MEMOIRS OF THE COLLEGE OF SCIENCE, KYOTO IMPERIAL UNIVERSITY, SERIES B,
VOL. VIII, NO. 1, ART. 2, 1932.

On some Cases of Abnormality of the Shell-Plates in Chitons

By

Iwao TAKI

(Zoological Institute, College of Science, Kyoto Imperial University)

(With Plate II and 45 Figures)

(Received May 12, 1932)

Contents

Introduction

During the several years in which the chiton fauna of Japan has been studied, some individuals with abnormal shell-plates have been found among the hundreds of specimens examined. The study of these individuals has been embodied in the present paper. All of the specimens are preserved in spirits, so that I could observe not only the external features and the mode of coalescence of the shell-plates but also some

other morphological characteristics, by disarticulating the abnormal valves from the specimen. In connection with this, the known cases of malformed specimens are considered at some length in the hope that it may throw some light on the teratology of the Polyplacophora.

I should like to express my hearty gratitude to Prof. T. Komai, of the Zoological Institute of Kyoto Imperial University, under whose kind direction the present paper was prepared, and who gave me constant encouragement. Also, I am indebted for valuable suggestions to Prof. Yô K. Okada of the same Institute. Dr. P. Pelseneer, of Brussels, Prof. Dr. H. F. Nierstrasz, of Utrecht, Prof. Dr. H. Hoffmann, of Jena, Mr. T. Kuroda of the Geological Institute of Kyoto Imperial University, and also my elder brother Isao Taki, of the Zoological Institute of Tokyo Imperial University, have been very generous in helping me in various ways. To all these gentlemen are due my sincere thanks.

Descriptions of abnormal chiton specimens

No. 1 A 7-valved specimen of *Acanthochiton rubrolineatus* (Lischke)

(Pl. II. fig. 1 ; figs. 1–3)

Locality : Coast of Minatoyama, Mitsu, Prov. Iyo. (20. VIII. 1929, Iw. Taki coll.)

Measurements :

		length	width
body		26.0	18.0
valve		24.0	6.7
no. of valve	I	3.2	5.4
	II	5.2	6.0
	III	4.8	6.5
	IV	4.7	6.7
	V	5.2	6.7
	VI	5.7	6.3
	VII	3.7	4.6

	right	left
Number of ctenidia :	27	24
Position of genital pore :	24/25	21/22
Position of renal pore :	26/27	23/24

The specimen is of medium size, rather short in length, so that the outline is oval, while the normal specimen is elongate-oval. The length-width ratio is 14 : 10, whereas it is 17 : 10 in the 30 normal individuals examined.

The tegmental surface of all valves is for the most part eroded, and only a narrow marginal part of the tegmentum[1] shows the characteristic sculpture and colour. The posterior margin of each valve is so much eroded that in the median valves it is sinuated instead of being beaked.

The valves appear normal except for the number, which is reduced to 7. They are uniformly arranged, however, the length of the tegmental surface of each valve is greater than

1. Although the chiton shell-plate is divided into 4 layers (periostracum, tegmentum s. s., articulamentum s. s., hypostracum) by recent authors (cf. von Knorre, 1925), for the sake of convenience I employ in this paper the traditional terms, tegmentum and articulamentum.

normal and gives the specimen an elongated appearance.

In valve VII, the tegmentum is almost flat, the mucro is missing owing to erosion, and no remarkable structure is seen. As to its size, the tegmentum measures 4.6 mm. wide and 3.7mm. long, its ratio being 100 : 80, while in the normal specimen of about the same size it is 3.8 mm. wide and 2.8 mm. long, or 100 : 74. Thus, this valve as a whole is unusually large in both its length and width (fig. 3). Valve VI also has been disarticulated and examined, but no peculiarity has been found except that it is a little elongated axially (fig. 2).

The bundles of spicules number 8 pairs in all, i. e. a pair less than usual. They are distributed practically uniformly on the girdle. The anterior two pairs are situated along the anterior margin of the head valve, and the 3rd —6th pairs are just at the sutural position of the corresponding valves. The 7th pair lie at about half the length of valve VI, and the 8th at the posterior extremity of the hindmost (VII) valve. Thus in regard to the relative position to the shell-plate, these two pairs of spicule-bundles of the present specimen correspond with the 8th and 9th pairs in the normal specimen.

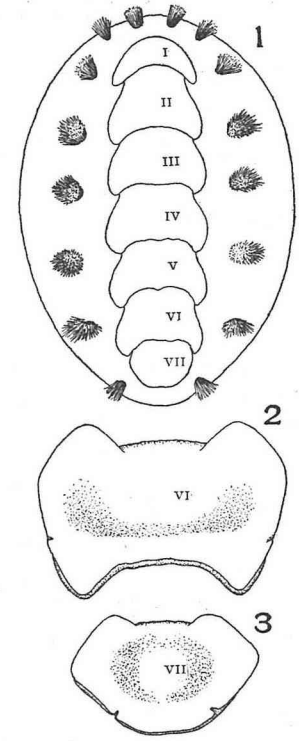


Fig. 1. A 7-valved specimen of *Acanthochiton rubrolineatus*, No. 1. (× 2) figs. 2,3. Ventral views of valves VI and VII.

This abnormal specimen bears 27/24 ctenidia on each side. In the normal specimens of about the same size (25–28 mm. long), the ctenidial number ranges between 22 and 28, being mostly 24. Therefore it is hard to estimate the difference of the specimen from the normal with regard to this point.

No. 2 A 6-valved specimen of *Acanthochiton rubrolineatus* (Lischke)

(Pl. II, fig. 8 ; figs. 4–12)

Locality : Coast of Minatoyama, Mitsu, Prov. Iyo (20. VIII. 1929, Iw. Taki coll.)

The specimen is juvenile, the adult generally attaining a length of 36 mm. The

Measurements :

	length	width
body	8.0	4.5
valve	6.8	1.8

axial length is reduced, and the median axis bends to the left in the posterior region. The margin of the girdle is sinuated in the left posterior part, including two notches, of which the right one (fig. 4,5,*) lies on the median axis of the body.

The valves, which are 6 in number, are somewhat larger than in a normal specimen (cf. Pl. II, fig. 9). Valves I–V are apparently normal except for the size. Valve VI shows a peculiarity in its structure.

