NOTES ON THE GENUS *CARINARIA* (HETEROPODA) FROM JAPANESE AND ADJACENT WATERS

TAKASHI OKUTANI
Tokai Regional Fisheries Research Laboratory, Tokyo

With Plates XII–XIII and 25 Text-figures

I. Introduction

Many taxonomic papers have been published on the genus *Carinaria* of Heteropoda by SMITH (1888), TESCH (1906, 1949), BONNEVIE (1920), and others. However, this animal group from Japanese waters has been recorded only fragmentally to this date, although a few papers have been presented about some heteropods from Japanese waters by TOKIOKA (1955) and OKUTANI (1955a, 1957a, 1957b, 1957c).

This paper is devoted to record the occurrences of Carinarias in Japanese waters by describing the specimens found in plankton samples preserved in the Marine Resources Section of the Tokai Regional Fisheries Research Laboratory and those in the Misaki Marine Biological Station.

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II. Systematic Account

Heteropoda: Family Carinariidae

For the convenience of becoming familiar to this animal group, the characteristics of animals of the genus *Carinaria* are redescribed here by summing up criteria given by previous authors.

Genus *Carinaria*, LAMARCK 1801, Syst. Anim., p. 98

Type species: *Carinaria vitrea* Làmarck (=*Patella cristata* LINNÉ)

Body cylindrical in shape, translucent as it is thickly covered with translucent, gelatinous cutis throughout, proboscis thick; tail laterally compressed and usually with a tail-crest on the dorsal side, pointed at the posterior tip. Eye with triangular or cylindrical base; a pair of cephalic tentacle in front of eye, the right one frequently vestigial or absent.

Visceral nucleus on the dorsal side approximately at the middle of the entire body, apparently pedunculated, covered by a capuliform shell. Ctenidia projecting a little beyond the anterior edge of the free margin of mantle.

Musculature distinct through the cutis; muscle bands of trunk generally oblique, while those of posterior part of body and tail longitudinal, divided into several stripes on the latter. The dorsal-most muscle band of tail issues a number of delicate muscle threads radially into the crest.

Swimming fin located nearly opposite the nucleus, usually semicircular or quadrilateral in outline, with a network of regularly crossing muscle fibers; sucker without a stalk, situated on the ventro-posterior margin of fin in both sexes. Cutis generally colorless, studded with gelatinous tubercles.

Shell with a carina on the anterior margin and a number of transverse ribs on the lateral side; sperture nearly subovoid, longer than broad; larval shell helicinoid, preserved in adult.

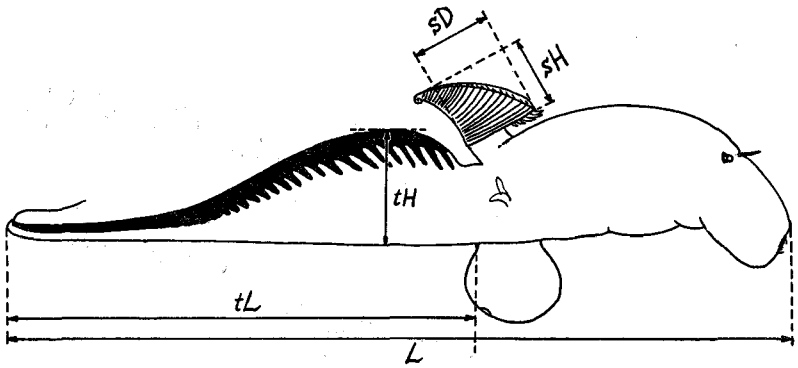
Radular formula 2-1-C-1-2; the rhachidian tooth usually depressed trapezoid in shape, with 3 cusps at the tip; both marginals nearly equal in shape and size, sickle-shaped and pointed at the tip; lateral oblong, with a small crest and a shallow dentation on the free margin; jaw plate shield-shape, elastic.

As the specimens are easily deformed by fixation, specific characters are rather subtle excepting the shell which is, however, very frequently found destroyed. That is why a great number of species had been described under different trivial names until TESCH (1949) made a thoroughful criticism on the validity of various works prior to him and rearranged them.

In the present descriptions, the following measurement (Text-fig. 1) are given on every specimen.

L : Entire length from the anterior tip of the proboscis extended in natural condition to the posterior tip of the tail, but excluding the tail filament.
sH : Shell height; the heighest part of the shell standing on the aperture; the height of the nucleus is measured in place of sH when the shell is lost.
sD : The major diameter of the shell aperture.
tL : Tail length from the posterior margin of the base of the swimming fin to the posterior tip of the tail.
tH : Tail height from the ventral side to the crest margin at the highest part of the dorsal crest.

In addition, body height, length of the eye including both the lens and basal part, eye diameter and ratios between these measurements are occasionally taken into consideration.



Text-figure 1. Diagram showing various measurements referred. L: entire length, sH: shell height, sD: major diameter of the aperture, tL: tail length, tH: tail height.

1. *Carinaria cristata* (LINNÉ, 1766)

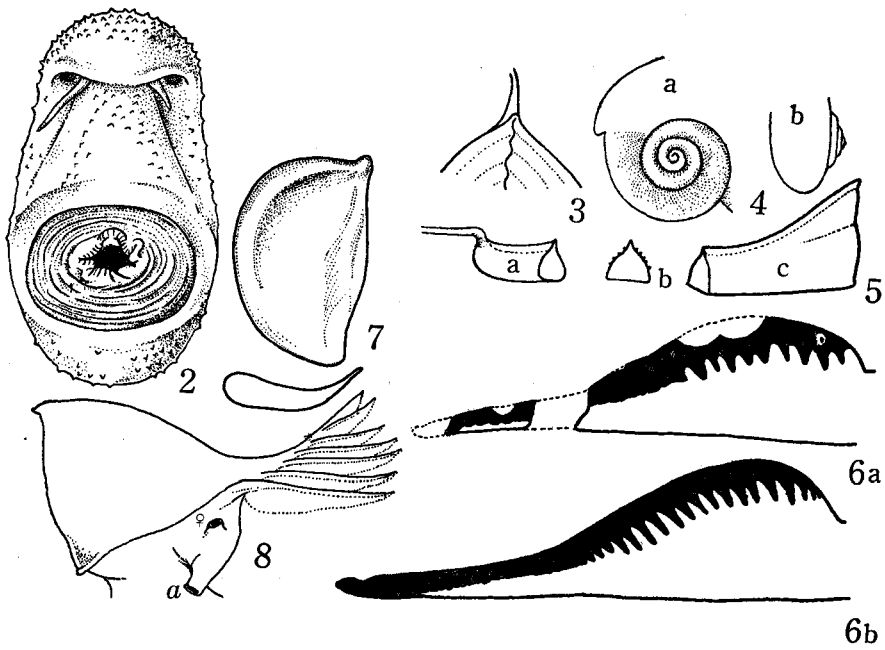
(Text-figs. 2–8; Pl. XII, figs. 1–4; Pl. XIII, fig. 1)

Carinaria vitrea, REEVE, 1865, vol. xv, pl. 1, figs. 2a–b;
Carinaria cristata, E. A. SMITH, 1888, p. 30, figs. 3a–b, 4a–b;
Carinaria cristata, TESCH, 1906, p. 65, pl. 9, figs. 35–42; pl 10, fig. 43;
Carinaria cristata, THIELE, 1929, p. 257;
Carinaria cristata, TESCH, 1949, p. 28, pl. 2, figs. 3A–D;
Carinaria cristata, TOKIOKA, 1951, p. 1134, fig. 3223;
Carinaria cristata, TAKI, 1954, pl. 129, fig. 1.

