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A Comparative Study of Two Species of Viviparidae (Mollusca: Prosobranchia): *Cipangopaludina chinensis malleata* and *C. japonica* in Korea

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= 국문 요약 =

한국산 논우렁이 2종의 형태학적 비교연구

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한국에 분포된 논우렁이과(family Viviparidae)에는 논우렁이(*Cipangopaludina chinensis malleata*)와 큰논우렁이(*C. japonica*) 두 종으로 알려져 있으나 그 형태적 차이점을 구별하기는 쉽지 않다. 형태학적 주요 차이점은 논우렁이에서 패각의 봉합이 깊어 나탑이 뚜렷하고 둥글며 spire angle이 약 62° - 66°인데 비해, 큰논우렁이는 봉합이 깊지 않아 나탑이 뚜렷하지 못하고 밋밋하며 각 나층에 두개씩의 나륵이 있는 점과 spire angle이 약 58° - 61°인 점이다. 유생낭 속의 유패에서의 형태적 차이점을 보면 논우렁이는 각정 부분이 낮아 둥글고 큰논우렁이는 각정 부분이 길어 각을 이루는 것이 특징이다. 한편, 연체부의 해부학적 특징들도 매우 유사하나, 우선 연체부의 체색에서 차이를 보이고 있다. 즉, 논우렁이의 연체부 전체가 연노랑색인데 비해 큰논우렁이는 연한 백색이다. 소화기관과 생식기관에서는 2종의 암, 수 모두에서 특이할만한 차이점을 찾아 볼 수 없으나 논우렁이는 큰논우렁이에 비해 전반적으로 크고 긴 기관들을 갖고 있었다. 논우렁이와 큰논우렁이 모두에서 1M, 1OL, 1IL, 1C, 1IL, 1OL, 1M의 치설 배열을 보였으나 분치(cusp) 배열이 다소 상이하였으며, 논우렁이 개체군 사이에도 분치 배열의 상이점이 관찰되었다. 그러나 위의 두 종은 형태적으로 유사성이 높기 때문에 β-분류 및 γ-분류로 그 체계를 확실히 구명하여야 할 필요성이 인정된다.

Key words : *Cipangopaludina chinensis malleata*, *Cipangopaludina japonica*, Viviparidae, Radula, Anatomy

INTRODUCTION

The snails of the family Viviparidae are common and wide-spread in the Asian countries and are the dominant group of freshwater gastropods in Korea. They are commonly called as "rice field snails" in Korea, and widely distribute in rice fields, ponds, rivers and many other kinds of water bodies. These snails are large in size, easily found, and edible as a food source in Korea. They also play an important role as molluscan intermediate hosts of some human trematode parasites. However, these snails have been little known of their biology.

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The family Viviparidae was established mainly on the basis of shell morphologies by Gary (1847), and a systematic study of this family has been done using the shape of radulae by Thiele (1929). Descriptions of shell morphologies and the geographical distribution of a Korean rice field snail [*Viviparus* (*Cipangopaludina*) *chinensis malleatus* (Reeve)] were made by Shiba in 1935. Only two viviparid species, *Cipangopaludina chinenesis malleatus* (Reeve), 1860 and *C. japonica* Martens, 1863 have been reported so far in Korea; however, the systematic problems of these snails have not been solved (Yoo, 1976; Kwon and Habe, 1979; Kwon and Choi, 1982; Burch *et al.*, 1987; Je, 1989; Kwon, 1990; Kwon *et al.*, 1993).

The purpose of this study was to ensure the taxonomic positions of genus *Cipangopaludina* in Korea through conchological and anatomical studies.

MATERIALS AND METHODS

Snail specimens of *C. chinensis malleata* used in this study were from the localities at Chunchon, Kangweon-Do and Kimhae, Kungsangnam-Do and those of *C. japonica* were only from Kimhae, Kyungsangnam-Do.

Ten specimens each in both male and female snails were used for the shell measurements with a vernier caliper. The parameters for measurements were shell length, shell width, shell height, aperture length, aperture width and shell angle.

Observations on the external characteristics of the whole animals and each organ system of the snails were made only on living animals without their shells. External pigmentation of the various parts of the snail bodies, sizes, proportions and relative positions of the body parts were mainly taken care during the period of morphological observations.