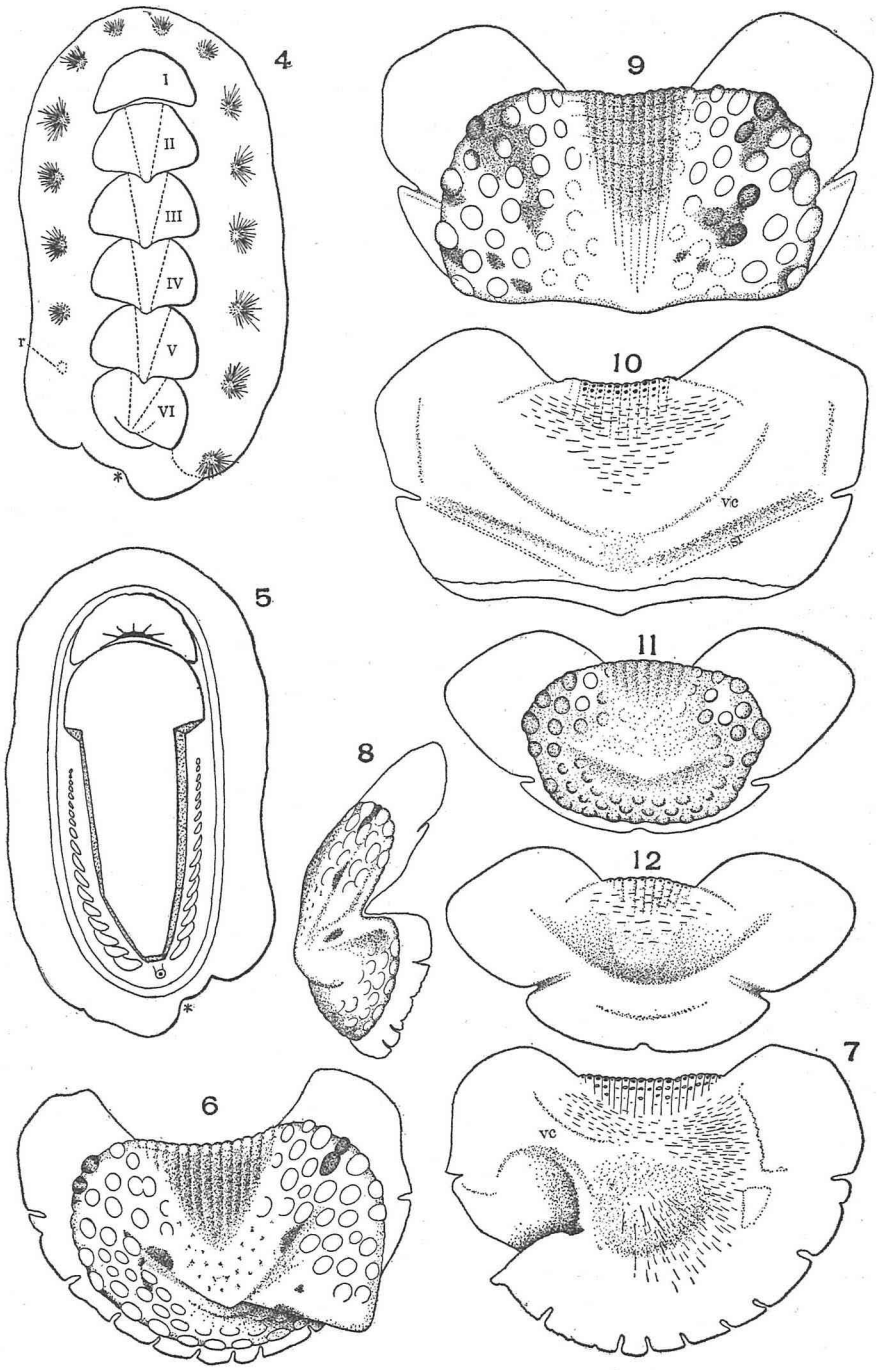
The girdle is a little narrower than in the usual case. It is normal except that the left posterior corner of the body is sinuated irregularly, and the posterior extremity is produced bluntly. The spicule-bundles are disposed asymmetrically, viz., 6 on the left side and 8 on the right, the latter being better developed than the former. At the left sutural position between valves V and VI, the bundle is quite obsolete, being represented only by a minute depression where the spicule is entirely missing; this may be a rudimentary pore-tuft (fig. 4, r). On the right side, between valves V and VI, the bundle is well developed; another bundle is found on the right side of the irregular outgrowth of valve VI; the girdle upon which the spicules are planted is prominently swollen and elevated. Behind the line which connects the hindmost pore-tufts on both sides, the girdle as well as the valve is abruptly concave, suggesting that growth has been suppressed to some extent in this region.

The number of ctenidia is 18 on the right and 16 on the left side. Although these numbers are not necessarily smaller than normal, the number being fairly variable[1]; it is likely that the growth has been hindered more on the left side than on the right side.

Valve VI is very characteristic; it is smaller than valve VII and remarkably larger than valve VIII of the normal specimen of corresponding size (figs. 9–12). However, by the sculpture of the jugal tract and of the latero-pleural area, and also by the black patches scattered on these regions, it can be judged that the anterior half of the tegmentum represents valve VII of a normal specimen. The sutural lamina is undersized and is somewhat asymmetrical; but it is provided on each side with a slit, which corresponds to that of the normal valve VII. The posterior half of the tegmentum shows a peculiarity; the posterior margin, which is otherwise smooth and rounded, is provided with a triangular outgrowth on the right side, so that this part appears as if it were pulled behind and depressed downward. The round granules which are found on this

1. In normal juvenile specimens at my disposal, ctenidial counts are as follows:

body length (mm.)	9.6	10.8	11.2	16.0
no. of ctenidia	19/19	17/18	19/20	21/22



Figs. 4–5. A 6-valved specimen of *Acanthochiton rubrolineatus*, No. 2. (×8). Dorsal and ventral views. r, a rudimentary pore-tuft; * indicates the posterior extremity of the median axis of the body. 6–8. Valve VI of the abnormal specimen; 6. dorsal, 7. ventral views; 8. view from right side. 9–12. Normal specimen of similar size. 9. dorsal, 10. ventral views of valve VII. 11. dorsal, 12. ventral views of valve VIII. sr. slit-ray. vc. valve callus.

irregular outgrowth, are fewer in number and more obsolete than normal, and elongated axially instead of radially as in the normal case.

The peculiarity of the articulamentum is no less remarkable than that of the tegmentum. In the anterior half a number of minute transverse striations[1] are scattered near the jugal sinus as in the normal case, but the valve callus is found on the right side only (fig. 7, vc). The side slits are both slightly irregular, lacking slit-rays (cf. fig. 10, sr).

The posterior half of the articulamentum is nearly semicircular, with a deep depression on the right side. On the left side occur many short striations radiating from beneath the mucro ; these striations are not found on the right lateral margin. In the normal specimen these striations are seen only in the neighbourhood of the jugal sinus (figs. 10, 12), so that their presence in such a posterior part of the articulamentum is quite unusual. If we suppose, however, that the valve in question has resulted from the fusion of valves VII and VIII of the normal specimen, the occurrence of such a peculiarity becomes more intelligible.

The insertion-plate is well developed and its margin is roughened by 7 slits separated by unequal intervals, the teeth being more or less undulated. In a normal specimen of the genus *Acanthochiton* the tail valve is provided with only one slit on each side, and also with a median shallow caudal sinus (fig. 12). The number of the slits, as generally recognized by systematists, is constant, and I doubt if the occurrence of a specimen having several slits in the tail valve has ever been reported. So that this is by far the most prominent feature of valve VI in this specimen. The posterior margin is reminiscent of the multifissate tail valve of the genus *Cryptoconchus*, the nearest ally of the genus *Acanthochiton*. Of course this may be due to a mere coincidence ; however, it is not unlikely that the formation of a multifissate tail valve is due to parallelism between these two genera, accidentally produced in a teratological case.