Body attains more than 500 mm in entire length (L); dorsum of the trunk conspicuosly elevated, height reaching 16% to L in adult; tail-crest semi-circular in outline, tH generally 20–26% to tL, and with the dorsal margin sharply edged

(Text-fig. 5); the posterior part of the crest is gently sloping down posteriorly and tapering to a whip-like prolongation with a nearly triangle cross-section; a dark-colored short filament follows the prolongation, 30 mm in length in a 240 mm long specimen.

Eye relatively small, dark in color, with the triangular retinal part broadly-based; a pair of cephalic tentacle in from of eyes, sometimes hidden in the



Text-figures 2–8. *Carinaria cristata* (LINNÉ)

2. Frontal view, showing the cephalic tentacles of different length; 388 mm long specimen from Koajiro Cove, Sagami Bay.
3. Carina of shell, apertural view; 501 mm long individual from Sagami Bay.
4. Protoconch, 1.15×0.9 mm; from Tosa Bay, sH=22.6 mm.
5. Diagram showing the shape of the posterior part of tail.
6. Two types of color-pattern of tail; a. 210 mm long injured specimen; b. 340 mm long injured individual.
7. Jaw plate of a full-grown specimen.
8. Anus and genital opening of the 430 mm long injured female from Misaki.
a: anus, ♀: genital opening.

transverse groove frequently observed on the brow of full-grown specimens, right one sometimes smaller than the left (Text-fig. 2), for example, right 6 mm and left 16 mm in a 340 mm-specimen.

Shell highly elevated, curved backwards; sH about 80% to sD; carina about 7% as wide as sD, consisting of two lamellae spaced by an extremely narrow slit and slightly inclined to the right side (Text-fig. 3).

Cutis covered with many variously sized gelatinous tubercles all over the surface, most densely on the dorsum, but rather sparsely on the ventral side. The body usually milky white in young specimens, but often faintly purplish on the dorsal side; the dorsal half of the tail-crest dark reddish purple or burgundy, but usually sprinkled with white spots formed by large-sized mamillar tubercles; the ventral margin of this colored area is asymmetrically undulating (Text-fig. 6).

Table 1. Data of examined *C. cristata* (L.).

Locality		Date	Sex	L (mm)	sH (mm)	sH/sD	tH/tL
Lat. N Long. E							
Koajiro Cove, Miura Peninsula	(Misaki MBS)	Aug. 26, '36	♀	430*	—	—	0.18
Koajiro Cove, Miura Peninsula	(")	"	♂	388	—	—	0.36
Neighbourhood of Misaki MBS	(")	—	♂	500	—	—	0.26
Araihama Beach, Miura Peninsula	(")	Jan., '56	♀	160*	—	—	—
Moroiso Cove, Miura Peninsula	(Mr. HAMASAKI)	Dec. 23, '57	♀	340*	—	—	0.26
Maehama Beach, Niijima Isl.	(Mr. KURATA)	Mar. 8, '58	♀	340*	—	—	—
Moroiso Cove, Miura Peninsula	(Dr. HORIKOSHI)	Oct. 12, '58	♀	210	—	—	—
Najima, Sagami Bay	(Misaki MBS)	Mar., '59	♀	501	56	0.82	0.20
Kasajima, Sagami Bay	(Mr. NAKAMIGAWA)	May 11, '59	♂	240	35	0.95	0.33
Tôshiki Beach, Ôshima Isl.	(Mr. KURATA)	July 26, '61	—	140*	—	—	—
Off Nomashi, Ôshima Isl.	(Mr. KURATA)	Apr. 24, '61	—	58*	—	—	—
Tosa Bay	(Mr. TERAMACHI)	—	—	—	22.6	0.77	—
35°07.2 139°34.2 (Sôyô St. U3)		Dec. 7, '59	♀	—	—	—	—
34°06.7 136°51.8 (Sôyô St. 135)		Feb. 24, '61	♀	68	13.0	1.00	0.47

* Astrisk show the specimen measured in somewhat injured state.

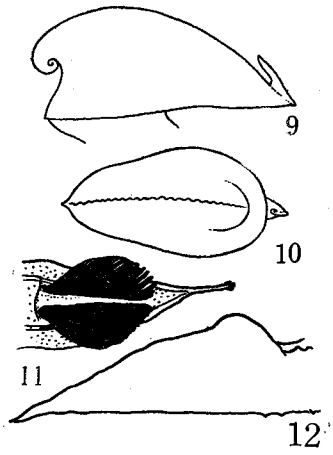
2. *Carinaria lamarcki* (PÉRON et LESUEUR, 1810)

(Text-fig. 9, 10 and 12; Pl. XIII, figs. 3, 6)

Carinaria fragilis, REEVE, 1865, vol. xv, pl. 1, figs. 1a-b;
Carinaria lamarckii E. A. SMITH, 1888, p. 32;
Carinaria cymbium, WOODWARD, 1890, p. 202, fig. 66;
Carinaria australis, VAYSSIÈRE, 1904, p. 22, pl. 1, figs. 11-16;
Carinaria mediterranea, VAYSSIÈRE, 1904, p. 11, pl. 1, figs. 1-10; pl. 2, fig. 17;
Carinaria mediterranea, PELSENEER, 1906, p. 162, fig. 142;
Carinaria mediterranea var. *oceanica*, VAYSSIÈRE, 1904, p. 17, pl. 4, figs. 51-53;
Carinaria lamarcki, BONNEVIE, 1920, p. 6;
Carinaria lamarcki, TESCH, 1949, p. 26, pl. 1, fig. 1.

