appearance. About two hours are needed until a newly emerged imago attains its normal coloration, which is completed in the following order: the tips of the elytra and abdomen, coxae, trochanters, the bases of tibiae and the rest of the body.

Life cycle: I could not confirm the duration of egg or each larval stage, as I could not rear them uninterruptedly. In the field observations larvae were found from February to the beginning of June, but by the beginning of May they become very few in number, and imagines from the preceding year could not be obtained after the end of May and newly emerged imagines were found from the end of March to June, the highest period of emergence may fall into the duration between the end of May and the beginning of June.

Helotrephes formosanus has only one generation in a year, the imagines appear early in summer and live until next spring and in the cold season they hibernate in mud at the shore.*

Description of larval stages

Coloration: Young larvae in second instar possess pale yellow ground colour with brownish markings, which are simple and symmetrical. These markings grow and become more complicate in shape and colourtone according to the progress of the growth, and at last occupy the majority of the dorsal surface of the body. The typical

* All specimens obtained in spring were soiled with mud on dorsal surface.

patterns on dorsal surface of the second, third and the fifth instar larvae are shown on Pl. 2, figures A, B and C.

Structure: Similar in structure to the larvae of *Tiphotrephes* and *Limnotrephes* but there are some differences between this genus and the others.

Head and pronotum fused and the suture between them is distinctly w-shaped as in imago. The antero-lateral angles of pronotum at the postero-lateral corner of the eyes are less acute and the pronotum is more dilated posteriorly in other Helotrephid-larvae. Antennae consisting of a single segment, oval in shape, covered with stout setae and with a circular structure placed near the base, as in *Idiocoris*, *Tiphotrephes* and *Limnotrephes*. Rostrum long, extending beyond posterior margin of prosternum. Labrum devoid of leaf-like sensory hairs, which are present in imago. Thoracic carinae not distinctly developed in earlier instars but they are nearby as well developed in last instar as in imago (Pl. 3, E, a-d). Legs shorter and more robust than in imago, all tarsi one-segmented. Armature of legs similar to that of imago, but with fewer spines and bristles in earlier stages.

The segmentation in abdomen is obscure, the first segment is

Tab. 3. Measurements of legs in larval instars are as follows:

	Coxa	Troch.	Femur	Tibia	Tarsus	Claw
Fore leg of 2nd instar	15	10.5	22	16.5	9.5	5
Middle leg of „	17	12.5	21	15	10	5
Hind leg of „	18	13.5	22.5	23	21.5	7.5
Fore leg of 3rd instar	19.5	13	27	21	11	5
Middle leg of „	21	16	28	20	12	6
Hind leg of „	24	17	30	31	26.5	8.5
Fore leg of 4th instar	24.5	16	35.5	27.5	14	6
Middle leg of „	25	20	36.5	26	15	7
Hind leg of „	28.5	20.5	38	40.5	32	9.5
Fore leg of 5th instar ♂	32	21	48	39	17.5	7
Middle leg of „	28.5	25	47	35	19	8
Hind leg of „	35	26.5	49	52	37	10
Fore leg of 5th instar ♀	31	20	47	35	16	7
Middle leg of „	34	25	46	33	17	7.5
Hind leg of „	35	26.5	48	52	36	11

67 units = 1.00 mm.

Tab. 4. Differences among larval instars are tabulated as follows:

	Second instar	Third instar	Fourth instar	Fifth instar
Thoracic median carinae	Undeveloped	Weakly developed	More or less developed	Well-developed as in imago
Fore leg	Without comb-headed bristles	With one comb-headed bristle on tarsus		With 2 comb-headed bristles on tarsus
Middle leg	With 2 comb-headed bristles on tibia and one on tarsus		With 4 comb-headed bristles on tibia and one on tarsus	
	Without bifurcate bristles	With 3 bifurcate bristles at the apex of tibia		
Hind leg	With one comb-headed bristle on tibia	Without comb-headed bristles		
	With one bifurcate bristle at the apex of tibia			Without bifurcate bristles
Two rows of long swimming hairs on tibia and tarsus of hind leg	Anterior row occurs on apical part of tibia and on tarsus, posterior one composed of a few long hairs and is restricted on tarsus only.	Well-developed except for basal one-third of tibia	Well-developed except for basal part of tibia	Well-developed as in imago
Abdominal median processes	Those on 2nd and 3rd sternites developed but not touched with each other	Those on 2nd and 3rd sternites more developed and touching each other		
	4th sternite without tubercle	4th sternite with a small tubercle		4th sternite with an elongate tubercle
Total length	1.08 mm.	1.44 mm.	1.77 mm.	2.37 mm.
Humeral width	0.76 „	0.89 „	1.31 „	1.69 „
Greatest width (across mesonotum)	0.85 „	1.08 „	1.44 „	1.86 „

completely separated from the others but covered by the posterior portion of the metanotum dorsally, the eighth tergite is more distinctly separated dorsally from the preceding one, from the fourth to eighth sternites and pleurites are fused together. The eighth sternite is furnished with four (in second instar) or five pairs (in later instars) of leaf-like sensory hairs (Pl. 3, C and D), which disappear in imago.

