

STUDIES OF THE RADULAE OF TAIWAN MURICID GASTROPODS¹

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ABSTRACT

The morphology and orientation of the radulae of twenty-five muricid gastropods from Taiwan are described. The muricid radula appears to be constant within each species, and it can be used for diagnosis of species. The muricids can be divided into two categories on the basis of differences in the rachidian. Genera with three-cusped rachidians are *Chicoreus*, *Morulina*, *Cronia*, *Nassa*, *Murex*, *Rapana*, *Mancinella*, and *Drupella*. Genera with five-cusped rachidians are *Thais*, *Thaisella*, *Purpura*, *Drupa*, and *Drupina*. *Morula* can be considered as an intermediate between the *Chicoreus-Morulina-Cronia* group and the *Thais-Thaisella-Purpura-Drupa* group. *Morula* resembles the *Chicoreus* group in having three waves on the anterior side of the rachidian, a concavity ("pit" of Cooke, 1919) on the posterior side of the base, and all the cusps and medial denticles sharply pointed. *Morula* resembles *Thais* in having wrinkled lateral denticles and slightly humped marginal angles. *Drupella* and *Mancinella* and *Nassa* and *Chicoreus* also show certain resemblances in radular structure. *Drupina* is conchologically similar to *Drupa* but is quite different in radular structure.

The systematics of the superfamily Muricea have long been confused in the literature. Although most workers agree that the number of varices is the most important single character, Burch has proposed that all possible characters be employed, *i. e.*, the number of varices; type, shape and size of the spines; size and sculpture of the nuclear whorl; length and width of the siphonal canal; type of operculum; form of the animal; and the radula (1). However, the varices, spines, sculpture and other conchological characters appear to be exceedingly variable, depending on the individual specimen and the environment.

The purpose of the present work is to suggest that radular studies are of importance in the classification of the Muricea if the orientation of the radula is standardized. In the following account the radulae of various muricid gastropods are re-described and possible relationships among the Muricea are discussed from the point of view of radular structures.

Bowell published an account of the history of radular studies (2), and the interpretation of radular characters in the classification of gastropods was discussed by Howe (3). Despite the arguments questioning the validity of radular characters in the diagnosis of species by various workers, radulae have been utilized in the taxonomy of the Mollusca in monographs such as that of Thiele (4), and Fretter and Graham suggested that radular

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characters remain fairly constant within a single species although the shape of the teeth differ from species to species (5).

Studies of the radulae of muricid gastropods include those of Cooke (6-7), Kinoshita and Kinoshita (8), Peile (9-10), and Arakawa (11-15). Except for Arakawa's work, none of the previous studies deal with the orientation of the radula, nor were the teeth shaded to indicate convexities and concavities. Since radular outlines differ greatly in different views, the figures in most of the early work have caused considerable confusion in identification and comparison of specimens and figures.

MATERIALS AND METHODS

The muricids studied for this report were collected during daylight low tide periods from the shorelines of Taiwan between August 1964 and June 1965. A few specimens were obtained from the nets of trawling boats.

The radulae were prepared by utilizing a modification of the oxidation-dahlia technique of Howell (16). In brief the procedure was as follows: 1) the radular ribbon was removed from the animal and soaked in a 1% solution of potassium hydroxide for a period of a week or more; 2) the ribbons were rinsed in distilled water and the slides flooded with a 1% potassium permanganate solution until the radulae became dark; 3) the radulae were decolorized with a 1% solution of oxalic acid and washed again in distilled water; 4) the slides were subjected to the mordant action of a 1% solution of acetic acid and stained with dahlia (dahlia dissolved in 1% acetic acid); 5) the radulae were differentiated in 80% alcohol, and, at the same time, the rachidian and lateral teeth were dislodged from the radular membrane; 6) finally, the radulae were dehydrated through absolute alcohol and mounted in Euparal.

ORIENTATION AND MORPHOLOGY OF MURICID RADULAE

The radula of muricid gastropods may be formulated as 1-C-1. In the formative portion of the radula the lateral teeth overlap the rachidian so that the teeth form a long, narrow band. The rachidian teeth are hooked, with the tips of all cusps pointing posteriorly except when the odontophore is protruded. When the odontophore is protruded, the rachidian cusps are oriented anteriorly and the tips of the lateral teeth antero-laterally; in retraction the movement of the odontophore is reversed and the teeth are again oriented posteriorly (17).

The rachidian or central tooth, as in *Drupa ricina*, is 5-cusped (Fig. 1) with 1 central (CC), 2 lateral (LC), and 2 marginal (MC) cusps. The central cusp is simple and usually the longest and strongest of all the cusps. In some species the base of the central cusp projects strongly anteriorly in dorsal view (Figs. 1B and 3). This projection gives the radula the "doubly waved" configuration described by Cooke (7). The lateral cusps are either simple or furnished with medial and lateral denticles. The medial denticles (MD) are simple, either high or low on the cusp; when they are low on the cusp they appear to be separated from it. The lateral denticles (LD), situated between the lateral and marginal cusps, are variable in number and degree of separation from the lateral cusps; they may be either deeply cut or saw-like. The marginal cusps are also variable: prominent, knob-like, or indistinct. When the marginals are knob-like or indistinct, the rachidian is three-cuspid, as in the genera *Mancinella*, *Murex*, *Rapana*, etc.