The abnormality of this specimen may be accounted for as follows : In its embryonic stage it possibly had only 6 rudiments of shell-plates, but in a subsequent period growth was suppressed in the left posterior region of the body, which caused the abnormality of the margin of the girdle as well as of the spicule-bundles in that region. The hindmost valve, in spite of suffering a serious disturbance in its growth on the right margin, has grown in so great a measure that it occupies an area as large as the other valve, and has become a shell-plate of a peculiar appearance which is quite different from that of either the penultimate or the tail valve of a normal specimen.

1. " Mittleres durchbohrtes Feld " of von Knorre (1925).

No. 3 Coalescence of shell-plates in *Placiphorella stimpsoni* (Gould)

(Pl. II, fig. 4; figs. 13–18)

Locality: Coast of Minatoyama, Mitsu, Prov. Iyo (8. VIII. 1926, Iw. Taki coll.)

Measurements:

		length	width
body		44.0	29.0
valve		30.7	24.0
no. of valve	I	4.8	20.5
	II	3.6	22.8
	III/IV	6.8	24.0
	V	7.0	23.0
	VI	3.2	20.0
	VII	3.2	16.6
	VIII	3.3	11.2

No. of ctenidia: right 25, left 23.

The specimen is as large as a matured one, its dorsum is very flat and the tegmental surface is so much eroded that the characteristic sculpture is scarcely visible. Of the shell-plates, valves III/IV and V are much longer than the others.

Valves III/IV and V.

a) Dorsal view (figs. 14, 15)

Valve III/IV is longer than normal. The tegmentum is eroded at the middle and also at the left posterior margin. On the right anterior margin there is a rounded projection of the tegmentum, which fits well into a small notch at the right posterior margin of the foregoing valve. At about the anterior third of the length of the lateral margin on the right side, there is a deep incision, whence start a few indistinct lines of a crack.

Valve V is the longest of all the valves, but it is a little narrower than the foregoing valve. Its dorsal surface is irregularly roughened by erosion, and the posterior margin is also rugged.

b) Ventral view (figs. 16, 17)

By the disarticulation of the shell-plate it has been revealed that essentially valve III/IV alone is concerned with the abnormality of this specimen. On the right side the side slit is situated somewhat posterior to the usual position, but the sutural lamina in front of it is much reduced and represented by a short lateral process of the articulamentum. Another sutural lamina occurs at the deep notch on the right lateral margin of the tegmentum, which, in the normal case, should attain as far forward as the anterior margin. At its basal portion there is a well-defined incision, which is without doubt a side slit.

On the left side the insertion-plate is simple, and has 3 notches. Of these, the 1st notch is just under the anterior corner of the tegmentum, the 2nd at about the anterior 1/5, and the 3rd at the posterior 3/5 of the length of the insertion-plate. These incisions are not very deep, and are of nearly the same size. In the median valves of the normal specimen of

the genus *Placiphorella*, as is generally known, there is only one side slit on each side. The existence of 3 slits on the left insertion-plate, as well as the presence of an abnormal notch and sutural lamina on the right side, suggests that the valve under consideration is of a double nature, representing valves III and IV which are coalesced. Valve III is represented by a normal sutural lamina, a side slit, a very short insertion-plate and a small area of the tegmentum on the right margin, and valve IV by an abortive sutural lamina, a normal side slit, an insertion-plate, and an almost normal amount of the tegmentum.

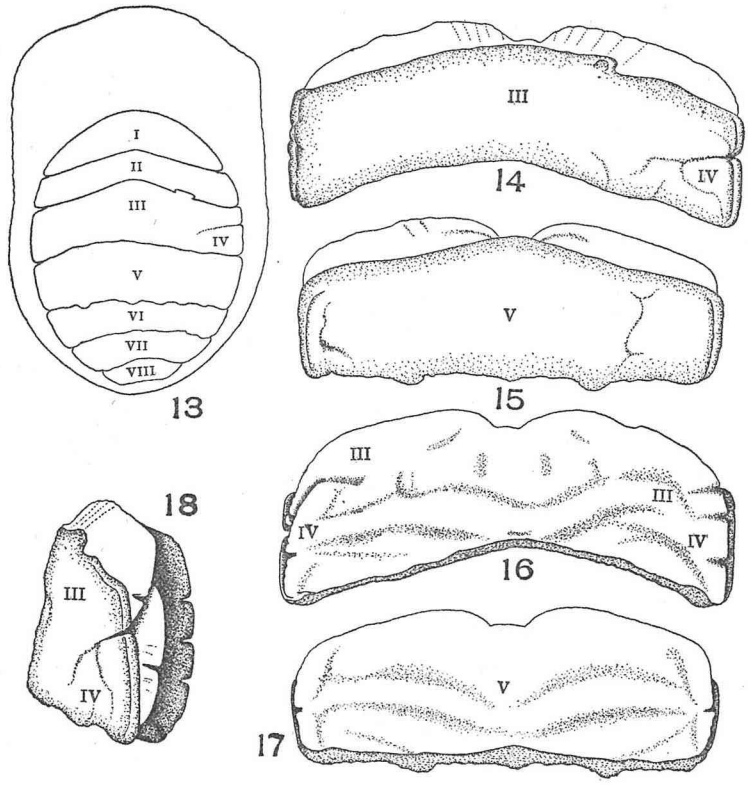


Fig. 13. *Placiphorella stimpsoni*, specimen No. 3, with a coalesced valve. (×1.2). 14–15. Dorsal views of valves III/IV and V. 16–17. Ventral views of valves III/IV and V. 18. Right side view of valve III/IV to show the insertion-plates on both sides.

On the left side, the boundary between valves III and IV is insufficiently shown ; however, it is not unlikely that the 2nd incision in the insertion-plate corresponds to a line of coalescence, judging from the fissure on the right side.

The whole surface of the articulamentum is irregular. The valve callus is asymmetrical, and the minor sculpture is more complex than in

the normal specimen. The reversed area of the tegmentum[1] at the posterior margin is also normal.

In valve v nothing seems abnormal except that the articulamentum and the reversed area of the tegmentum are axially more elongated than usual.

In the external form and in the size of the area occupied by the shell-plates, this specimen does not differ from the normal ones. The malformation of this specimen is due to an almost complete coalescence of valves III and IV. Valve II is relatively short, and valve III/IV is not so long as the normal valves III plus IV; so that valve V has undergone an axial elongation to fill up the gap.

No. 4 Coalescence of shell-plates in *Placiphorella stimpsoni* (Gould)

(Pl. II, fig. 5; figs. 19–22)

Locality: Coast of Minatoyama, Mitsu, Prov. Iyo (20. VII. 1929, Iw. Taki coll.)