The median abdominal processes (Pl. 3, E, a–d) of the second and third sternites are well-developed in all instars, the median tubercle of the fourth sternite is absent in the second instar but present in later instars, and the fifth sternite is destitute of such a process as in *Tiphotrephes indicus*.

The position of the spiracles are as in imago (Pl. 3, A, B, and F); the second or mesothoracic spiracle is situated just under a row of long setae in the second instar (Pl. 3, A), and is covered by a semicircular lobe of the subcoxal plate (Pl. 3, B) in later instars.

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Explanation of Plates

Plate 1

A and **B** Venters of male and female respectively, showing diagrammatically the outline of the plastron when the insect is submerged.

C Attitude of the bug when it attacks the prey under surface of water. The prey is a young larva of the same species.
w—water surface.

D Attitude of the bug when it attacks the prey on the bottom under water. The prey in this case is a Dryopid-larva.

E Prelude of copulation.

F Preparating movement for copulation, the male retracting the body postero-dextrally to the mate.

G Attitude of the sexes during copulation.

Plate 2

A Dorsal view of 2nd instar larva.

B The same of 3rd instar larva.

C The same of 5th instar larva.

D—G Lateral views of 2nd, 3rd, 4th and 5th instars respectively.

Plate 3

A Ventral view of 2nd instar larva.

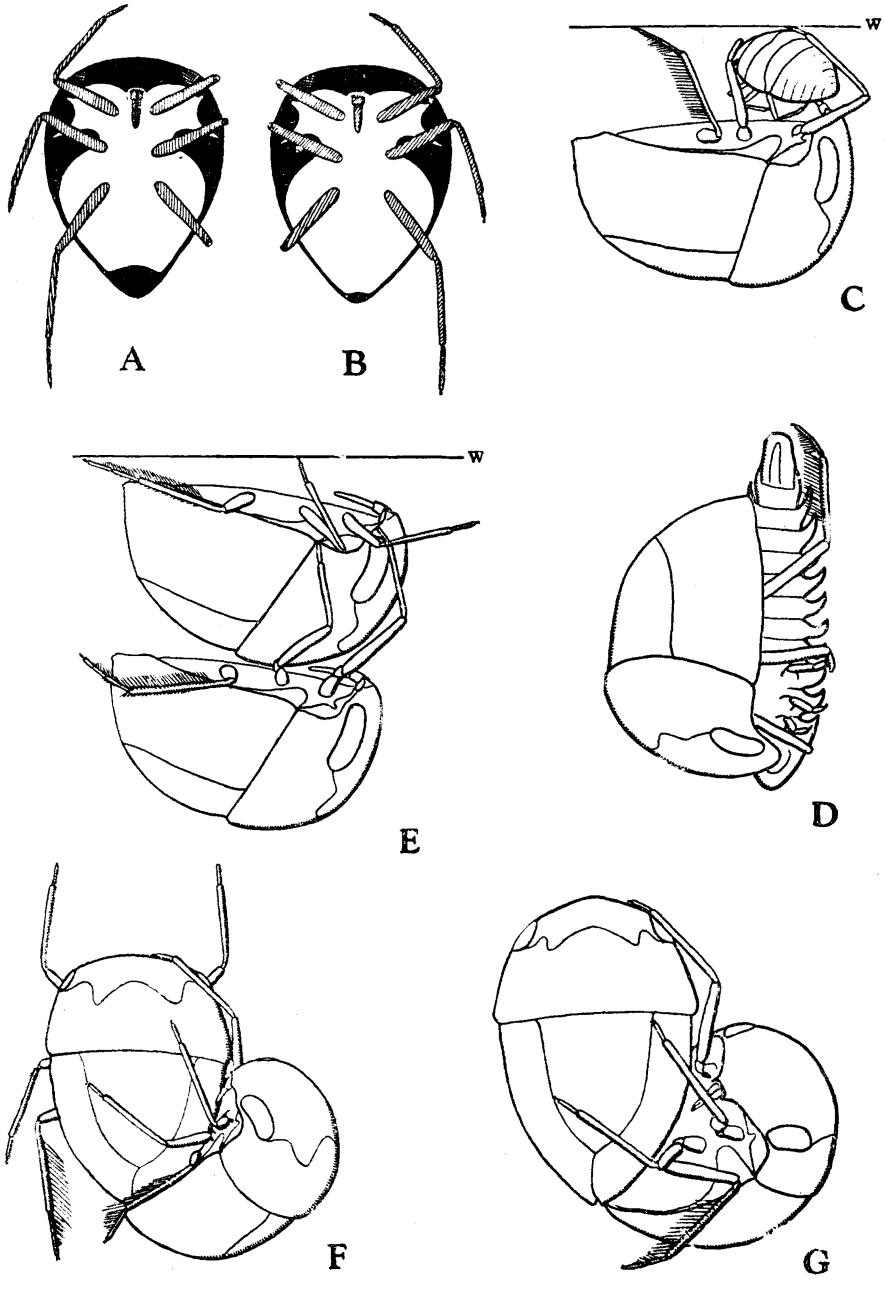
B The same of female 5th instar larva.
Sp_2—2nd or mesothoracic spiracle