The base (B) of the rachidian, where all the teeth are attached, is variable. In those species where the rachidians are closely set (Fig. 1C), the teeth have 3 sides; the anterior (AS) and posterior (PS) sides facing the posterior and anterior sides respectively of the succeeding rachidian, and the ventral side (VS) which is fixed

to the radular membrane. In those species in which the succeeding rachidians are widely spaced, the anterior and posterior sides are not obvious. The configuration of the ventral side is variable and probably different in different groups.

The lateral teeth are typically uniformly sickle-shaped, with a thick, broad base and a long process. Cooke pointed out that the lateral teeth are so similar that they offer little help in determining the relationships of the various forms (7). Cooke's generalization has been confirmed in the present study, except in the case of *Drupella cornus* (Figs. 33-35) which has distinctly serrated and tapering lateral teeth.

DESCRIPTIONS OF THE RADULAE

Genus *Chicoreus* Montfort

1. *Chicoreus torrefactus* (Sowerby). Figs. 2 and 3.

Rachidian 3-cusped. Lateral cusps with a strong denticle medially, no denticle laterally. All the cusps and denticles similar in shape. Outer margins slightly raised forming a hump. Anterior border of the base just opposite the central cusp and marginal humps protruding anteriorly resulting in the effect of 3 strong waves (Fig. 3). Posterior of base concave; ventral side projecting posteriorly.

Genus *Nassa* Roding

2. *Nassa francolinus* Bruguière. Figs. 4 and 5.

Rachidian 3-cusped. Central cusp long, narrow and sharply pointed, deeply set in the base so that it does not appear as long as the lateral cusps in dorsal view (Fig. 5). Lateral cusp long, tip pointing laterally. Medial denticles small and inclining medially. Another small denticle lies close to the inner base of the lateral cusps. Lateral side of the lateral cusps inclined toward the base; no trace of hump formation. Both anterior and posterior edges of the base almost straight (Fig. 4). Base with a shallow concavity

on its posterior surface (Fig. 5).

Remarks: Cooke described the great variety of lateral cusps present in *N. sertum* (Lamarck) (7). Specimens from Samoa and Durban have a long and sharp lateral and a small denticle lying close to the inner base of the lateral cusps, while others from Berbera (Cooke, *loc. cit.*) and Japan (Arakawa) (14) have small and blunt lateral cusps slanting medially. The irregularities in the teeth of this species are, as Cooke (*loc. cit.*) pointed out, probably due to environment and/or sexual dimorphism, neither of which have yet been studied in detail.

Genus *Morula* Schumacher

3. *Morula granulata* (Duclos). Figs. 6 and 7.

Rachidian 3-cusped. Central cusp narrow and sharp but not much long as the lateral cusps. Lateral cusps sharp and strong. Medial denticle strong; lateral denticles as 2 wrinkles. Angles of margin somewhat raised, forming a hump. Posterior side of base with a concavity as in *Chicoreus*.

Genus *Morulina* Dall

4. *Morulina anaxares* (Kiener). Fig. 8.

Rachidian 3-cusped. Central cusp long and sharp, strong at the base. Lateral cusp small, sharp and strong. Medial denticle close to the lateral cusps. No lateral denticles present. Base extremely wide. Posterior side of base with concavity like that of *Morula* and *Chicoreus*.

Genus *Cronia* H. and A. Adams

5. *Cronia margariticola* (Broderip). Fig. 9.

Rachidian similar to that of *Morulina anaxares* except that the fine medial denticle is equidistant from both the central and lateral cusps, and the lateral cusps are narrower, with the tip curved away from the central cusp.

Genus *Rapana* Schumacher

Rachidian 3-cusped. Lateral cusps not greatly shorter than the central cusp.

Medial denticle high on the lateral cusps (*Figs. 10 and 11*); lateral denticles absent but there are wrinkles on the sides of the lateral cusps and at the marginal angles. Both anterior and posterior base lines almost straight.

6. *Rapana bezoar* (L.). *Fig. 10.*

Central cusp pointing smoothly upward. Wrinkle medial denticle situated one-half way up the lateral cusps. Lateral outline irregular, especially at the base.

7. *Rapana rapiformis* (Born). *Fig. 11.*

Central cusp stouter and shorter than those of *R. bezoar*. Wrinkled medial denticle small and high, almost reaching the tip of the lateral cusps.

Genus *Murex* Linné

Rachidian 3-cusped. Medial denticle free from the lateral cusps; lateral denticles absent. Base broad; anterior basal line waved.

8. *Murex triremis* (Perry). *Fig. 12.*

Tips of lateral cusps directed slightly laterally. Medial denticle large and strong, well separated and equidistant between central and lateral cusps. Lateral side of lateral cusps inclined toward the marginal angle.