The largest specimen in the present material measured only 30 mm in L, although TESCH (1949) stated that specimens from the Mediterranean Sea attained 220 mm; tail-crest abruptly increases the height at the proximal one third (Text-

fig. 12), not so rounded in outline as in the forgoing species, and without any distal prolongation; tH 25% to tL. Cephalic tentacles long, the right one longer than the left. Shell much depressed, apex conspicuously involute, sH 50% to sD in fully grown specimen (after Reeve, 1865). Cutis covered sparsely with large tubercles all over the surface.



Text-figures 9, 10, 12. *Carinaria lamarcki* PÉRON et LESUEUR

9. Outline of visceral nucleus; a specimen from Naples, preserved in Tokyo University.
10. Apertural view of a full-grown shell (after REEVE, 1865).
12. Tail; a 25 mm long individual from the station 30°38′.9 N, 131°23′.8 E.

Text-figure 11. *Carinaria lamarcki challengeri* BONNEVIE, ventral view of the "clasper"; a 15 mm long specimen from the station 34°18′ N, 140°56′ E.

Table 2. Data of examined *C. lamarcki* (PÉRON et LESUEUR).

Locality			Date	Time	Layer (m)	Sex	L (mm)	sH (mm)	tH/tL
Lat. N	Long. E								
30°38.9	131°23.8	(Sôyô St. 70)	Feb. 18, '52	1839	0	♀	25	—	0.20
43°00.0	160°00.0	(Tenyô St. F1)	Aug. 3, '55	0715	0–25	—	19	—	0.23
32°11.5	139°51.0	(Sôyô St. 25)	Jun. 28, '56	0000	0–150	—	6.6	—	—
32°46.3	133°08.8	(Sôyô St. 32)	Feb. 10, '57	2107	0	—	30	3	0.40
Isl. Hachijô (Mr. KURATA)			Mar. 17, '55	—	0	—	—	—	—

3. *Carinaria lamarcki challengeri* BONNEVIE, 1920

(Text-fig. 11; Pl. XIII, fig. 8)

Carinaria lamarcki (part?) E. A. SMITH, 1888, p. 37;
Carinaria poseudo-rugosa (part) VAYASSIÈRE, 1904, p. 20, pl. 6, figs. 82–5;
Carinaria lamarcki var. *challengeri* BONNEVIE, 1920, p. 6, pl. 2, figs. 16–25.

Body up to 15 mm in L; dorsum remarkably elevated; tail-crest much depressed; eye small; left cephalic tentacle long but hidden in the transverse groove on the brow, the right one absent; a dark colored appendage—clasper by BONNEVIE (1920)—on the ventral side of tail (Text-fig. 11); cutis wholly punctate.

Table 3. Data of examined *C. lamarcki challengeri* BONNEVIE.

Locality		Date	Time	Layer (m)	Sex	L (mm)	sH	tH/tL
Sat. N Long. E								
34°18.0 140°56.0	(Meiyô St. C53)	Mar. 26, '58	1730	0	♀	15	—	—
32°23.0 135°51.0	(No. 2 Kuroshio St. 6)	Dec. 8, '59	1750	0	♂	15	—	—
33°08.0 140°00.0	(Sôyô St. B3)	Mar. 3, '60	2142	0	♀	11	—	—
The Sea off Enshu-Nada		—	—	0	♀	20	—	—

Remarks: Various forms of *C. lamarcki* (PÉRON et LESUEUR) has been described from different localities of the world seas. Especially, BONNEVIE (1920) described a well-defined small form trom Gibralter and African waters which is only 30–40 mm in entire length. Although her specimens were at first considered to be a juvenile of a known species, she showed by histological examination that the gonads of the specimens were already matured. Moreover, the specimens were distantly characterized by having the "clasper" consisting of a pair of darkly pigmented folds on the postero-ventral side of the body. This organ is not found on any other forms including the typical *lamarcki* in the present material. No comprehensive works have been made on this "clasper" until to-day, but it is very interesting to state here that the similar black organ is observed on other Carinarid animal, *Cardiopoda richardi* (VAYSSIÈRE).

4. *Carinaria* (*cristata* var.?) *japonica* OKUTANI, 1955

(Text-figs. 13–16; Pl. XIII; figs. 2, 7)

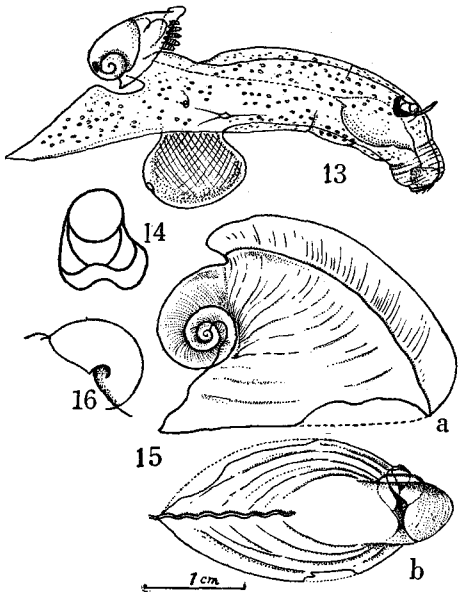
Carinaria lamarcki, DALES 1952, p. 1110, fig. 4 (non PÉRON et LESUEUR);
Carinaria japonica, OKUTANI 1955, p. 251, figs. 1–3.

Body attains 62 mm in L; tail-crest conspicuously elevated nearly to the level of the tip of the nucleus, triangle in outline, tH 43–53% to tL; eye with the broardly based and traianglar retinal part (Text-fig. 14); the right cephalic tentacle slightly shorter than the left, although both tentacles may often be of equal length.

Shell moderately elevated, sH 80–100% to sD; nuclear whorl coils 4 times and marked with very fine striae on the surface, umbilicus very narrow, faintly

yellow; post-nuclear parts translucent, width of carina 15% to sD (Text-figs. 15, 16). Cutis smooth with several gelatinous tubercles on the ventrolateral area of trunk.

Rhachidian depressed trapezoid in shape, with 3 very slender acute cusps on the tip; laterals oblong and with a sharp crest on the free margin; 2 marginals sickle shaped sharply pointed at the tip; on a 34 mm-long specimen rachidian 0.75 mm in width, lateral 0.45 mm long and 0.15 mm wide, marginal 0.50 mm in length.



Text-figures 13-16. *Carinaria* (*cristata* var. ?) *japonica* OKUTANI.

13. A 14.5 mm long individual from the station 43° N, 179° E.
14. Eye of the same specimen, dorsal view.
15. Shell of an individual from the station 43°02′N, 176° E; sH=2.0 mm.
16. Umibilicus of the same shell.

Table 4. Data of examined *C. japonica* OKUTANI.