More than 20 living specimens for each taxon were dissected for anatomical observations. Internal anatomies of the snails were made with live, unrelaxed specimens. Dissections were done under a Nikon stereoscopic microscope at magnifications of 10-20 X. Drawings were made with the aid of a camera lucida attached to a Wild M-5 stereoscopic microscope.

The radular were prepared for scanning electron microscopy by macerating fresh buccal masses in a 10% potassium hydroxide solution for 24 hrs at room temperature and then removing the radulae from the disintegrating muscle tissues and adherent membranes of the buccal mass. Each separated radula was placed in a vial containing 70% ethanol and cleansed in an ultrasonic cleaner for 5 15 sec. and then secured with double sticky tape on an SEM stub (a drop of double distilled water was first placed on the tape on the stub, and the radula was transferred to the tape with a pipette; the radula was spread out with the aid of a dissecting microscope, microforceps and fine brush; when the radula was in the proper position on the stub, excess water was removed with a brush or capillary tube). The completely dried radulae were stored in a dust-free container until the gold coating was applied. The gold-coated radulae were observed with a JEOL JSM-U3 scanning electron microscope (Chung, 1984).

RESULTS

1. Shell morphologies

***Cipangopaludina chinensis malleata* (Reeve), 1863**
(Figs. 1, 2)

The shell is large in size, moderately thick, globose with impressed sutures. The size of full-grown shells is longer than 60 mm. There are 5 ½ or 6 whorls of which one or two are often eroded. The body whorls are well rounded. The shell is mainly greenish-brown in color. The sculpture of surface consists of numerous, oblique and longitudinal ridges. The operculum is large and trans- parent, broadly ovate and concave. It is also concentric with the parietal margin. The spire is globosely conic and spire angle is 62°to 66°. The juveniles have two or three hair lines on the surface

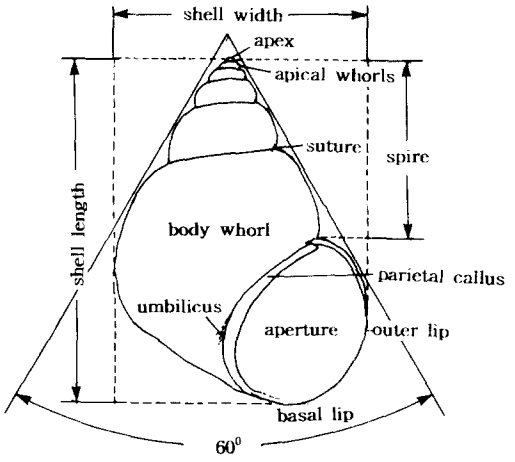

Fig. 1. Shell terminology of genus *Cipangopaludina*.

of shells. Mean number of embryos in the female brood pouch was ca. 60. The young shells are also ovate in shape. Conchological measurements in this study are presented in Table 1.

***Cipangopaludina japonica* Martens, 1860** (Fig. 3)

The shell is relatively large in size, moderately thick, subglobose with shallow sutures. The mean size of full-grown shells is ca. 48 mm long. There are about 5 or 5 ½ whorls. The body whorl is quite convex in obtuse angle and it has the faint growth lines. The shell is yellowish brown or olive-brown in color. The aperture is ovate with white-edged peristome. The operculum is concentric with the parietal margin. Mean number of embryos in the female adults was ca. 55. The apexes of young shells are much more conic. The juveniles also have two or three hair lines on the shell surface. The columella is moderately thick and white-colored. The umbilicus is less distinct as compared with that of *C. chinensis malleata*. The outer lip of aperture is thin and weak. The spire is straight with spire angle of 58°to 61°.

2. Anatomical studies

***Cipangopaludina chinensis malleata* (Reeve), 1863** (Figs. 4, 5)

Table 1. Shell characters of *C. chinensis malleata* and *C. japonica*

Characters	*C. chinensis malleata**	*C. japonica**
Adult shell		
Shell length	60 mm	48 mm
Shell width	36 mm	32 mm
No. of whorls	5 ½ or 6	5 or 5 ½
Spire angle	62-66°	58-61°
Aperture length	27 mm	23 mm
Aperture width	24 mm	20 mm
Operculum shape	concentric	concentic
Suture	well-impressed	shallow
Umbilicus	distinct	less ditinct
Body whorl	broadly oval	obtuse angle
Spire	globose	straight
The juveniles		
Mean No. of embryos	60	55
Shell length	5.2 mm	5.5 mm
Shell width	6.2 mm	6.1 mm

* Measurements were made ten specimens each in both male and female snails.