Measurements:

		length	width
body		43.0	34.0
valve		35.7	27.0
no. of valve	I	5.5	18.5
	II/III	10.0	25.0
	IV	6.5	26.0
	V	7.2	27.0
	VI	6.8	24.5
	VII	5.5	19.0
	VIII	3.4	12.8

No. of ctenidia: right 25, left 27.

The specimen is as large as a mature one of the same species. Though it bends ventrad, the area occupied by all the valves is longer than usual. The anterior 4 valves (I–V) are much eroded on the median parts, the characteristic colour pattern being retained only on the marginal area; otherwise the valves (VI–VIII) are nearly perfect. The length of each valve is quite unusual, viz. valves II/III, V and VI are much elongated, while IV is shortened, and valves VII and VIII remain unchanged. The lateral area can be distinguished only in the left half of valves IV and V.

Disarticulation of the valves has revealed that the coalescence occurs not only between valves II and III, but also between the latter and valve IV; thus we see here a case of fusion of three valves, which seems to be of rare occurrence.

The head valve.

This is asymmetrical, the left half being much shortenend (8 mm. wide), while the right half is normal (10.5 mm. wide). The number of

1. "Umgeschlagener Teil des Periostracum und Tegmentum" of von Knorre (1925).

slits, however, is 8 as usual, of which 4 on the left half are much more shifted to the median axis than those on the right half. No causal relation can be seen between the modification of the head valve and the coalescence of the following ones.

Valves II/III and IV.

a) Dorsal view (fig. 20)

Valve II/III is much elongated in the axial direction, and its compound nature is shown on the right half of the tegmentum. On the left antero-lateral corner of this valve, the tegmentum is sinuated in front so as to fit the rounded lateral margin of the head valve. There is a short oblique fissure in the tegmentum on the anterior 1/3 of the length of the left lateral margin; this fissure, though shallow and superficial, seems to represent the boundary between valves II and III.

A weak transverse line exists almost in the middle of the length of the right half of the tegmentum, and is connected beneath with a deep fissure in the articulamentum. On the left side this line of boundary ends in two longitudinal cracks. The right lateral margin is divided by this line into two regions, of which the anterior represents valve II, and the posterior, valve III. Each of these in its axial length is shorter than normal, being nearly 2/3 as long as the latter. The right postero-lateral corner of valve III is apparently lost, but in profile we find that this part is reflected downward and concealed beneath the articulamentum.

Valve IV is shorter than the normal one and asymmetrical in shape. At the middle of the anterior margin the tegmentum is injured, forming a depression. The left lateral margin is especially shortened and leaves a small space between it and the foregoing valve. The lateral area is sharply marked and elevated on the left side, while on the other side it is imperceptible. On the right half, the tegmentum is so much produced forward that this part of the tegmentum is completely concealed under the foregoing valve, but without coalescing with it. Thus, in front, the right lateral margin is connected with the reflected area of valve III, so that its length is almost twice as long as that of the left side (fig. 22). This valve is produced obtusely behind the middle, and sinuated on either side, somewhat more deeply on the right. With these abnormal features, the tegmentum of this valve appears to have been pushed forward on the right side alone, while on the left side it remains undisturbed.

b) Ventral view (fig. 21)

The peculiar mode of coalescence of the three shell-plates is well exhibited in the ventral view. The compound nature of valve II/III is shown on the right half of the articulamentum, by a deep and well-marked

fissure, which begins on the right lateral margin and passes leftward across the mid-ventral line by about 4 mm. The sutural laminae of valves II and III are, therefore, well established, although on the left side these laminae are firmly fused together, leaving no line of coalescence between. The side slit is quite abnormal; there is only one slit at the antero-lateral corner of the right insertion-plate of valve II; elsewhere none exists at all. Although the coalescence between the articulamenta of valves II and III occurs on the left side, the union between the latter and valve IV is

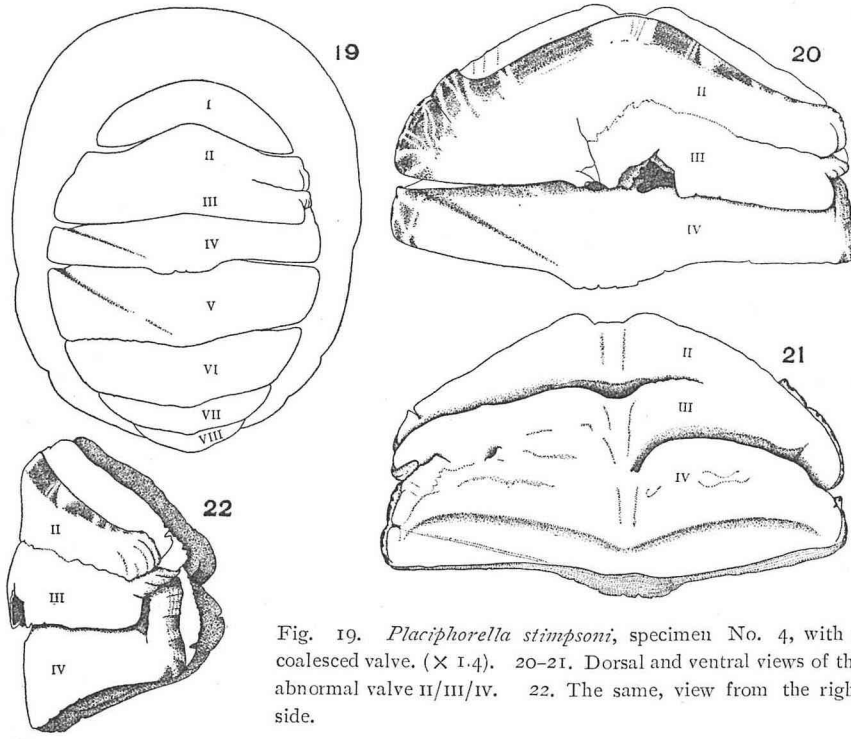


Fig. 19. *Placiphorella stimpsoni*, specimen No. 4, with a coalesced valve. (× 1.4). 20–21. Dorsal and ventral views of the abnormal valve II/III/IV. 22. The same, view from the right side.

effected mainly on the right side. The left sutural lamina of valve IV is nearly perfect, whereas on the right side a thick deposition of articulamental substance has made the boundary between valves III and IV quite obscure, a small shallow depression at about the middle being the only trace. The valve callus, which is comparatively well developed along each boundary fissure of the anterior two valves, shows a normal formation in the articulamentum of valve IV. On the right side the anterior margin of valve IV shows dentation, whence originate several weak radial furrows; at about the posterior 1/4 of the length of the free margin there is a well-defined side slit, whence a slit-ray runs inward. The free margin on the left side is much shorter, and provided in front

with a rudimentary side slit, which is not associated with a slit-ray. Thus, we find only two side slits and a slit-ray in these three shell-plates which have suffered coalescence, and the reduction of the number of incisions forms a peculiar feature of these abnormal valves.

Valve V.