Locality			Date	Time	Layer (m)	Sex	L (mm)	sH (mm)	sH/sD	tH/tL
Lat. N	Long. E									
44°11.0	159°30.0	(Kôyô St. 20)	Aug. 7, '54	0820	0	—	19	—	—	—
*36°21.0	141°00.0	(Heiwa-Ibaraki St. 5)	Jun. 29, '55	1340	0–150	♀	62	—	—	0.43
43°48.0	164°38.5	(Sôyô St. 38)	Sep. 6, '58	1827	50	♀	28	4.5	1.12	0.43
41°00.0	175°00(W)	(Sôyô St. 25′)	Aug. 21, '58	1840	0–150	♀	62	6.5	0.93	0.51
Off Kinkazan		(Tokiwa St. 14)	Jul. 24, '59	1005	0	♀	60	—	—	—

* Holotype, stored in the Tokai Reg. Fisher. Res. Lab., Tokyo.

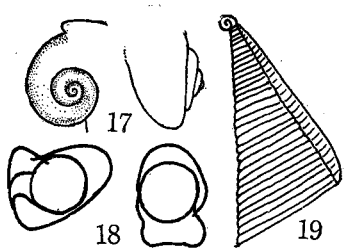
Besides the specimens shown in the above table, a great number of specimens of various stages were collected at some of the serial stations along the latitude of 43° N, the data of which is given in Chapter V where the distribution of the genus is discussed.

5. *Carinaria galea* BENSON, 1835

(Text-figs. 17, 18; Pl. XIV, figs. 4, 5)

Carinaria galea E. A. SMITH, 1888, p. 35;
Carinaria galea TESCH 1906, p. 71, pl. 10, figs. 44, 45;
Carinaria galea TESCH 1949, p. 27, pl. 1, figs. 2.

Body attains 42 mm in L, rather slender; tail short, tail-crest much depressed, tH 60% to tL; cutis quite transparent, furnished with large gelatinous tubercles distributed sparcely all over the surface. Eye darkly colored, retinal part with narrow base (Text-fig. 18); right tentacle vestigial.



Text-figures 17, 18. *Carinaria galea* BENSON.
17. Protoconch of an Individual from Tosa Bay, 1.3 ×1.2 mm; sH=13.2 mm.
18. Eye of the same specimen.
Text-figure 19. *Carinaria cithara* BENSON, shell (after TESCH, 1949).

Shell elevatrd, curved backward, sH larger than sD; carina enormously high, its width attaining nearly 25% to sD; protoconch slightly inclinated (Text-fig. 17).

Table 5. Data of examined *C. galea* BENSON.

Locality	Date	Time	Layer (m)	Sex	L (mm)	sH (mm)	sH/sD	tH/tL
Lat. N Long. E								
30°49.3 140°48.3 (Sôyô St. B5)	Sep. 11, '57	—	0	♀	21	5.0	1.0	0.6
35°25.0 142°29.0 (Sôyô St. 43a)	Sep. 12, '58	1838	0	♂	49	11.2	1.25	0.6
35°35.9 137°05.0 (Sôyô St. 133)	Feb. 23, '61	1938	0	♀	46	17.5	0.86	0.6
Tosa Bay (Mr. TERAMACHI)	—	—	—	—	—	13.2	1.37	—

6. Other species hitherto known but not found in the present material

Carinaria cithara BENSON, 1835.
Carinaria cithara procumbens TESCH, 1949.

The above-mentioned two forms were not found in the present material as they are likely to be distributed in the tropical waters. These forms are small ones attaining only 50 mm in L at the maximum and distinctly characterized ay thəir much elevated shell with sH about two times sD (TESCH, 1949). TESCH's extremely rare subspecies, *procumbens* is differentiated from the typical form in having the shell bending anteriorly; this feature is quite unique as the shell is generally curved backward in other forms of the genus.

III. Interspecific Relationship

Species of the genus *Carinaria* are considered to be divided into two groups characterized by structures of eye and protoconch, which might deserve to be treated as subgenera. One of them comprises *cristata*, *lamarcki*, *japonica* and *galea* posessing each the triangular retinal part and nearly smoothly surfaced protoconch. The other is represented by a single species, *cithara*, with cylindrical eyes and protoconch ornamented with apiral lines on the surface.

Juvenile specimens of three species, *cristata*, *japonica* and *lamarcki* are hardly distinguished from each other because of close morphological resembalance in details. In this respect, TESCH (1949, p. 26) stated, "it is not always possible to identify a mass of such small Carinariae with absolute certainty, when, as is frequently the case, the shell is absent; and only an experienced eye can tell specific differences which are hardly fit to be put in words." However, young specimens of *lamarcki* seem to have retinal parts proportionally broarder than in juveniles of *japonica* in the same body length as is show below:

	L	Length of eye including retina	Diameter of retina
lamarcki	25 mm	0.63 mm	1.08 mm
japonica	26	0.63	0.63
lamarcki	11	0.55	1.00
japonica	9	0.47	0.47

Furthermore, it is noteworthy that juveniles of *cristata* resemble strikingly those of *japonica*, although the former can be distinguished by the existence of dorsal tubercles even in immature states and by low and more rounded dorsal-crest as TESCH already showed (1949, p. 25 & pl. 2, fig. 3C). The ratio between sH and sD may be useful to identify immature specimens of these two species. As none of the immature specimens of *cristata* was found in the present material,

the ratio was estimated here on the measurements made by retracing growth lines on the mature shell.

	sD	sH	sD/sH
cristata	2.6 mm	2.6 mm	1.00
japonica	2.6	1.7	0.65

Morphological similarities between juvenile *cristata* and *japonica* seem to suggest that the latter might be a local form of the former confined to the northern Pacific.*

Adults of species of the genus, *Carinaria* are easily distinguished by the characters shown below.

Table 6. Shell characters of five species of *Carinaria.*

	General appearance	Protoconch	sH(max.)	sH/sD
cristata	Elevated, top curves backwards.	Helicinoid, faintly yellowish	56 mm	0.7–0.8
lamarcki	Depressed, top conspicucusly involutes.	Helicinoid	41	0.5
japonica	Elevated, top curves backwards.	Helicinoid, with fine growth striae	6.5	0.8–1.0
galea	Elevated, top curves backwards, carina very high.	Helicinoid, inclinated	13.2	1.0–1.4
cithara	Highly erected; in *procumbens* anterior edge concave.	Situating at the top, with spiral lines.	11	2.0

Table 7. Characters of soft body parts of five species of *Carinaria.*

	Eye	Dorsal-crest	L (max.)	Tubercles
cristata	Triangular, with broad base	Semi-circular; with tapering whip-like prolongation at the end.	500 mm	Very densely on the whole surface
lamarcki	"	Depressed	220**	Large, on the whorl surface
lamarcki challengeri	"	Much depressed	30	Inconspicuous
japonica	"	Elevated, triangular	62	Only on the ventro-lateral part
galea	Triangular, with narrow base	Not prominent	49	Sparsely on the whole surface
citbara	Cylindrical	Not prominent	50	Sparsely

* Although the Mediterranean forms may grow up such a large size (TESCH 1949, p. 27), the Indo-Pacific specimens are always as small as shown in the present material. This reveals that at least two local forms are differentiated in this species.