The gross anatomy of males of *C. chinensis malleata* was done, and its dorsal view is shown in Fig 4. The animal has large, thick head and foot. The color is blackish above and yellowish underneath. The mantle surrounds the neck and head-foot region of the snail. The mantle is dark gray or blackish in color. It protects the neck and the anterior organs, especially the head, foot and sensory organs. It also acts as a buffer between the hard calcareous shell and the animal itself, spreading like a cushion throughout the entire inner surface of the body whorl. In live specimens the mantle may be seen adhering closely to the inner surface of the body whorl. The collar or anterior margin of the mantle is smooth and surrounds the edge of the

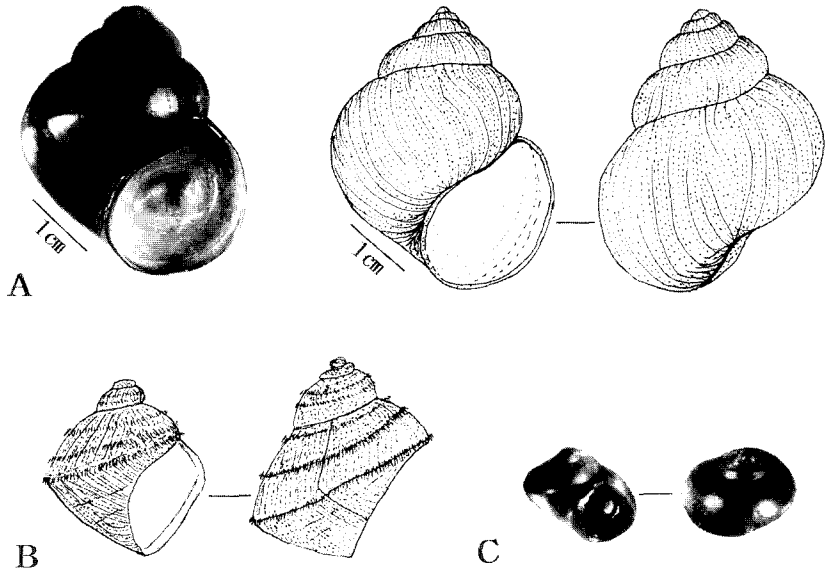

Fig. 2. The shells of *C. chinensis malleata:* (A) adult shells, (B) young shells, (C) embryos

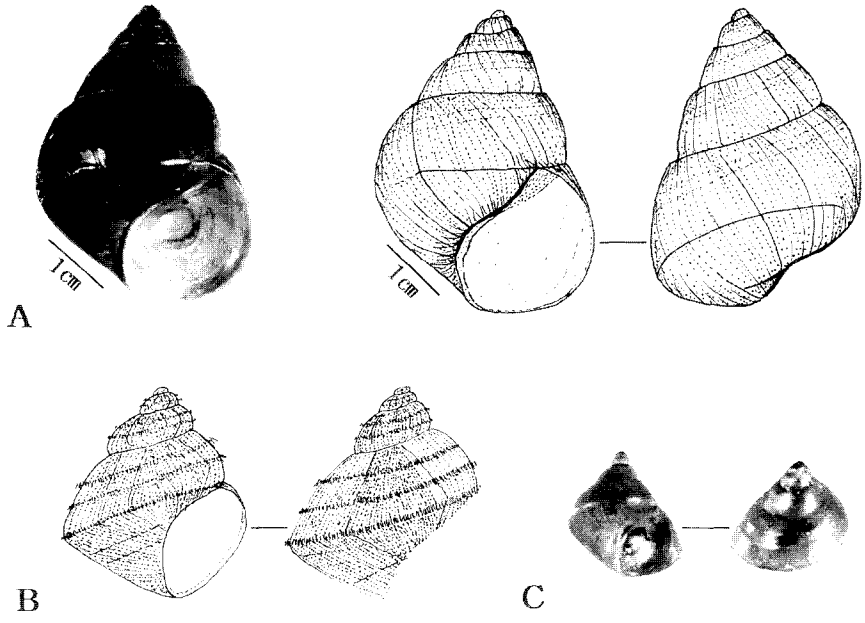

Fig. 3. The shells of *C. japonica:* (A) adult shell, (B) young shells, (C) embryos

aperture. The space between the neck, the head-foot region, and the mantle is called the mantle cavity. The ctenidium and osphradium are located in this cavity. The tentacles on the anterior dorsal head are