C and **D** Apical segments of the male and female of 5th instar larva respectively, showing the leaf-like sensory hairs on 8th abdominal sternite.
VII and VIII—7th and 8th abdominal sternites
Sp_{10}—8th abdominal spiracle

E, a—d Median carinae and processes of 2nd—5th (a—d) instars.
Pr—Prothoracic carina
Ms—Mesothoracic carina
Mt—Metathoracic carina

F Ventral view of female adult.
Sp_1—1st or prothoracic spiracle

G Left-hand plectrum, mesothoracic subcoxal plate removed.



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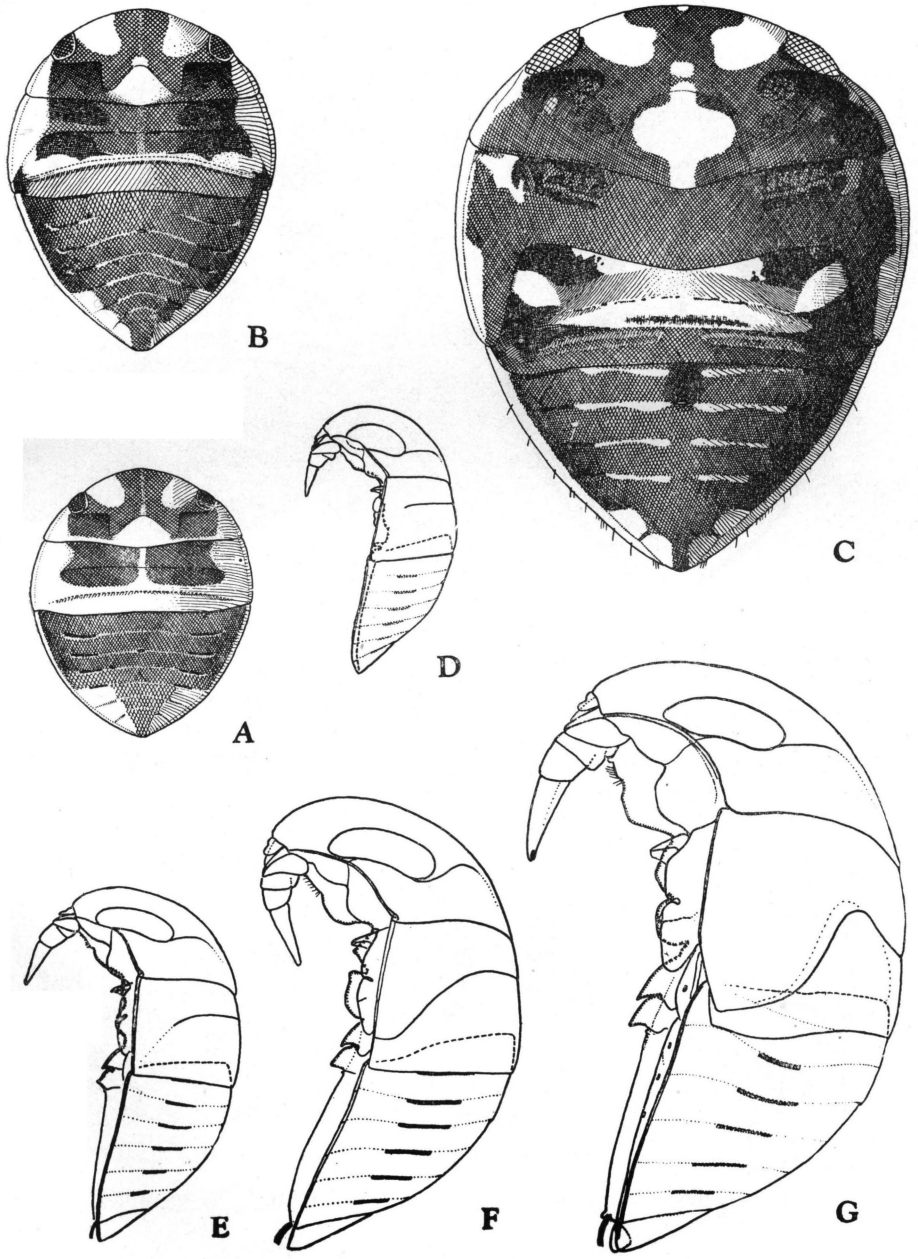