9. *Murex trapa* (Roding). *Fig. 13.*

Lateral cusps broad and stout at the base. Medial denticle stout and small, not separate from either the central or lateral cusps. Lateral side of lateral cusps inclining steeply and levelling off toward the rounded marginal angle.

Genus *Mancinella* (Link)

10. *Mancinella mancinella* (L.). *Fig. 14.*

Rachidian 3-cusped. Central cusp long, broad and thick. Lateral cusp slender and much smaller than central cusp. Medial denticle blunt, half way up the lateral cusp, situated medio-posteriorly to lateral cusps. Configuration of basal side of base oval.

11. *?Mancinella tuberosa* (Roding). *Figs. 15 and 16.*

Rachidian 3-cusped. Central cusp broad at base, tip pointed. Lateral cusps well-

separated from central cusps, with a small, sharply pointed medial denticle between lateral and central cusps. Lateral side of lateral cusps inclining steeply toward marginal angles. Configuration of base is rectangular.

Genus *Drupa* Roding

Rachidian 5-cusped. Lateral cusps not, as a rule, shorter than central cusp. Both medial and lateral denticles either deeply cut as in *D. morum* and *D. speciosa* or merely claw-like as in *D. ricina* and *D. arachnoides*. Marginal cusps predominant.

12. *Drupa ricina* (L.). *Fig. 17.*

Central cusp relatively longer than lateral cusps. Lateral cusps pointing laterally. Medial denticle strong, situated almost at the level of the tip of the lateral cusps. Four lateral denticles, the inner one ascending the cusps.

The dorsal view of the rachidian was described in detail by Wu (17).

13. *Drupa arachnoides* (Lamarck). *Fig. 18.*

Rachidian similar to that of *D. ricina* except that there are 2 or 3 lateral denticles, the inner one ascending the cusp.

14. *Drupa morum* Roding. *Fig. 19.*

Central and lateral cusps almost equal in size. Medial denticle deeply cut by the central cusp. Four or 5 lateral denticles, the 2 inner denticles ascending the lateral cusps.

15. *Drupa speciosa* (Dunker). *Fig. 30.*

Rachidian in general similar to that of *D. morum*; it differs in that there are 3 denticles, the inner one ascending the lateral cusps.

Genus *Purpura* Bruguiere

Rachidian 5-cusped. Central cusp long and finely pointed. Lateral cusps broad and inclining laterally. Medial denticle conspicuous; lateral denticles deeply cut. Marginal cusps prominent and high. Configuration of anterior side of basal line concaves in the center (*Figs. 22 and 23*) while the posterior basal line is straight.

16. *Purpura panama* (Roding). *Fig. 22.*

Four lateral denticles, equidistant one

from another. Marginal cusps prominent, more or less pointing medially.

17. *Purpura luteostoma* (Holten). Fig. 23.

Rachidian similar to that of *P. panama* except that there are 6 or 7 lateral denticles, the outer 3 or 4 deeply cut and separated, the inner 2 or 3 ascending the lateral cusps. Marginal cusps blunt and pointing laterally.

Genus *Thais* Roding

Rachidian 5-cusped. Central cusp rather broad at the base and narrowing sharply toward the tip. Lateral cusps sharply pointed with a thumb-like medial denticle medially and with either deeply cut or wrinkle-like lateral denticles. Marginal cusps not prominent. Configuration of anterior basal line not waved as it is in *Purpura*.

18. *Thais kieneri* (Deshayes). Fig. 24.

Lateral denticles as 2 faint wrinkles. Marginal cusps distinct.

19. *Thais intermedia* (Kiener). Fig. 25.

Lateral cusps sharply pointed. Lateral denticles as faint wrinkles. Marginal cusps slightly humped or absent.

Remarks: The rachidian of *T. intermedia* agrees quite well to the figure 4, plate 6 of Arakawa (14) but differs in having faint wrinkles on the lateral side of lateral cusps.

20. *Thais distinguenda* (Dunker and Zelenbor). Fig. 26.

Three lateral denticles; inner denticle ascending the cusp. Medial denticle relatively large.

21. *Thais armigera* (Link). Fig. 27.

Six or 7 lateral denticles, the inner 3 merely wrinkles but ascending the cusp; outer 4 deeply cut.

Genus *Thaisella* Clench

The rachidian, in general, like that of *Thais* but differing in the following respects: 1) central cusp smoothly pointed at the tip; 2) medial denticles small and set low down; and 3) lateral denticles rather deeply cut.

22. *Thaisella gradata* (Jonas). Fig. 28.

Central cusp much longer than lateral cusps. Medial denticles extremely small. Four or 5 lateral denticles, the inner 2 ascending the cusp. Base as in *Thais*.

23. *Thaisella rugosa* (Born). Fig. 29.