On the left side, the tegmentum of valve V is much elongated axially, while on the opposite side it is nearly of the normal length. The lateral area is prominently elevated on the left side alone, while on the other side it is entirely missing. The structure of the articulamentum is almost free from monstrosity, though, its regularity is slightly injured by the presence of two shallow slits on the left lateral margin, neither of which is connected with a slit-ray.

In this malformed specimen, the length of the whole series of valves is reduced in the front part by the union of valves II and III, and also by the shortness of the following valve; however, both valves V and VI are elongated so much that the total length of the whole series rather exceeds the normal one. It is probable that valve IV has failed to attain the normal length because of its close coalescence with the foregoing valve. It is of some interest to note that to compensate for the insufficient length of the three shell-plates which have suffered malformation, not only valve V which follows them, but valve VI also, has undergone an axial elongation. The remaining valves VII and VIII have not shared the teratological modification; the effect has apparently been checked by the foregoing valves.

No. 5 Coalescence of shell-plates in *Placiphorella stimpsoni* (Gould)

(Pl. II, fig. 6; figs. 23–28)

Locality: Coast of Minatoyama, Mitsu, Prov. Iyo (8. VIII. 1926, Iw. Taki coll.)

Measurements:

		length	width
body		33.0	26.0
valve		27.3	22.8
no. of valve	I	3.7	18.0
	II	5.0	22.1
	III	5.2	22.8
	IV/V	6.6	22.8
	VI	4.7	19.8
	VII	4.7	15.7
	VIII	3.1	10.0

No. of ctenidia: right 22, left 23.

The specimen is almost as large as an adult, and curves ventrally a little. The hairs of the girdle are gone except on the peripheral margin. The tegmental surface is very clean and the characteristic sculpture and colouration are retained well. Valves I–III are perfectly normal, but in valve IV and the subsequent ones, the mid-dorsal line is bent to the right side. This abnormal curvature of the median axis is brought about by the asymmetrical shape of valve IV/V, the left

part of the tegmentum of which is much elongated axially, while its opposite half is as long as the usual shell-plate. Moreover, in valve VI the right half of the tegmentum is axially shorter than the normal one. Although the elongation of the left part of the tegmentum of valve IV/V is somewhat compensated for by the shortness of the right half of the following valve, the left half exceeds in length the right so much that the median axis of valves IV–VIII has been shifted to the right.

Valve IV/V (text-figs. 24, 26)

The central area of valve IV/V is normal, but on the left side of its posterior margin there is a well-defined ridge which recalls a diagonal rib. This is a peculiar feature, since the lateral area of the normal specimen of this species is elevated without forming any such ridge. The lateral areas show a remarkable asymmetry; the right side is shortened axially, while the left side is much elongated. Especially noteworthy is the fact that this left lateral area is divided into two by a deep and narrow furrow (f) which connects the apex of the valve to the lateral margin. This furrow interrupts the growth lines of the tegmentum, and turns over beneath the surface. On the left side there are two insertion-plates apparently united together, and bounded by the furrow. The narrow posterior wedge-shaped area, bounded by the furrow, represents the posterior part of valve V, the main part of its tegmentum being gone.

The ventral surface is quite abnormal. On the right a side slit and a slit-ray are seen as usual, but the insertion-plate is weakly cut into a few notches. An oblique, sharply keeled ridge (r_1) traverses the right half of the articulamentum; this ridge starts at the apex of the valve and terminates in an open triangular tube. The reversed area of the tegmentum covers almost all the posterior half of this ridge. Another weak ridge (r_2), nearly parallel to the former, is seen on the right side of the median axis.

The left side of the articulamentum consists of two insertion-plates. The anterior one, which belongs to valve IV, is practically normal; the side slit lies just below the antero-lateral corner of the tegmentum. The posterior one, lying nearly parallel to the former in the side view, coalesces firmly with it, leaving a narrow boundary groove between, and is also provided with a side slit. It fits well with the wedge-shaped tegmentum which represents valve V. The valve callus is irregular, owing to the abnormality of the articulamentum stated above. The posterior margin is covered by an unusually wide reversed area of the tegmentum.

Valve VI (figs. 25, 27)

The tegmental surface is normal on the left half; on the opposite

side, however, an oblique deep groove (gra) runs from the apex of the valve to one-third the breadth of the anterior margin. On the right side of this groove, the tegmentum is axially reduced, to almost 2/3 the normal