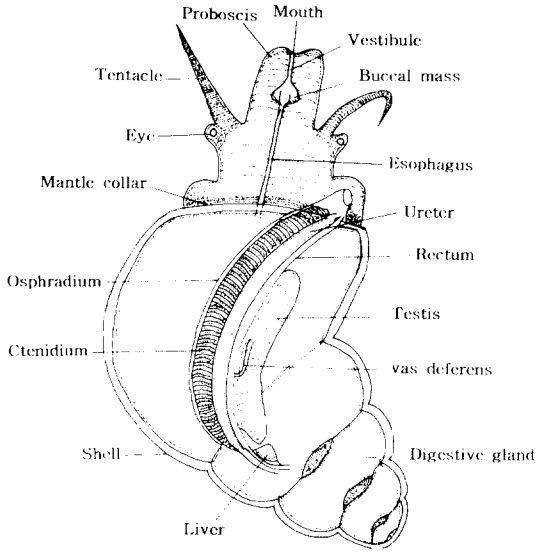

Fig. 4. Dorsal view of a male of *C. chinensis malleata.*

elongate (ca. 15 - 20 mm in length) and their bases are wide (ca. 2.1 mm in size). They point forward and are capable of considerable extension and contraction. The right side of tentacles is modified as a penis sheath and usually bent down in male specimens. When the snail is active, the tentacles generally extend fully.

The eyes are located at the outside of the predominantly swollen base of the long tentacles. Ctenidium in manner of a comb is well developed and runs parallelly with kidney, uterus and large intestine in dorsal surface of mantle cavity. The large ctenidium has many numerous filaments (ca. 32 mm long; ca. 8 mm wide). The genital pore and anus are located at the edge of mantle cavity (Fig. 5).

The features of various organs are described in Fig. 5. The excretory system is composed of the kidney and ureter and its pore. The kidney is large, flat and opaque white to light gray in color. It is made up of a series of leaf like fused lamellae and covered with a thin layer of connective tissue. The kidney is closely associated with the edge of the anterior portion of the ureter and ctenidium. The osphradium as a sensory role is found in the mantle cavity to the left of the ctenidium. The opening of the ureter in the edge of mantle cavity is narrow. The tubular heart with 2 chambers, an anterior auricle and posterior ventricle, lies at the apical end of the ctenidium. The auricle is thin walled, white and oval in outline. The shape of the thick ventricle is more or less tube-like. Two vessels enter the anterior end of the auricle: the main and larger vessel which is the "efferent ctenidial sinus" draining blood from the gills and to the antero-dorsal portion of the mantle fold, and a smaller vessel which is the "efferent renal sinus" and comes from the kidney. At the posterior end of the ventricle leaves the large, short aortic trunk which immediately divides into 2 main vessels supplying blood to the various organs.

No significant difference was found between the alimentary systems of *C. chinensis malleata* and *C. japonica*, excepting that the organs of the alimentary tract of *C. chinensis malleata* is relatively larger than those of *C. japonica*. The following structures are parts of the alimentary tract: mouth, pallial duct, esophagus, stomach, intestine, anus. The other attached organs are: salivary gland, buccal mass, digestive gland (liver), jaw and radula. The thickly musculated proboscis was a little extended to the anterior dorsal head. The mouth is a narrow slit-like opening at the anterior end of the proboscis and connected to the buccal mass and esophagus. The most prominent pair of nerve centers in the antero-dorsal part of these snails are the cerebral ganglia. They are located on each side of esophagus and are connected to each other by a commissure which horizontally crosses the dorsal portion of the esophagus. This commissure is short, thick, and wide, with the narrowest part in the middle. The radulae were situated in the narrow, elongate buccal mass. The esophagus proceeds in a more or less straight line from the posterior end of the buccal mass to the