Central cusp not much longer than lateral cusps. Lateral cusps widely separated from central cusp. Medial denticle with 2 or 3 minor denticles; 4 lateral denticles of which the inner 2 ascend the cusp. Marginal cusps relatively prominent. Base broad.

Genus *Drupina* Dall

24. *Drupina glossularia* (Roding). Figs. 20 and 21.

Rachidian 5-cusped and comb-like. Central cusp short and broad. Lateral cusps tridentate. Marginal cusps not prominent, usually like the lateral denticles. Four or 5 lateral denticle deeply cut, equidistant one from another.

The dorsal view of the rachidian (Fig. 21) shows an obtuse angle in the middle with its concavity facing anteriorly.

Genus *Drupella* Thiele

25. *Drupella cornus* (Roding). Figs. 31-35.

Rachidian (Figs. 31 and 32) 3-cusped, flat and triangular in shape. Central cusp (mesocone of Peile, 1939) stout and broad. Lateral cusp bifid and much smaller than the central cusp. Medial denticle slender, needle-like. Nine or 10 lateral denticles edging the triangular rachidian.

Lateral teeth (Figs. 33-35) long and slender, at least 3.5 times the height of the rachidian, serrated at the base for a short distance (Fig. 33), and the tip recurved and bifid (Figs. 34 and 35).

Remarks: The features of the lateral teeth are so peculiar that they may be incorporated into the generic description of *Drupella*. Arakawa reported that *Drupella* shows a remarkable sexual dimorphism (11), judging from his figures 6 to 15 of plate 6, the only specimen which I had available would be a female. The tiny specimen (18 mm in height) has a remarkably large radula.

DISCUSSION

The radulae examined in the present work agree with those described by Arakawa (11, 13-15) from Japan and with those of Cooke from different parts of the world (7). The general agreement indicates the constancy of radular configuration within a species. Cooke (*loc. cit.*) said "as regards synonymy and the correct naming of species I have thought it best to make but few rectifications, leaving the specimens on the slides to speak for themselves" (7). It would seem, therefore, that radular structure must be used not only in the diagnosis of species, but also in characterizing genera.

On the hypothesis that the radular structure of muricid gastropods can be used for the diagnosis of species, the sizes and sexes of specimens and the width of the radulae examined, were tabulated and compared with Arakawa's figures (11, 13-15). The comparison reveals that the greater the size of the animal, the greater the width of the rachidian. Size of radular teeth is, therefore, not a criterion on which to base specific determinations; however, it is suggested that in future work either animal size or shell size be stated with the radular description for reference in comparative studies.

The length of the radular ribbon appears to be related to the amount of work which has been done in feeding (5). The muricids typically possess a long radular ribbon, and in all cases examined the anterior portions were extensively worn.

The radulae of the muricid gastropods studied here can be divided into 2 main categories: those genera with 3-cusped rachidian—*Chicoreus*, *Nassa*, *Morula*, *Morulina*, *Cronia*, *Rapana*, *Murex*, *Mancinella*, *Drupella*, and those with 5-cusped rachidian—*Thais*, *Thaisella*, *Purpura*, *Drupa*, and *Drupina*. With respect to radular structure alone, *Morula* appears to be intermediate between the *Chicoreus-Morulina-Cronia* group and the *Thais-Thaisella-Purpura-Drupa* group. *Morula* resembles the former group in having 3 waves on the anterior

side of the rachidian, a concave posterior side, and all the cusps and median denticles sharply pointed, characters which Cooke (7) previously pointed out. On the other hand, *Morula* also resembles the *Thais* group in having lateral denticles or wrinkles and slightly humped marginal teeth.

Arakawa designated *M. granulata* as the type of the genus *Tenguella* because of the atrophied lateral denticles, the broad base, and the small, nodule-like marginal cusps (15). Remarking that his examination of the radula exactly corresponded with Cooke's description of animals from Ishipingo, Natal (7), Arakawa (*loc. cit.*) described the central cusp as very long, prominent, and thin (15). Actually, Cooke's description of *M. granulata* was as follows: "Central cusp short, not very thick; side cusps projecting well beyond it" while that for *M. tuberculata* was: "Central cusp remarkably short, blunt, almost equal in length to side cusp". My studies on *M. granulata* resulted in descriptions identical with those of Cooke (7). Since the radular teeth of *M. granulata* resemble those of *M. morum* Lamarck (7) which is a synonym of *M. uva* (Roding), the designated type of the genus *Morula*, I believe that *M. granulata* should be retained in the genus *Morula*.

Morula appears to be closely related to *Drupa*, and the rachidian of *Morula* may well represent a form in which the lateral denticles have degenerated becoming merely wrinkle-like, the medial denticles has separated out, and a pit or concavity has appeared on the posterior side of the base.

As Arakawa has pointed out, *Morula* also resembles *Thais*, not only in having certain radular characteristics in common (15), but also in their common possession of a biconical shell and extranuclear, lamellate operculum. *Thais*, in turn, resembles *Purpura* and *Thaisella*.