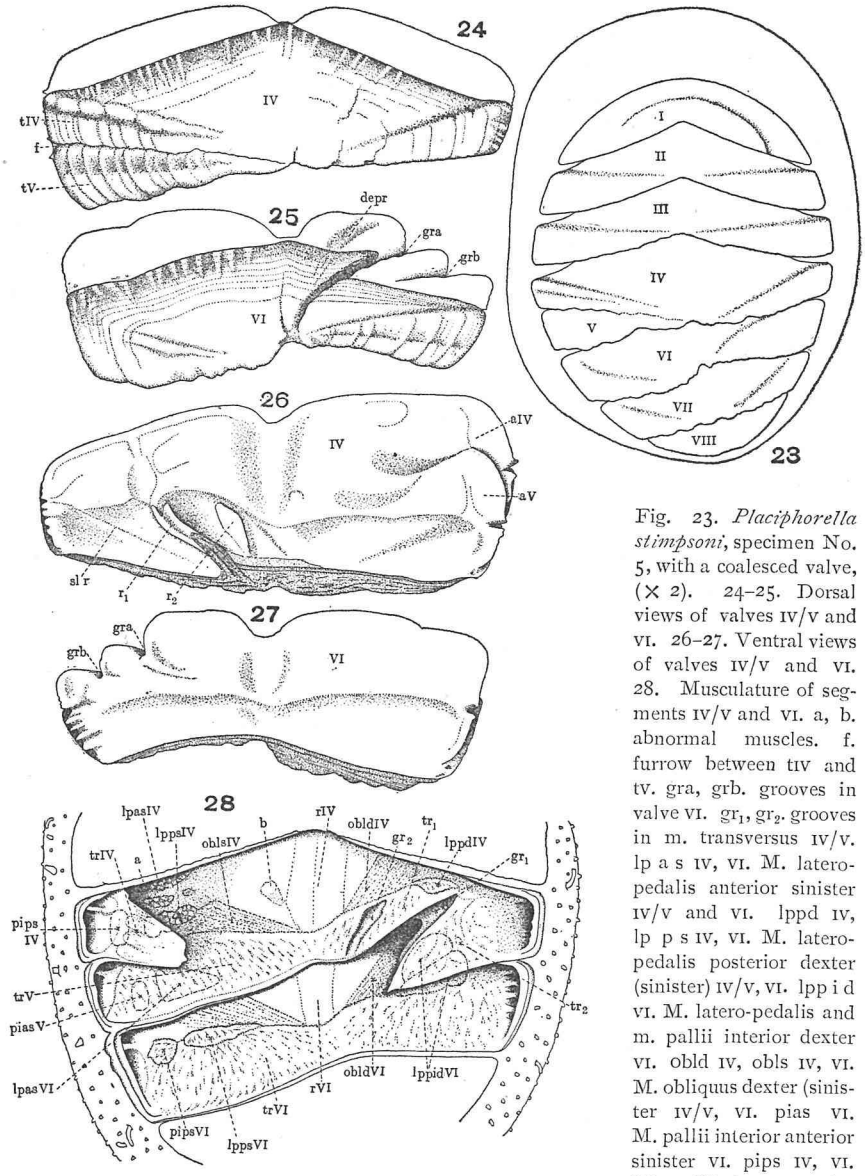


Fig. 23. *Placiphorella stimpsoni*, specimen No. 5, with a coalesced valve, (× 2). 24–25. Dorsal views of valves IV/V and VI. 26–27. Ventral views of valves IV/V and VI. 28. Musculature of segments IV/V and VI. a, b. abnormal muscles. f. furrow between tIV and tV. gra, grb. grooves in valve VI. gr_1, gr_2. grooves in m. transversus IV/V. lp a s IV, VI. M. latero-pedalis anterior sinister IV/V and VI. lppd IV, lp p s IV, VI. M. latero-pedalis posterior dexter (sinister) IV/V, VI. lpp i d VI. M. latero-pedalis and m. pallii interior dexter VI. obld IV, obls IV, VI. M. obliquus dexter (sinister IV/V, VI. pias VI. M. pallii interior anterior sinister VI. pips IV, VI. M. pallii int. posterior sin. IV/V, VI. r_1, r_2. ridges. rIV, rVI. M. rectus VI/V, VI. sl. r. slit-ray. tIV, tV. tegmenta of valves IV and V. tr_1, tr_2, M. transversus IV (right half). trIV, V, VI. M. transversus IV, V, VI.

length, and the lateral area is well-defined. The sutural plate is trilobate, on account of the presence of two parallel grooves (gra, grb) of different length.

In the articulamentum the following features are noticeable :—The right half is axially shorter than the left half, where no abnormality is seen. The antero-lateral corner is atrophied in the right sutural lamina, which is trilobate. The right insertion-plate is roughened by three sharp teeth, deeply incised by four notches.

If the two shell-plates described above are put together so as to overlap each other in situ, the relationship of the irregular structures becomes evident. Of course, the anterior margin of the articulamentum of valve VI fits well to the ridge in the valve callus of the foregoing valve. The oblique ridge (r_1) of the articulamentum of valve V fits closely to the oblique groove (gra) of valve VI, the weak ridge (r_2) to the shallow depression (depr), and the right slit-ray (sl. r) of valve V to the weak groove (grb) of valve VI. Hence, the irregularities of the right halves of both the valves have been brought about into close relationship with each other. The right half of valve V, which is apparently missing in this specimen, can be regarded as represented by two abnormal ridges (r_1, r_2), which are concealed beneath the foregoing valve. On the left side of these overlapping shell-plates the three insertion-plates fit so well with each other that there is no abnormality at all.

The musculature (fig. 28)

The musculature exposed by the removal of those abnormal valves may deserve some comments. The area under valve IV/V is unusually broad, and shows the following irregularity :—At the left antero-lateral corner there is a thin membranous triangular muscular plate, which is inserted into the space between insertion-plates IV and V (a IV, a V). This muscular plate may be regarded as musculus transversus of segment IV, whereas in segment V this muscle is well-developed. On the right side, m. transversus is incised obliquely, where an oblique ridge of the articulamentum of valve IV/V (r_1) is inserted. A shallow oblique depression in this muscle (gr_2) corresponds to the weak ridge of the articulamentum (r_2).

M. rectus IV/V is a little wider than usual. M. obliquus is long on the right side, but much shortened on the left side, terminating in m. latero-pedalis posterior sinister IV/V. The muscle lying in front of the oblique incision in m. transversus can be identified as m. latero-pedalis posterior dexter IV/V.

M. latero-pedalis anterior IV/V is found only on the left side. M. pallii

interior anterior sinister IV is concealed under the muscular lappet of the antero-lateral corner. The muscles labelled a, b in figure 28 do not occur normally, and can not be identified.

Under valve VI, m. transversus, m. rectus, and m. obliquus are nearly normal. On the left side, m. latero-pedalis posterior and m. pallii interior posterior are exposed on the disarticulated area, while the anterior ones of both these muscles are under the muscular cushion (m. transversus) of the foregoing segment. On the right side these latter muscles are missing, and the posterior group of these muscles, which are united together and occupy a broad area, are found under the tongue-like muscular cushion (tr_2).

In general the arrangement of the muscles is closely related to the abnormality of the shell-plate.

No. 6 Coalescence of shell-plates in *Acanthochiton rubrolineatus* (Lischke)

(Pl. II. fig. 3 ; figs. 29-32)

Locality : Seto, Prov. Kii (July 1929, Iw. Taki coll.)

Measurements :

		length	width
body		26.5	17.0
valve		21.5	6.8
no. of valve	I	3.5	4.6
	II/III	5.5	6.8
	IV	4.0	6.8
	V	4.0	6.8
	VI	3.4	6.8
	VII	2.8	5.8
	VIII	1.8	3.0

No. of ctenidia : right 37, left 38.

The specimen is preserved in a well-extended condition. It is shorter in length than the normal specimen ; the ratio of the length to the width of the body is 16 : 10, while it is about 17 : 10 in the normal specimen. The tegmental surface is eroded, especially severely on valves IV and V. Each of the shell-plates is of unequal length. In the median valves they are more or less elongated than usual, especially in valve II/III, which is obviously double in its structure.

Dimensions :

valve	tegmentum		articulamentum	
	length	width	length	width
II	5.0	6.5	2.3	7.2
III	0.8	6.8	4.5	8.3

Valve II/III.

a) Dorsal view (fig. 30)

The tegmentum of valve II is almost normal, except the right posterior corner, where it is obliquely cut off. The tegmentum of valve III is a little broader than the former, but it is much shortened axially. About the anterior 5/6 of the tegmental area of valve III is atrophied, and the remaining part of it corresponds to the hindmost

region of the normal shell-plate. The coalesced margin is indistinct on the left side, but on the right side it is sharply marked by a groove.

The sutural lamina and the insertion-plate of valve II are nearly normal. On the left side, the free margin of the plate is undulated, but on the right side it is very narrow and ill-developed, in correlation with the abnormality of the neighbouring tegmentum.