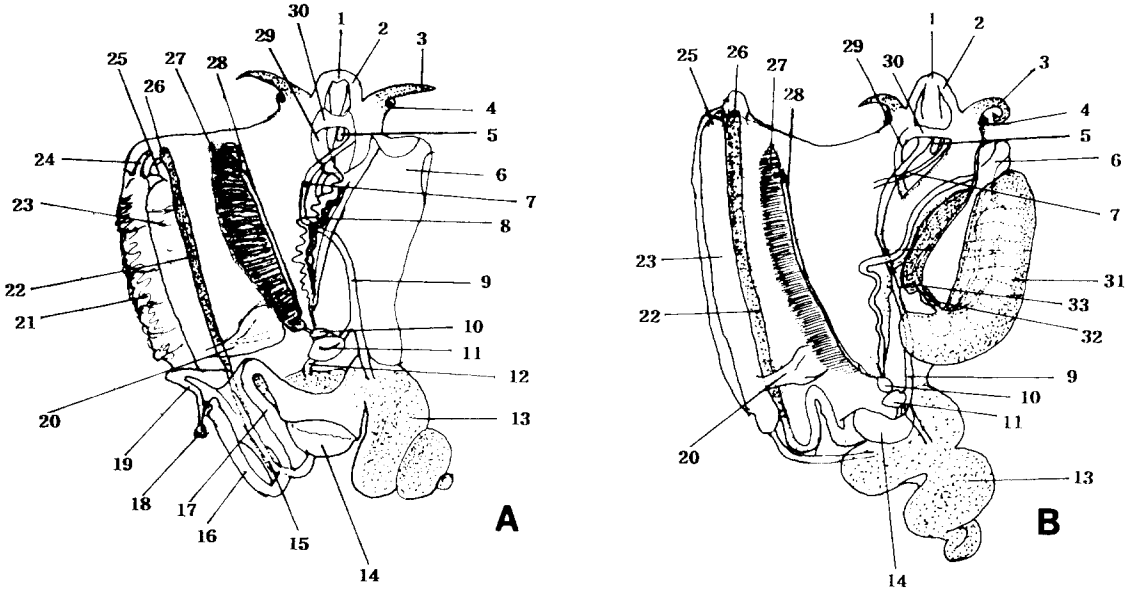

Fig. 5. Anatomy of *C. chinensis malleata:* (A) female, (B) male.
Terminologies of organs in Figs. 5, 6: 1. mouth 2. proboscis(snout) 3. tentacle 4. eye 5. radula 6. siphon 7. pallial duct 8. septum 9. esophagus 10. auricle 11. ventricle 12. posterior auricle 13. digestive gland 14. liver 15. intestine 16. receptaculum seminis 17. albumin gland 18. ovary 19. oviduct 20. kidney 21. uterus 22. rectum 23. ureter 24. uterus aperture 25. orificium ureteris 26. anus 27. ctenidium 28. osphradium 29. esophageal ganglion 30. cerebral commissure 31. testis 32. vas deferens 33. prostate

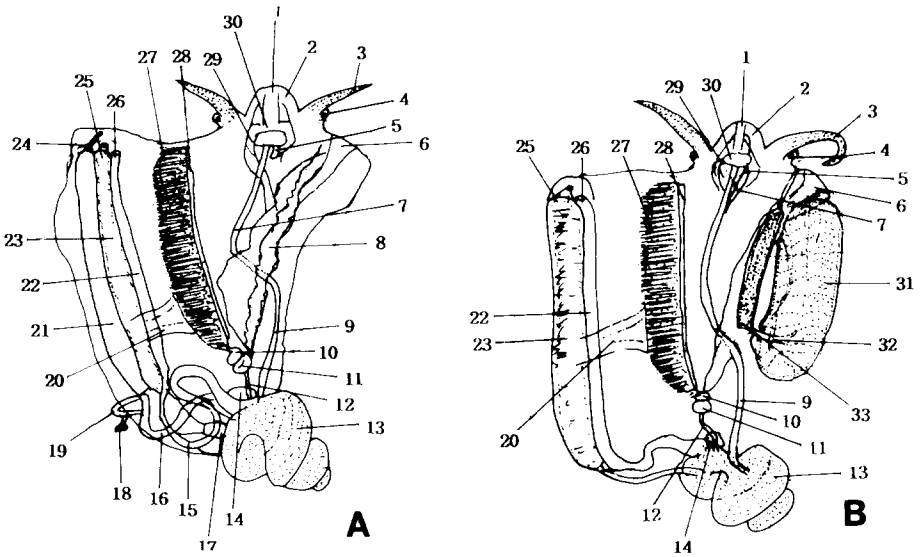

Fig. 6. Anatomy of *C. japonica:* (A) female, (B) male.

bag-shaped stomach on the ventral side. The digestive gland is a large organ, which consists of a large number of yellowish or light brown tubules with numerous scattered dark pigments. The intestine runs to the rectum and anus. The esophagus extends to the stomach from the lateral left side of the animal, and is twisted at the stomach region. The more or less straight intestine leaves to the dorsal, right side of the animal. The rectum is located at the edge of the right side of the main body whorl at the edge of the mantle.