The shell feature of *?Mancinella tuberosa* is identical to that of *Purpura*

TABLE I

The comparison of the specimen size, sex and width of rachidian of muricid gastropods from Taiwan to those from Japan (Arakawa, 11, 13-15)

Name	Taiwan						Japan					
	Sp. no.	Sex	Shell size		No. of rows	Wid. of R. (mm)	Sp. no.	Sex	Shell size		No. of rows	Wid. of R. (mm)
			Height (mm)	Dia. (mm)					Height (mm)	Dia. (mm)		
<i>Chicoreus torrefactus</i>	115	—	68.4	—	330	0.18	—	—	—	—	—	—
<i>Nassa francolinus</i>	012	—	39.0	20.6	—	0.23	158	M	38.5	19.5	100	0.29
<i>Nassa francolinus</i>	—	—	—	—	—	—	159	F	41.9	23.0	137	0.26
<i>Morula granulata</i>	144	—	17.8	12.7	—	0.10	26*	F	16.5	11.0	—	0.077
<i>Morula granulata</i>	145	—	21.2	13.9	—	0.09	171*	F	16.6+	12.0	131	0.078
<i>Morula granulata</i>	166	—	20.1	13.4	—	0.09	172*	M	16.3+	13.9	148	0.070
<i>Morulina anaxares</i>	159	—	24.5	23.8	—	0.19	143	—	12.2	8.0	116	0.060
<i>Morulina anaxares</i>	—	—	—	—	—	—	144	—	10.3	8.0	132	0.059
<i>Morulina anaxares</i>	—	—	—	—	—	—	145	—	11.1	7.6	174	0.047
<i>Cronia margariticola</i>	123	F	22.5	13.0	—	0.18	25	F	23.0	12.5	—	0.153
<i>Cronia margariticola</i>	—	—	—	—	—	—	26	M	—	—	—	0.217
<i>Rapana bezoar</i>	062	F	59.4	44.0	136	0.33	—	—	—	—	—	0.31
<i>Rapana rapiformis</i>	101	M	51.4	47.9	170	0.29	—	—	—	—	—	—
<i>Murex triremis</i>	100	M	145.0	—	170	0.29	103	F	127.0	70.5	203	0.25
<i>Murex triremis</i>	—	—	—	—	—	—	104	M	112.0	72.7	170	0.22
<i>Murex irapa</i>	152	F	83.0	—	—	0.26	—	—	—	—	—	—
<i>Mancinella mancinella</i>	011	—	—	—	—	0.16	—	—	—	—	—	0.18
? <i>Mancinella tuberosa</i>	047	M	51.4	36.3	204	0.25	—**	M	40.0	31.2	—	0.22
? <i>Mancinella tuberosa</i>	—	—	—	—	—	—	—**	M	42.0	33.0	—	0.24
<i>Drupa ricina</i>	086	F	20.5	18.5	214+	0.08	64†	—	22.1	18.9	—	0.102
<i>Drupa ricina</i>	087	M	20.4	19.3	215	0.08	—	—	—	—	—	—
<i>Drupa arachnoides</i>	079	F	28.5	—	241	0.11	20††	M	26.7	25.0	—	0.089
<i>Drupa arachnoides</i>	080	M	23.2	—	192	0.09	—	—	—	—	—	—
<i>Drupa morum</i>	073	F	35.4	—	255	0.16	170	F	35.0	31.0	—	—
<i>Drupa speciosa</i>	071	F	33.0	27.0	270	0.16	—	—	—	—	—	—
<i>Drupa speciosa</i>	072	M	30.9	28.6	315	0.15	—	—	—	—	—	—
<i>Purpura panama</i>	019	M	—	—	—	0.22	—	—	—	—	—	0.35
<i>Purpura luteostoma</i>	105	F	43.4	—	215	0.17	—	F	40.7	26.1	237	0.25
<i>Thais kieneri</i>	048	F	40.4	35.9	204	0.18	—	—	—	—	—	—
<i>Thais intermedia</i>	053	M	31.0	21.5	223	0.15	—*†	M	26.2	24.0	—	0.19
<i>Thais intermedia</i>	—	—	—	—	—	—	—*†	F	32.3	20.5	—	0.17
<i>Thais distinguenda</i>	049	M	30.0	20.6	260	0.14	—	—	32.0	26.3	—	0.14
<i>Thais distinguenda</i>	—	—	—	—	—	—	—	M	34.6	27.7	—	0.17
<i>Thais armigera</i>	127	M	65.0	47.0	274	0.22	—	M	71.0	57.0	228	0.22
<i>Thais armigera</i>	128	M	55.2	39.0	265	0.20	—	M	—	—	—	0.16
<i>Thais armigera</i>	129	M	43.2	34.1	204	0.17	—	—	—	—	—	—
<i>Thaisella gradata</i>	102	M	37.4	22.0	175	0.14	—	—	—	—	—	—
<i>Thaisella rugosa</i>	109	F	31.4	19.0	209	0.14	—	—	—	—	—	—
<i>Drupina glossularia</i>	069	M	20.3	24.1	254	0.11	111	M	24.0	24.1	339	0.102
<i>Drupina glossularia</i>	070	F	27.2	26.0	251	0.11	19	F	27.8	28.0	—	0.115
<i>Drupella cornus</i>	090	—	18.0	10.7	—	0.11	90	F	29.3	17.0	—	0.15
<i>Drupella cornus</i>	—	—	—	—	—	—	91	M	—	—	—	0.24

R. = rachidian; * = *Tenguella granulata*, Arakawa (15); ** = *Mancinella tuberosa*, Arakawa (13);

† = *Drupa albolabris*, Arakawa (15); †† = *Drupa ricina*, Arakawa (15); *† = *Mancinella intermedia*, Arakawa (13).