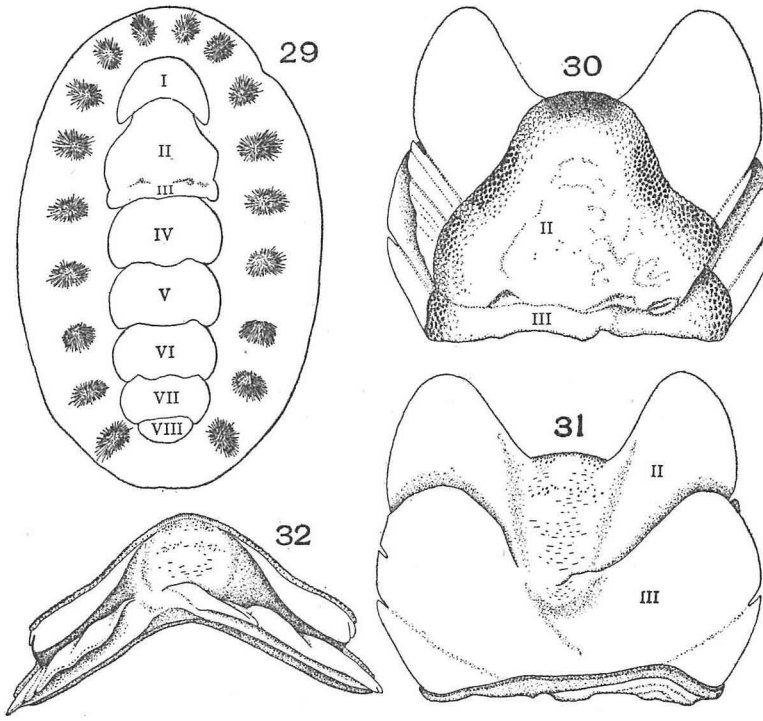


Fig. 29. *Acanthochiton rubrolineatus*, specimen No. 6, with a coalesced valve. (× 2.3) 30, 31, 32. Dorsal, ventral and front views of the coalesced valve.

b) Ventral view (fig. 31)

The sutural lamina of valve II is normal, but that of valve III is short and asymmetrical. It is undulated and narrow on the right side, and has two side slits, of which the anterior one is not connected with a slit-ray. But on the opposite side the sutural lamina begins at almost the mid-ventral line, and the space corresponding to the sinus is narrow and shifted to the left side. This sutural lamina is normal on the ventral side, but, there are a few irregular thickenings on its dorsal side. The central pitted area is very indistinct and narrow, represented only by a few pits behind the initial part of the left sutural lamina. The valve callus is

better developed than in valve III. The reversed area of the tegmentum covers the posterior margin of valve III asymmetrically, viz. it is narrow on the right side, but wider on the left, showing a well-defined reversed area of both the periostracum and the tegmentum.

c) Front view (fig. 32)

In the front view the sutural laminae of both valves II and III are nearly parallel. The articulamentum of valve II coalesces firmly with that of valve III at the dorsal base of the sutural lamina of the latter.

The spicule-bundles

There are 9 pairs of spicule-bundles on the girdle as in the case of a normal specimen. They are arranged uniformly around the valves, but the relative position of the spicule-bundle to the valve is quite characteristic. The 1st–3rd bundles are situated a little more anteriorly than in the normal case, viz. the 3rd spicule-bundle lies slightly in front of the sutural position between the head valve and valve II. The relative positions of the remaining spicule-bundles are as follows:

4 th . . . at about half of the length of valve II
5 th . . . at the sutural position between valves III/IV
6 th . . . „ „ „ „ IV/V
7 th . . . „ „ „ „ V/VI
8 th . . . „ „ „ „ VI/VII
9 th . . . on both sides of valve VIII.

While in the normal case the 3rd–6th spicule-bundles are at the sutural position between valves I/II, II/III, III/IV, IV/V, respectively, and the 7th is at about the anterior fourth of the length of valve VI, the 8th at about the middle of valve VII, and the 9th on either side of the posterior extremity of the tail valve (cf. Pl. II, fig. 2). The unusual relative position of the spicule-bundles of this specimen is brought about exclusively by the coalescence of the shell-plate, not by the spicule-bundles themselves, whose arrangement seems quite normal. Thus, to fill up the space lost by the abortion of the most of the anterior part of the tegmentum in valve III, valves I and II have retreated backward, and the latter has coalesced with valve III. Therefore each of the 1st–4th spicule-bundles lies apparently relatively more anteriorly than in the usual case. By these irregularities the relative position of the 5th and the following spicule-bundles have been restored to a normal state.

It may be noticed here that all the shell-plates in this specimen are larger than those of the normal individual, though erosion of the tegmentum has made this difference somewhat indistinct. Valves IV–VIII are

wider and longer than usual, and all of them seem to have retreated slightly backward, so that the posterior margins of valves v and vi coincide with the lines connecting the pairs of the 7th and 8th spicule-bundles, and the tail valve lies almost between the 9th pair, though in the normal specimen it lies a little anterior to the hindmost spicule-bundle.

Number of ctenidia

If we take the body length as a standard for comparison, the number of ctenidia of this specimen is a little more than normal. The ctenidium counting of the normal specimens collected together with the present specimen gives the following results:

	specimen no. 6	normal specimens					
body length (mm.)	26.5	20	22	24	27	31	35
no. of ctenidia	37/38	21/20	25/24 29/30	32/33 33/33	32/34 37/36	36/35	35/37

No. 7 Coalescence of shell-plates in *Liolophura japonica* (Lischke)

(Pl. ii, fig. 7; figs. 33–38)

Locality: Coast of Minatoyama, Mitsu, Prov. Iyo (20. viii. 1929, Iw. Taki coll.)

Measurements:

	length	width
body	13.0	8.2
valve	11.0	4.7
iii	1.7	4.5
iv	0.7	4.7

No. of ctenidia: right 53, left 56.

The specimen is very young. It is slightly reduced in length as compared with a normal specimen. The valves, except the posterior three, are more or less separated from one another by the encroachment of the girdle. But this is not necessarily a feature peculiar to this specimen, since the separation of valves by the girdle is often met with in young specimens of this genus.

The abnormality of this specimen consists in the coalescence between valves iii and iv. I succeeded in disarticulating them with little injury, but the connection between the valves was so feeble that later handling caused the separation of each valve.

Valve iii/iv

a) Dorsal view (fig. 34)

Valve iii appears practically normal in the size of the tegmentum, the sculpture, and in the arrangement of shell-eyes, etc. But the beak of the valve is shorter than in the usual case.