** In this respect, Dr. T. TOKIOKA thinks that *japonica* may be a form of *lamarcki* rather than that of *cristata.* For this reason he points out that *japonica* may differ from *cristata* in shape of tail and proportion of tail and trunk as well as in feature of carina (personal communication).

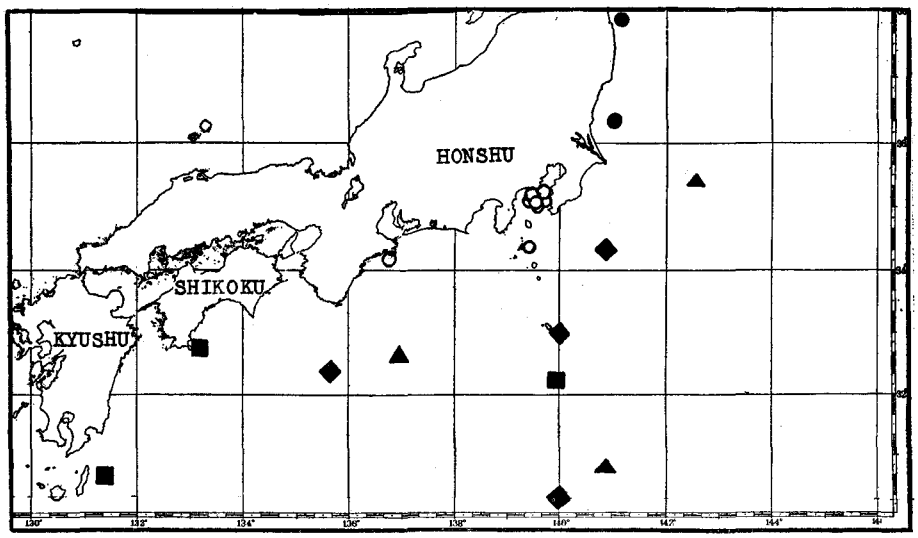
IV. Distributional Account

1. *Geographical distribution, with special reference to the occurrence of C. japonica in the eastern waters off Japan.*

Heteropods are the inhabitants of the warm waters of the world; all the species are known from the Indo-Pacific, but some are lacking in the Atlantic as the following table given by TESCH (1949, p. 49) shows clearly.

Table 8. Distribution of *Carinaria* in the world seas (modified from TESCH 1949).

	Atlantic Ocean	Indian Ocean	Pacific Ocean		Mediterranean Sea
			Tropical	Temperate	
cristata	—	×	×	×	—
lamarcki	×	×	×	×	×
lamarcki challengeri	×	×	?	×	×
japonica	—	—	—	×	—
galea	—	×	×	×	—
cithara	—	×	×	—	—



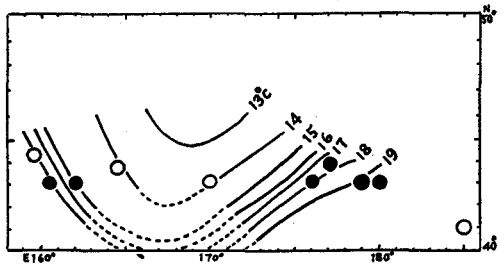
Text-figure 20. Distributional map of Carinarian species in Japanese waters.
○: *C. cristata*, ■: *C. lamarcki*, □: *C. lamarcki challengeri* ●: *C. japonica*, ▲: *C. galea*.

Generally speaking, in the Pacific, neither peculiar specific distributions nor peculiar distributional areas are conceivable, although some species show the trend to the tropical region and quite unseen in Japanese waters. In Japanese water Carinariae are usually collected in the Kuroshio area, sometimes by

plankton-net or found stranded. As is shown in text-figure 20, the stations of occurrence are found along the Kuroshio or in the area generally with surface water temperature of 20°C or thereabout. *Carinaria* may sometimes be found accumulated in a great number together with other plankters along the boundary between different waters, as is seen along the polar-front of the Kuroshio.

For instance, a considerable number of *Carinaria* were collectedby the R. V. *Tenyô-Maru* during her cruise in the summer 1955. They were collected at or near the serial stations along the latitude of 43° N. Although most of them were very young and some were coiled, they were identified as *C. japonica* after the close comparative studies arranging the specimens in the order of the size. And this cleared a part of the early larval stages of this species as is mentioned later in this paper.

According to OKUTANI (1957 b), the lowest water temperature estimated for the occurrence of *Atlanta* (probably *lesueuri*) was 160°C. And some workers



Text-figure 21. Occurrence of *Carinaria japonica* in the polar front area of the Kuroshio; solid circle shows the station where this species was collected in 1955; open circles shows that in other years; isotherms are for the summer 1955.

seem to consider that no heteropods inhabit in the northern part of the North Pacific. However, the oceanographic data of the R. V. *Tenyô-Maru* in the summer 1955 lowered the lower critical water temperature for the occurrence of *Carinaria* to 15°C or even below it. (Text-fig. 21).

In this polar front area of the Kuroshio are freqently met with other large sized plankton such as *Janthina*, *Velella* etc. which are always found in a full-grown stage. This seems to show that these animals are bred in the more southern warm water area and drifted to there by the current. On the contrary, *C. japonica* is considered to be propagating in the area surveyed by the *Tenyô-Maru*, as very early stages were found there in quantity. Anyhow it is evident that this species is distributed more northerly in the colder water than any other species of the genus. This seems to be supported by DALES (1952) who found a plenty of specimens probably belonging to this form from Californian waters where other heteropods were relatively scarce.

2. *Possible diurnal vertical migration.*

As has been cleared by the present author (1957 a, 1957 b), pteropodan and heteropodan faunas on the sea surface are completely changed by sun-set and sun-rise. Most of the specimens collected by the plankton net with a 130 cm diameter were fished by surface towing, and only two in the present material were collected at 25 m and another at 50 m layer by mid-layer horizontal haul. However, as the majority of them were got at night (from 18.00 to 06.00) and some Pterotracheas are known from the mid-layer between 256 and 600 m deep in daytime (OKUTANI, 1957 c), it is very possible that Carinarias do the diurnal vertical movement to some extent.