(*Thalessa*) *pica* of Hirase (pl. 4, fig. 34) (18) and also somewhat similar to that of

Thais (*Mancinella*) *deltoidea* of Clench (pl. 39, figs. 3 and 9) (19). Cooke's description

on *Thais pica* (7) quite agrees to my result on *?M. tuberosa* from Taiwan. *Thalessa* H. and A. Adams, 1853, was treated as a synonym of *Mancinella* Link, 1807 (19), but, Dodge inclined to separate *Mancinella* and *Thalessa* by the characteristics as follows (*loc. cit.*): "the aperture in *Mancinella* is closely lirate, whereas in *Thalessa* this is smooth and decorated with broad bands of brown. Moreover, in *Thalessa*, the inner aspect of the lip is provided with a series of pearly nodules, which are lacking in *Mancinella*" (20).

The radula of *?M. tuberosa* (Figs. 15 and 16) is quite different from that of specimens representing species of the type of the genus, *M. mancinella* (Fig. 14). In *?M. tuberosa* the fine medial denticle is equidistant from the central and lateral cusps while in *M. mancinella* the medial denticle is attached to the lateral cusp, the central cusp is massive, and the base of the rachidian is oval (Fig. 14). Furthermore, the shell feature of *?M. tuberosa*, lacking the nodules at the outer lip of aperture, is apparently not that of *Thalessa*. On the bases of radular and shell structures, the Taiwan specimens of what has been called *M. tuberosa* (13) should perhaps be transferred to the genus other than the genera of *Mancinella* and *Thalessa*.

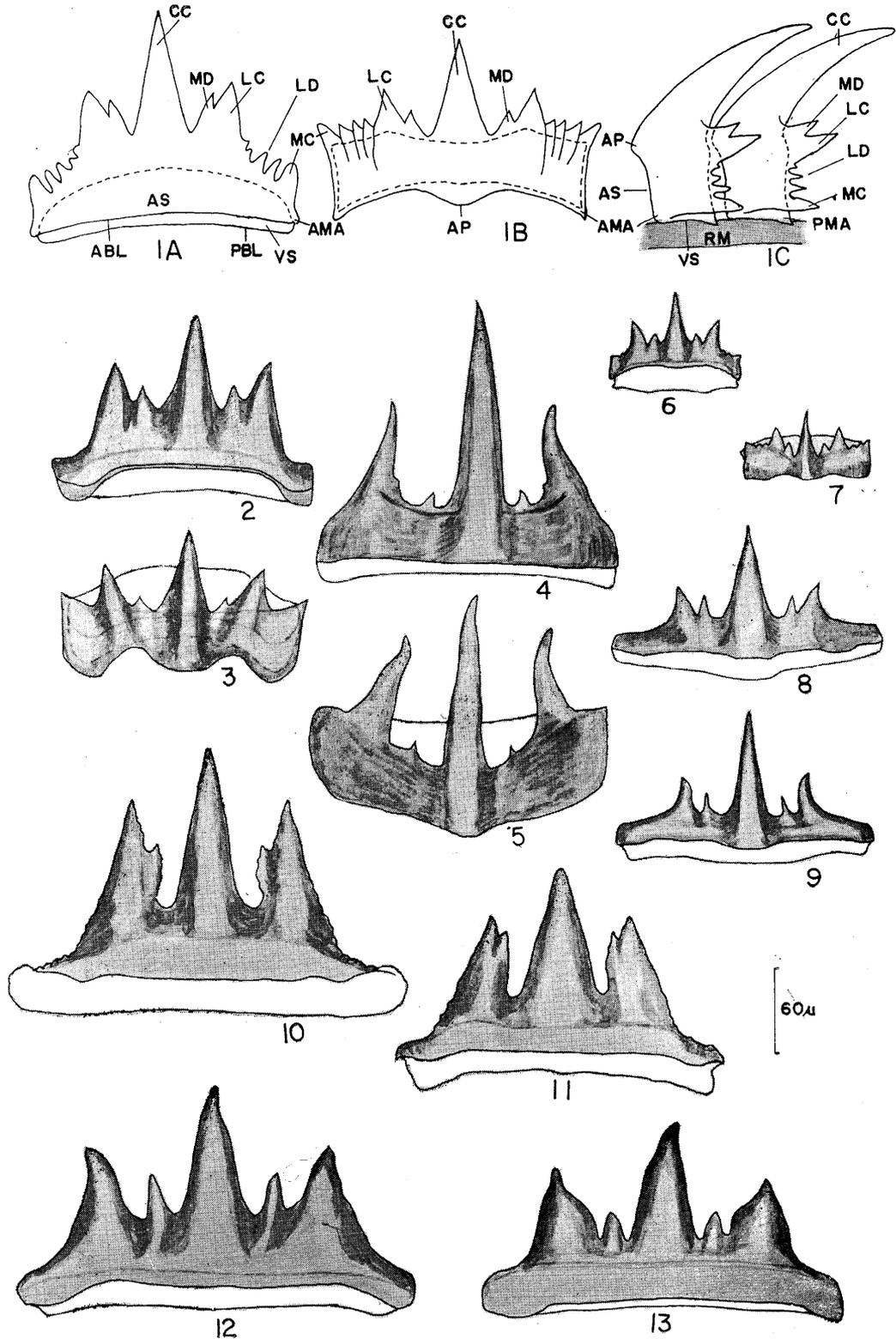
The radula of *Mancinella mancinella* is similar to that of *Drupella* in that the rachidians of both have a massive, flat central cusp. In *Drupella*, with its peculiar serrated lateral teeth (Figs. 33 and 35) there is apparently an interesting feeding adaptation.