The genus *Cipangopaludina* is ovoviviparous and dioecious. The female reproductive organs consist of the receptaculum seminis, albumin gland, ovary and oviduct. The male reproductive organs consist of the testis, vas deferens and prostate duct. Except for the sizes of organs, the system is identical in *C. chinensis malleata* and *C. japonica*. The ovary is situated on the visceral hump, connects to albumin gland and runs down to the uterus. The oviduct runs anteriorly from the gonad. The ovary is multibranched (the average length of ca. 1.5 mm; the average width of ca. 0.71 mm), and embedded in the ventral parts of digestive gland (Fig. 5). The male specimens are easily distinguished by their modified right tentacles, which serves as a copulatory organ. The testis is seen like a kidney bean, started from the side of right tentacle to first whorl. The color of testis is a light or pale yellow, which, during the breeding season becomes bright golden yellow due to the presence of pigmented granules. The average size of gonad is very large with the mean length of ca. 30 mm (26 - 35 mm in range), and with the mean width of ca. 8 mm (5-9 mm in range). Sperms from the gonad travel via the vas deferens to the prostate, enter the prostate, and leave through the anterior portion of the vas deferens which leads into the base of the verge. The prostate is a rod-shaped organ, yellowish in color, situated right portion in the gonad. The prostate is 13 - 18 mm long and about 4 mm in the greatest width. When the dorsal mid-line of the rostrum is opened, cerebral ganglion and cerebral commissure are observed.

***Cipangopaludina japonica* Martens, 1860** (Fig. 6)

The position and arrangement of organs in this species are the same as those of *C. chinensis malleata*. Differences between 2 species are mainly structural or dimensional modifications of homolo gous organs. The organ systems of *C. japonica* are presented in Fig. 6.

The ovary is multibranched and the average length of this organ is about 1.5 mm and the width is 0.71 mm at the widest portion. The ovary is embedded in the ventral tissues of the digestive gland.

The testis appears when viewed through the ventral epithelium of the coiled body whorl. The shape of this organ is like kidney bean, and yellowish or dark brown in color. This organ is a little smaller than that of *C. chinensis malleata*. The length of the gonad is 27 mm and the width is 6.8 mm. The prostate is 11 - 15 mm in length and 4 - 7 mm in width. The relationship of the anterior and posterior portions of the vas deferens to the prostate is the same as that found in *C. chinensis malleata*.

There are no remarkable differences in each organ between *C. chinensis malleata* and *C. japonica*; however, the pigmentation of general organs of *C. chinensis malleata* is a little more yellowish and darker than in *C. japonica*.

3. Observations of radulae

***Cipangopaludina chinensis malleata* (Reeve), 1863** (Table 2, Fig. 7)

In general, the radular teeth of the Korean rice field snails examined for this study show a pattern having 1 central tooth (C), and 1 inner lateral tooth (IL), 1 outer lateral tooth (OL) and 1 marginal tooth (M) on each side of the central tooth on a single horizontal row. The formula of the radular arrangement is as follows: 1M, 1OL, 1IL, 1C, 1IL,

Table 2. Formulae of cusp arrangement in two species of *Cipangopaludina*

Species	Teeth†			
	C	IL	OL	M
C. chinensis malleata from Sorae	5-1*-5	4~6-1*-4~6	3~4-1*-3~4	11
C. chinensis malleata from Changweon	5-1-5	4~5-1-4~5	3~4-1-3~4	11
C. chinensis malleata from Jangseong	5-1-5	4~6-1-4~6	5-1-5	11
C. japonica from Kimhae	5~6-1-5~6	4~6-1-4~6	3~4-1-3~4	11

† C = central teeth, IL = inner lateral teeth, OL = outer lateral teeth, M = marginal teeth

* Central cusp

1OL, 1M.

Each of the radular teeth has several cusps on the edge of the tooth and the types of cusp arrangement for the different teeth are varied a little by species. *C. chinensis malleata* collected from Changweon have less cusps (4 - 5) on each side of the central large cusp of inner lateral teeth than those in the other species (4 - 6) collected from Sorae and Jangseong.