Table 9. Data of *C. japonica* from the polar-front area of the Kuroshio in the summer 1955.

St. No.	Lat. N	Long. E	Date (1955)	Time	Layer (m)	Num. Spec.	Sex ratio	L (range) in mm
12	43°00	160°01.5	Aug. 3	0135–40	0	5	?	17–20
13	43°00	162°00	" 3	0813–18	0	18	♀15, ♂3	12–44(sH 5.5–5.6 for L 35–37)
20	43°02	176°00	" 6	2254	0–150	2	?	2.8, 3.0
20	43°02	176°00	" "	0020–25	0	ca. 1000	?	1.2×1.9–0.6×1.0*
21a	43°00	179°00	" 7	1620–25	0	60 1	? ♂	4–39 61
22	43°00	180°00	" "	2018–23	0	15	—	8–15
22	"	"	" 8	0530	0–25	1	♂	59
23	43°57	177°30	" "	1621–26	0	2	♂2	15, 18

* Height×diameter is given on these coiled specimens.

V. Ecological Account

1 *An aspect of larval history*:

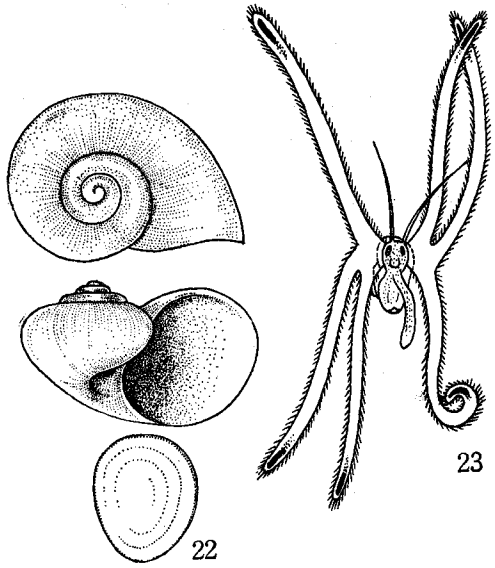
The male copulatory organ of *C. cristata* is situated on the right side of the trunk just below the visceral-nucleus. As was illustrated by TESCH (1906, pl. 9, fig. 34), the penis recurves a little, have the seminal groove and is accompanied with "Haftapparat" on its side. The female genital pore is a tiny opening adjoining to the anus (Text-fig. 8). In spite of the existance of such copulatory structures, no one has ever observed the copulatory behaviour of Carinarias. BONNEVIE (1920) found that *Carinaria lamarcki challengeri* posseses a "clasper" which is a darkly pigmented organ on the postero-ventral side of the animal, but it is hardly possible that the animal may "clasp" the mate with this organ.

Few informations have been available on the larval shells of Carinarias. Recently, however, FRANC (1949) described living larval specimens of various heteropods including *C. "mediterranea"* whose veliger is remarkable in having a

very extensive velum as is seen in the reproduction of his figure (Text-fig. 23). He showed also that *C. "mediterranea"* is provided with eyes having the characteristic triangular base, this feature was observed on the specimens collected by the *R. V. Tenyô-Maru*, too.

Next, a young specimen of *C. japonica* found coiled in about 1.4 mm diameter and with 0.75 mm height is described:

Shell of right-handed, helicinoid, very thin, transparent, entirely yellowish in color, polished and entirely with extremely fine growth lines; whorls $3\frac{1}{2}-3\frac{3}{4}$; spire rapidly increasing diameter to the aperture; the lower part of body-



Text-figure 22. Larval shell and operculum of *C. japonica* from St. 20 of the *Tenyo-maru*, collected on Aug. 6, 1955.

Text-figure 23. Veliger of *C. "mediterranea"* from the Mediterranen Sea (after FRANC, 1949).

whorly more inflated than the upper; operture ovate; umbilicus narrow but distinct; operculum as large as aperture, horny with a few concentric lines, transparent; animal can be wholly withdrawn inside the shell (Text-fig. 22).

This structure of the shell agrees well with that of the protoconch preserved at the tip of the adult sgell. Slight inclination of the protoconch is responsible for the oblique appearance of the aperture lips in the coiling stage. Shell metamorphoses to a capuliform one with developmental stages. The boundary between the coiled and capuliform parts is quite distinct. In a stage with sH 1.8 mm and sD 2.3 mm, there are only 4 transverse ribs on the shell and the keel is 0.8 mm

wide; the animal then attains 14.5 mm in L and yet the triangular tailcrest is differentiated already (Text-fig. 13).

2. *Feeding habit*:

TESCH (1949, pp. 50–51) found that fragments of Ctenophores, Salpae and pelagic Hyperiidae, such as *Phronima*, were spread upon the radula hooks of heteropods or remained in the gizzard. There were reportedly found mostly unidentifiable detritus, but sometimes fragments of Euphausids and even of other heteropods. He also guessed that the fish larvae might often be preyed by rapacious Carinarias and Pterotracheas. GRAHAM (1955) stated that *Carinaria* feeds on fish, scyphozoan medusae and crustaceans. And it must be necessary to introduce here that *Carinaria* is regarded as a predator of the eggs of a sardine, *Sardinops ocellata* (FISH. BIOL. BR., FAO, 1959).

Of the present material, two samples of food contents in the alimentary canal were examined. These contents were offered to Mr. K. HONJO of our Laboratory who identified them so kindly for the writer. Here the writer wants to express his hearty thanks for Mr. HONJO's kind help.

(i) Food contents of a 44 mm long female *Carinaria japonica* from St. 13 of the *Tenyô-Maru*

Euphausid larvae	6
Paracalanus parvus	1
Calanus sp.	1
Oithona pulmifera	1
Amphipoda juvenile	1
Evadne sp.	1
Sagitta bedoti	1
Thalassiothrix longissima	plenty

(ii) The same of a 17 mm individual from St. 12 of the *Tenyô-Maru*

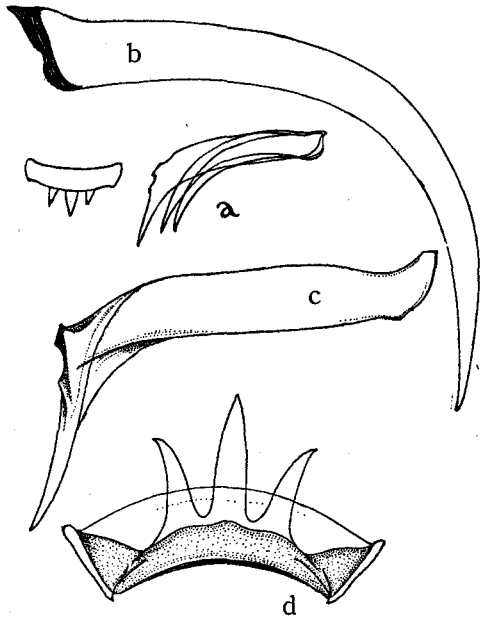
Euphausid larvae	1
Crustacean remains	many

The above mentioned results seem to show that Carinarias feed on the plankton organisms *in situ*. Here it is very questionable that Carinarias take diatoms as food, although the alimentary canal of Carinarias contains some diatoms occurring in the same area. Rather it is impossible that Carinarias can take diatoms with radula, most probably these vegetable substances are brought in with salps which apparently feed on diatoms and then are preyed by heteropods. The fact that heteropods are occasionally collected together with a large number of Salps were already noted by DALES (1952, p. 1013).