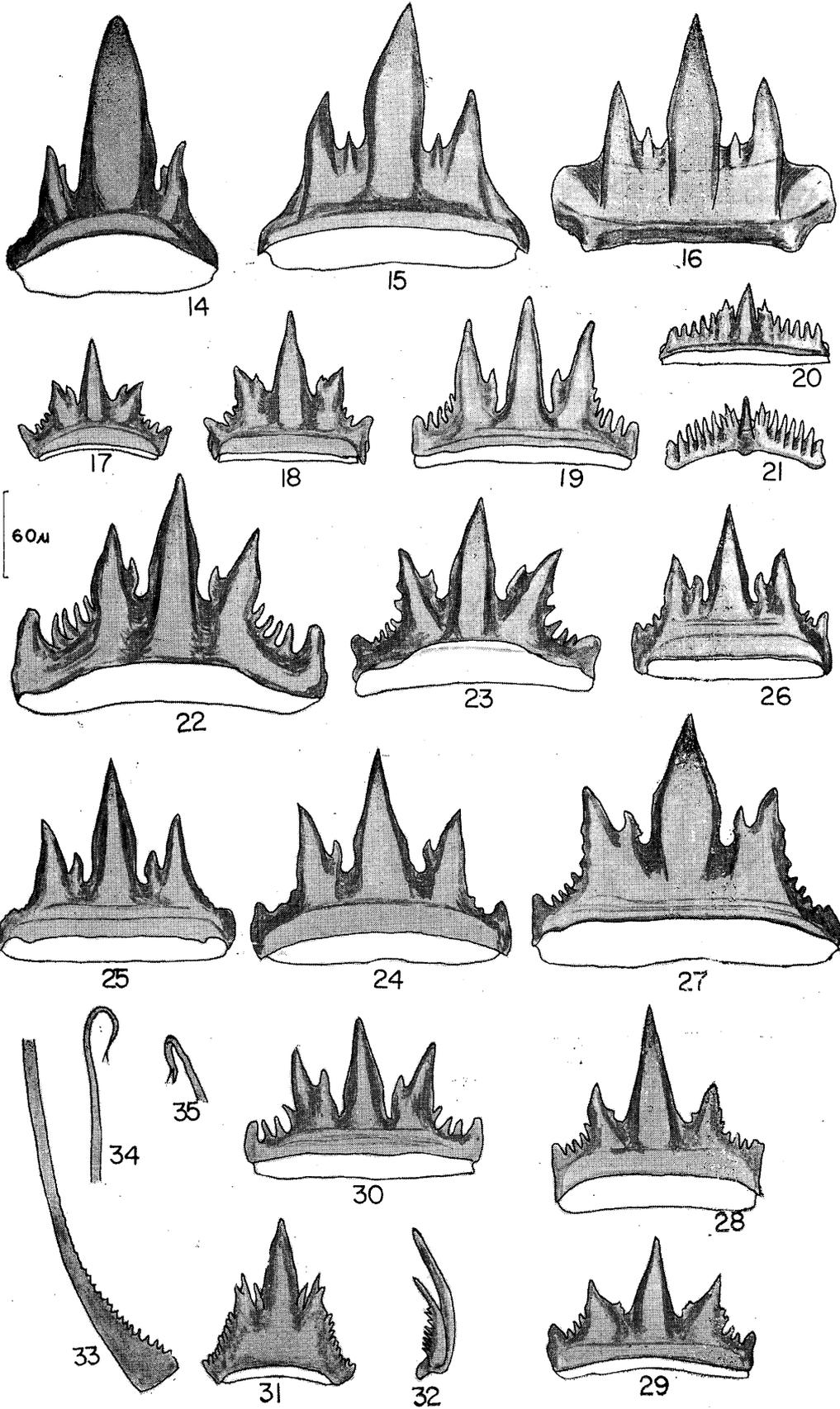
Nassa has a peculiar radula which shows no similarities to other members of the family in so far as at the present work goes. The presence of a concavity on the posterior side of the base suggests it may be rather close to *Chicoreus* and *Morula*, however.