The outer lateral tooth of *C. chinensis malleata* collected from Jangseong has more cusps (5) on each side of the central cusps than those of the other populations (3 - 4) collected from Sorae and Changweon.

The formulae of the cusp arrangement in 3 populations of *C. chinensis malleata* and *C. japonica* examined for this study are presented in Table 2.

***Cipangopaludina japonica* Martens, 1860** (Fig. 7)

The radular morphology in *C. japonica* examined is apparently similar in general view except in some of their cusp arrangement. In species *C. japonica*, the central tooth has 5 - 6 cusps on each side of the large central cusp on the anterior edge. The inner lateral tooth has 4 - 6 cusps on each side of the large tongue-like central cusp on the anterior edge. The outer lateral tooth which is smaller than the inner one has 3 - 4 cusps on each side of the relatively large central cusp. The marginal tooth has only 11 small cusps without a large central cusp on the anterior edge unlikely to lateral teeth. As in Table 2, *C. japonica* have relatively more cusps (5 - 6) on each side of the central cusp of the central tooth than those in *C. chinensis malleata* (5).

DISCUSSION

Comparative shell morphologies and anatomy data have been used for classifying species in many taxa of mollusks; however, anatomical details on Korean *Cipangopaludina* species have not been done before for systematic distinctions. Therefore, the concho logical and anatomical studies of two species of genus *Cipangopaludina* were carried out in this study. In general, morphologies of *C. chinensis malleata* are quite similar to those of *C. japonica*. However, *C. chinensis malleata* can be distinguished from *C. japonica* in a few characters: The spires of *C. chinensis malleata* are globose with impressed sutures, while those of *C. japonica* are straight with shallow sutures and obtuse angle in the body whorl. There are no remarkable anatomical differences in each organ between *C. chinensis malleata* and *C. japonica* except the color variations and sizes.