Carinaria has very acute radulae, the formula of which is given in Chapter II (p. 88). Every tooth is sharply pointed at the tip (Text-fig. 24) and sickle shaped marginals are very effective to hook preys and usually peeping out of

the mouth. One of the radular ribbons examined during the present study was found provided with 60 rows of radulae. The present author observed once on board the R. V. *Sôyô-Maru* that the animal occassionally extended the proboscis straightly and some food particles jiggling in the gizzard were distinctly observable through the cutis.

The coloration of the gizzard and oesophagus of living animals is apparently caused by food organisms. Some examples of colorations of living Carinarias observed during this study are as follows:



Text-figure 24. Radula teeth of *C. cristata* (L) of an individual from Sagami Bay.
a: half of a row, b: marginal, c: lateral, d: rhachdian.

i) *Carinaria cristata* from Sagami Bay: purplish.
ii) *Carinaria japonica* from St. 25′ of the *Sôyô-Maru*: Orange with faintly brownish particles on the posterior part of the gizzard.
iii) *Carinaria galea* from St. 43a of the *Sôyô-Maru*: Deep purplish red.

Yellowish coloration is caused by crustacean, while purplish coloration is probably caused by scyphomedusae, *Janthina* or amphipods, though this is not ascertained definitely.

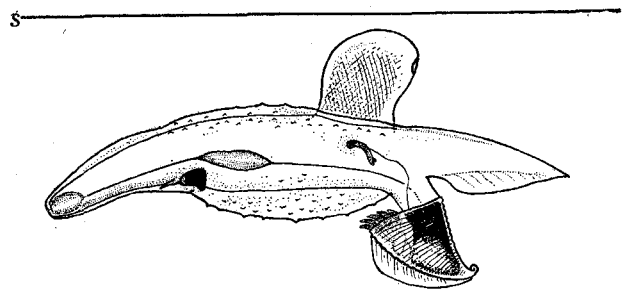
3. *Swimming behavior*:

Living *C. galea* and *C. japonica* were observed by the present author on

board the R. V. *Sôyô-Maru* in August 1958. Carinarias swam just like *Pterotrachea* (OKUTANI, 1957 c, pp. 17–19), but they kept themselves nearly always horizodtally while *Pterotrachea* usually keeps the body rather inclined when it is resting. The animal keeps the ventral side upwards and moves the fin as in file-fishes or puffers. In swimming the trunk winds like S, but the parts of the body seem hardly to contribute to locomation (Text-fig. 25).

4. *Possible predators of Carinaria*:

KING and IKEHARA (1959) reported that some heteropods were occasionally found in the stomach contents of tunas. However, It is not likely that tunas took those heteropods selectively. Although records of Carinarias being eaten by any predators are rare, it is met with very frequently that visceral nucleus



Thxt-figure 25. *C. galea* in natural posture observed at St. 43a of the *Sôyô-Maru* on Sept. 12, 1958.
s: water surface.

of the animal is bitten off probably by some fishes. A kind of turtle may be regarded as one of the predators of them, because some Pterotracheas have been found from the stomach of the turtle (KURATA, unpublished).

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EXPLANATION OF PLATES XII–XIII

PLATE XII

Figure 1. *Carinaria cristata* (L.); a 240 mm long male from Kasajima, Sagami Bay, collected by NAKAMIGAWA, coll. 3907.

2–3. *Carinaria cristata* (L.); Shell of an individual from Tosa Bay, sH=22.6 mm (leg. TERAMACHI).

4. *Carinaria cristata* (L.); Darkly colored 340 mm long injured female from Niijima Isl. (Mr. Y. KURATA photo).

PLATE XIII

Figure 1. *C. cristata* (L), the same specimen with that shown in Pl. XII fig. 1.
a: anus, c: ctenidia, d: vas deferens, g: male gonad, k: kidney, l: liver, t: atrium of the heart v: ventricle of the heart.

2. *C. japonica* OKUTANI, type specimen, 62 mm. long female.

3. *C. lamarcki* PÉRON et LESUEUR; a 25 mm long female from the station 30°38.9′ N, 131°23.8′ E. (Mr. NAKAI orig.)