Drupa can be divided into 2 groups, as suggested in the previous section above. *D. ricina* and *D. arachnoides* fall in 1 group, while *D. morum* and *D. speciosa* represent the other. Cooke's (7) description of the radula of *D. clathrata* (7) suggests it should be associated with *D. ricina* and *D. arachnoides*, while *D. horrida*, *D. hystrix*, *D. affinis*, and *D. iodostoma* (7) appear to be associated with *D. morum* and *D. speciosa*.

D. ricina and *D. arachnoides* have long been confused, the latter often considered a subspecies of *D. ricina*. Conchologically *D. arachnoides* is almost identical with *D. ricina*, differing only in having a yellow ring around the aperture of the shell.

- Fig. 1. Semidiagrammatic figures of rachidian tooth of *Drupa ricina*.
 IA anterior view (dotted line indicates the configuration of AS of rachidian base)
 IB dorsal view (dotted line indicates the configuration of VS of rachidian base)
 IC lateral view (dotted line indicates the configuration of posterior side of rachidian base)
 ABL, anterior basal line; AMA, anterior marginal angle; AP, anterior projection of central cusp; AS, anterior side of the rachidian base; CC, central cusp; LC, lateral cusp; LD, lateral denticle; MC, marginal cusp; MD, medial denticle; PBL, posterior basal line; PMA, posterior marginal angle; RM, radular membrane; VS, ventral side of rachidian base.
- Fig. 2. Rachidian tooth of *Chicoreus torrefactus* (anterior view).
 Fig. 3. Rachidian tooth of *Chicoreus torrefactus* (dorsal view).
 Fig. 4. Rachidian tooth of *Nassa francolinus* (anterior view).
 Fig. 5. Rachidian tooth of *Nassa francolinus* (dorsal view).
 Fig. 6. Rachidian tooth of *Morula granulata* (anterior view).
 Fig. 7. Rachidian tooth of *Morula granulata* (dorsal view).
 Fig. 8. Rachidian tooth of *Morulina anaxares* (anterior view).
 Fig. 9. Rachidian tooth of *Cronia margariticola* (anterior view).
 Fig. 10. Rachidian tooth of *Radana bezoar* (anterior view).
 Fig. 11. Rachidian tooth of *Rapana rapiformis* (anterior view).
 Fig. 12. Rachidian tooth of *Murex tiremis* (anterior view).
 Fig. 13. Rachidian tooth of *Murex trapa* (anterior view).





Both forms occur in the same habitat. The only difference in radular structure appears to be in the number of lateral denticles. Cytological and biochemical studies of both forms are needed before their taxonomic status can be properly ascertained.

Though in shell structure *Drupina* is similar to *Drupa*, its radular structure is different. This may be a case where there has been parallel development of shells in different lines of muricid gastropods.

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Fig. 14. Rachidian tooth of *Mancinella mancinella* (anterior view).

Fig. 15. Rachidian tooth of ?*Mancinella tuberosa* (anterior view).

Fig. 16. Rachidian tooth of ?*Mancinella tuberosa* (ventral view).

Fig. 17. Rachidian tooth of *Drupa ricina* (anterior view).

Fig. 18. Rachidian tooth of *Drupa arachnoides* (anterior view).

Fig. 19. Rachidian tooth of *Drupa morum* (anterior view).

Fig. 20. Rachidian tooth of *Drupina glossularia* (anterior view).

Fig. 21. Rachidian tooth of *Drupina glossularia* (dorsal view).

Fig. 22. Rachidian tooth of *Purpura panama* (anterior view).

Fig. 23. Rachidian tooth of *Purpura luteostoma* (anterior view).

Fig. 24. Rachidian tooth of *Thais kieneri* (anterior view).

Fig. 25. Rachidian tooth of *Thais intermedia* (anterior view).

Fig. 26. Rachidian tooth of *Thais distinguenda* (anterior view).

Fig. 27. Rachidian tooth of *Thais armigera* (anterior view).

Fig. 28. Rachidian tooth of *Thaisella gradata* (anterior view).

Fig. 29. Rachidian tooth of *Thaisella rugosa* (anterior view).

Fig. 30. Rachidian tooth of *Drupa speciosa* (anterior view).

Fig. 31. Rachidian tooth of *Drupella cornus* (anterior view).

Fig. 32. Rachidian tooth of *Drupella cornus* (lateral view).

Fig. 33. Basal portion of lateral tooth of *Drupella cornus*.

Figs. 34 and 35. Tips of lateral tooth of *Drupella cornus*.

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