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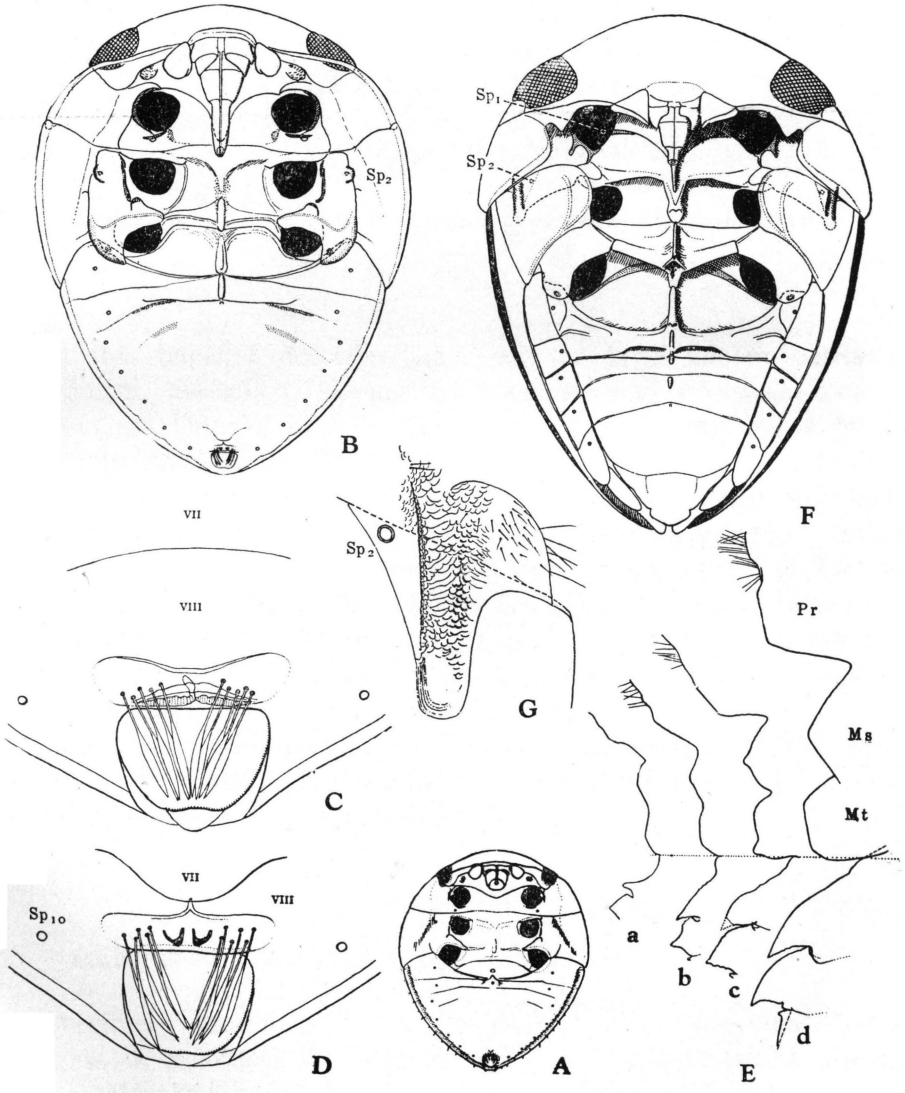

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