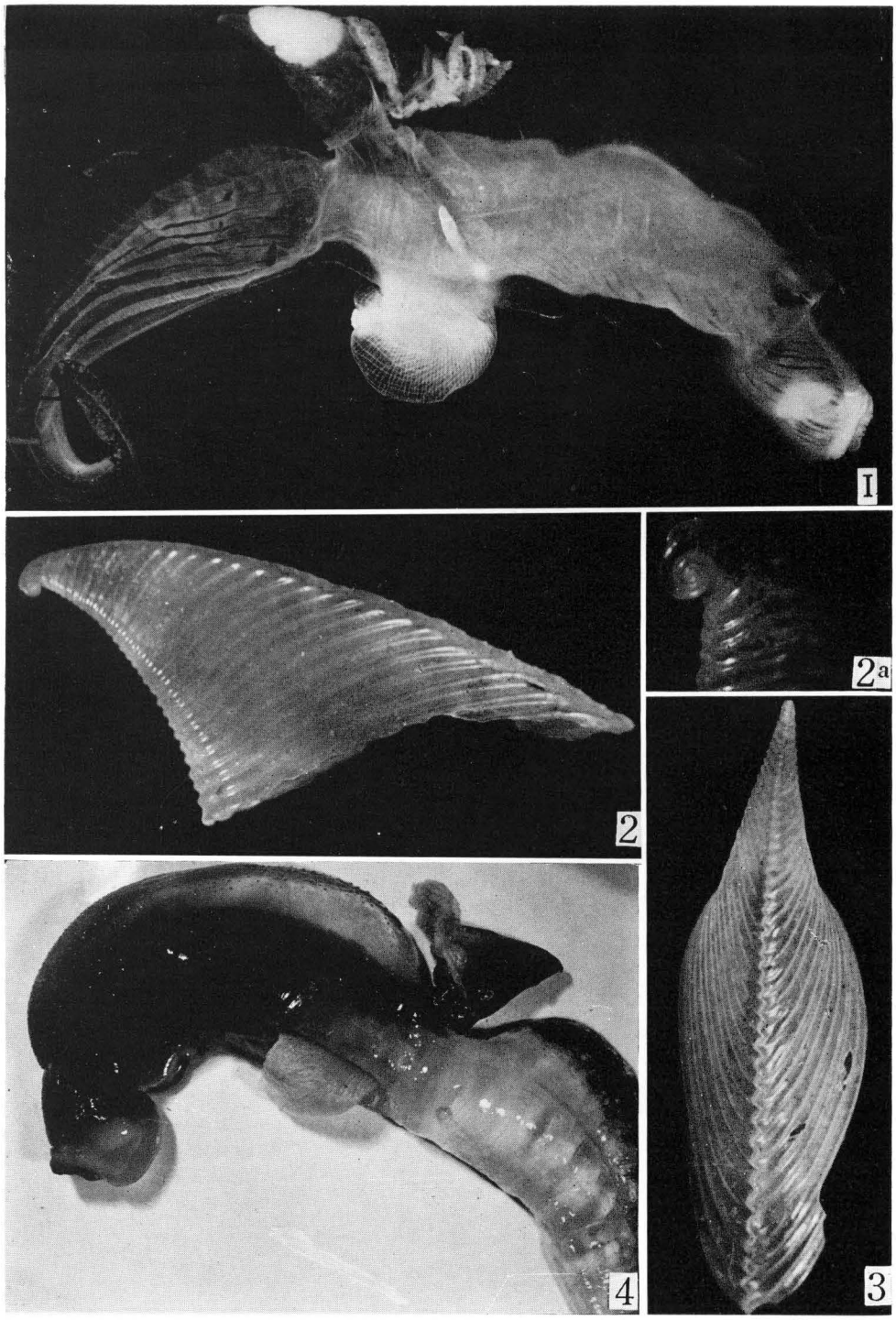
4. *C. galea* BENSON; a 21 mm. long female from the station 30°49.3′ N, 140°48.3′ E.

5. *C. galea* BENSON; shell of a male from the station 35°25′ N, 142°29′ E, sH=11.2 mm.

6a–b. *C. lamarcki* PÉRON et LESUEUR; shell of an individual from the station 32°46.3′ N, 133°08.8′ E, sH=3 mm.

7. *C. japonica* OKUTANI, shell of an individual from the station 43° N, 162° E, sH=5 mm.

8. *C. lamarcki challengeri* BONNEVIE; a 15 mm long female from the station 34°18′ N, 140°56′ E.



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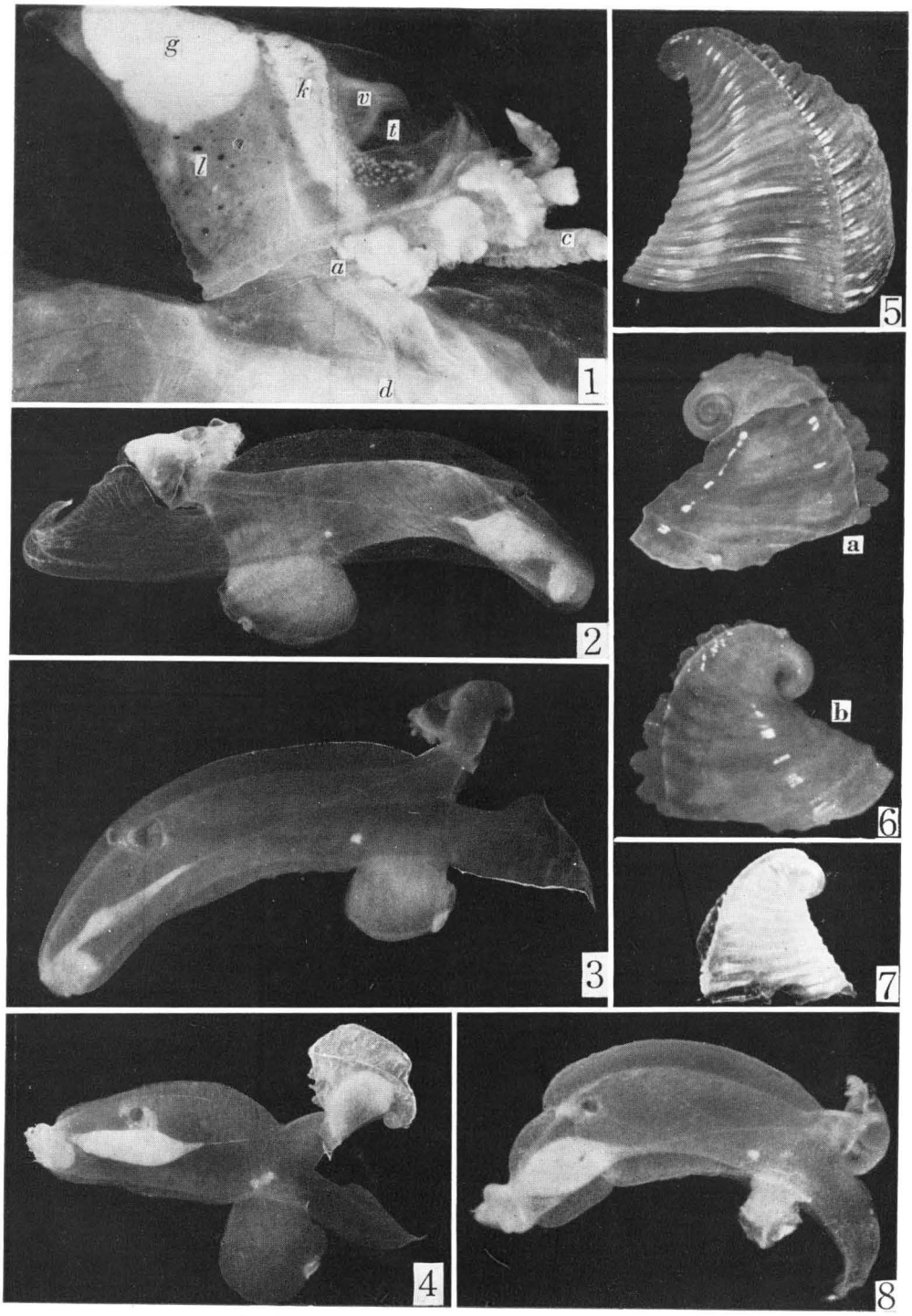

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