The shell characters and geographical distribution of

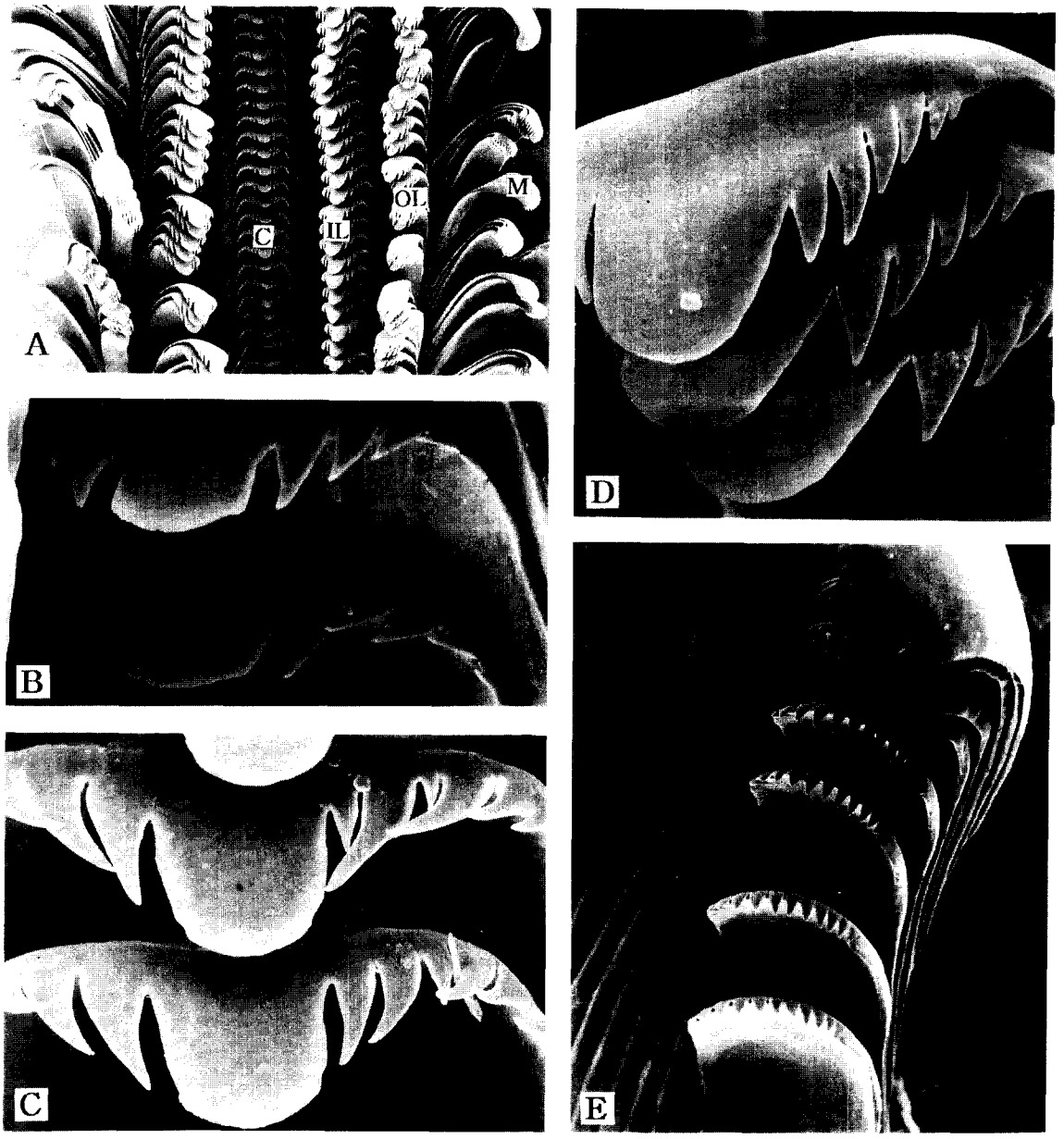

Fig. 7. SEM view of radular teeth of *C. chinensis malleata* and *C. japonica:* (A) a part of radular band of *C. chinensis malleata* collected from Sorae, Kyonggi-do (X 130.8), (B) central teeth of *C. chinensis malleata* from Changweon, Kyongsangnam-do, with 5 cusps on one side (X 1,554), (C) central teeth of *C. japonica* from Kimhae, Kyongsangnam-do, with 6 cusps on one side (X 1,776), (D) inner lateral teeth of *C. japonica* from Kimhae, Kyongsangnam-do, with 6 cusps on one side (X 1,554), (E) marginal teeth of *C. chinensis malleata* from Jangseong, Chollanam-do, showing 11 cusps without a central cusp (X 777).

Viviparus (*Cipangopaludina*) *chinensis malleatus* occurring in Korea were described by Shiba (1935). He distinguished the shells in three types: The shells of the first type (river type) tend to be large, globose, thin and translucent, with a bright greenish-brown colour, and their apertures are rather smaller. The shells of the second type (pond type) are smaller than the others; but, varied both in size and shape. The whorls are relatively tumid. The shells of the third type (rice field type) are small with a dirty brown colour, and the upper parts of the shells are much less distinctly flattened. As the locality data of the Korean viviparid snails in this study, *C. chinensis malleata* belong to the river and rice-field types, and *C. japonica* are as the pond type according to Shiba's classification. The snails of *C. chinensis malleata* widely distribute in many kinds of freshwater regions, while *C. japonica* live in the restricted area in southern part of Korean. The *C. japonica* prefer to inhabit relatively larger water bodies. In fact, we collected those of *C. japonica* only in a large, deep pond from the Kimhae area.

In this study, anatomical findings in both viviparid species are quite similar, though there are some distinctions in the shell morphologies. Radular morphologies of two species of the Korean rice field snails are also in similar patterns, except for minor differences in cusp arrangement. These similarities emphasize that *C. chinensis malleata* are closely related to *C. japonica*. Taxonomic evidences with morphological characters in these groups, do not seem to provide a good criteria for their classification. Further more enzymatic and molecular studies of these two species may provide useful taxonomic clues in the future.

SUMMARY

Two species of family Viviparidae, *Cipangopaludina chinensis malleata* and *C. japonica* have been known to distribute widely in Korea; but, *C. japonica* occur only in the restricted area in the southern part of Korea. The spires of *C. chinensis malleata* are globose with impressed sutures, while those of *C. japonica* are straight with shallow sutures and with obtuse angle in the body whorl. The shell shapes of embryos in the female brood pouch are distinctly different from each other. The apexes of shells of *C. japonica* are much more conic than those of *C. chinensis malleata*. The anatomical differences between these two species were observed only in external body color and quantitative sizes of each organ.

C. japonica have 5 - 6 cusps on each side of the central cusp of the central tooth, while *C. chinensis malleata* have 5 cusps on it. However, radular formula of two species is all 1M, 1OL, 1IL, 1C, 1IL, 1OL, 1M.

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