Valve iv is attached to the foregoing valve, and is partly concealed

beneath the latter. Its tegmentum is wider than in valve III; but it is axially reduced in length, measuring nearly one-third as long as valve III along the mid-dorsal line. The beak is developed normally and the posterior margin is irregularly roughened, and extended somewhat backward on both extremities. The tegmental sculpture is condensed axially,

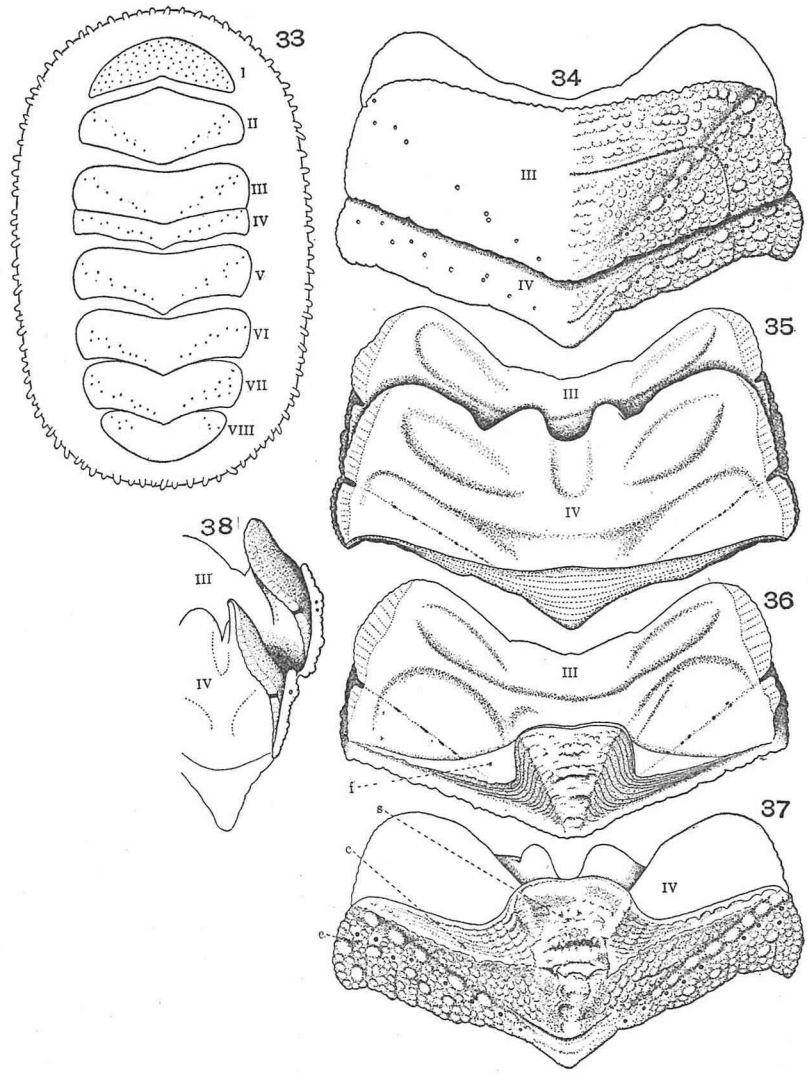


Fig. 33. *Liolophura japonica*, specimen No. 7, with a coalesced valve. (× 5) 34, 35. Dorsal and ventral views of the coalesced valve. 36. Ventral view of valve III. 37. Dorsal view of valve IV. 38. Coalesced valve, viewed from left side. c. covered area. e. exposed area. f. film. s. scar.

and the diagonal row of tubercles intersects the mid-dorsal line at a more obtuse angle than in valve III.

b) Ventral view (fig. 35)

The deviation of this valve from the normal state seems slight. In valve III the sutural lamina is undersized, but the valve callus, the insertion-plate, the side slit and the slit-ray are normal. On each side of the mid-ventral line in the sinus of valve IV, is a projecting lobe of the articulamentum, which gives the anterior margin a peculiar configuration. The reversed area of the tegmentum is as usual.

In its profile the tegmentum of valve III, whose posterior margin is united with the tegmentum of valve IV, is smoothly arcuate, the latter being quite shortened and straight (fig. 38).

By separating the component valves the following features have been observed. In the ventral surface of valve III there is a subquadrate raised area mesially behind. Its surface is irregularly roughened; the central triangular region is coloured grayish, while the rest is of a dark chestnut colour. On either side of its posterior part, this area extends to the postero-lateral corner of the articulamentum. There are a number of lines of growth in this region, on each side of which is found a thin film (f). This area corresponds to the reversed area of the periostracum and the tegmentum; however, it shows marked modification owing to its coalescence with valve IV. It is broader and longer than usual, reaching half the length of the valve, and is attached loosely to the anterior part of the tegmentum of valve IV, while in the normal case this area is protruded freely behind.

In the dorsal view of valve IV some irregularities may be seen. An extension of the articulamentum on both sides of the jugal sinus is bounded from the sutural lamina by an oblique groove. The tegmentum, though not shorter than in the normal specimen, lacks the anterior part on both sides, where it is about 2/3 as long as the normal length. A line passing midway between the mid-dorsal line and the antero-lateral corner of the tegmentum, divides the area into two. In front of this line the sculpture is weaker than in the hind region. The broad area in the central part (s), to which the central triangular part of the foregoing shell-plate was attached, is irregularly roughened, without having any characteristic sculpture. On each side of this area, which is shortened axially, the sculpture is very faintly shown and the granules are arranged nearly parallel to the anterior margin of the tegmentum. This part of the tegmentum is covered by the posterior margin of valve III, and united with it so firmly that the development of the sculpture has been injured here.

Number of ctenidia

The adult of this species has about 50 ctenidia on each side (Is. Taki, 1923; Baba, 1929), so that the present specimen, though very juvenile in appearance, has rather many ctenidia for this species. But it seems difficult to find any relation between the ctenidial number and the abnormality of the shell-plate.

No. 8 Splitting of shell-plate in *Liolophura japonica* (Lischke)

(Pl. II, figs. 10, 11 ; figs. 39-44)

Locality : Gogoshima, Onsen-gun, Prov. Iyo (July 1920, Isao Taki coll.)

Measurements :

		length	width
body		40.0	23.0
valve		36.0	16.0
no. of valve	I	6.0	11.0
	II	8.0	13.4
	III	5.0	14.8
	IV	6.4	16.0
	V	(r.) 4.4 (l.) 8.0	—
	VI	8.8	15.0
	VII	4.8	14.0
	VIII	4.0	10.2

No. of ctenidia : right 58, left 55.

The specimen is of moderate size, but is poorly preserved and curved ventrally. The valves as a whole show normal development, except valve V, whose abnormality is quite characteristic.

The abnormal valves

Valve IV/V

a) Dorsal view (fig. 40)

The tegmental surface of valve IV is nearly normal ; however, on the left half of its posterior margin a triangular area is attached to it. This area is probably the remnant of valve V, as it is bounded in front by a somewhat irregular shallow furrow, and the lines of growth as well as other tegmental features are wholly contiguous with those of valve IV ; it is, however, represented merely by a part of the tegmentum which corresponds to the left lateral area, so that the central area of valve V is completely atrophied on the left side.

b) Ventral view (fig. 43)

The mode of coalescence exhibited on the dorsal surface does not agree with that on the ventral side. In the ventral view this shell-plate is apparently normal, except on the left lateral margin, where, at about the anterior one-third of the length of the left margin, there is a deep, well-defined cleft, which is connected behind with the terminus of the furrow of the tegmentum between valves IV and V. Therefore the insertion-plate of valve V is well exhibited here. The attachments of musculus latero-pedalis anterior (inside) and m. pallii interior (outside) are seen on three regions in this valve.

On the right side the muscle impression in valve IV is well developed, but on the opposite side it is somewhat reduced, probably owing to the unusual coalescence on this side. The left insertion-plate of valve V is impressed with three isolated attachments, of which the outer one is

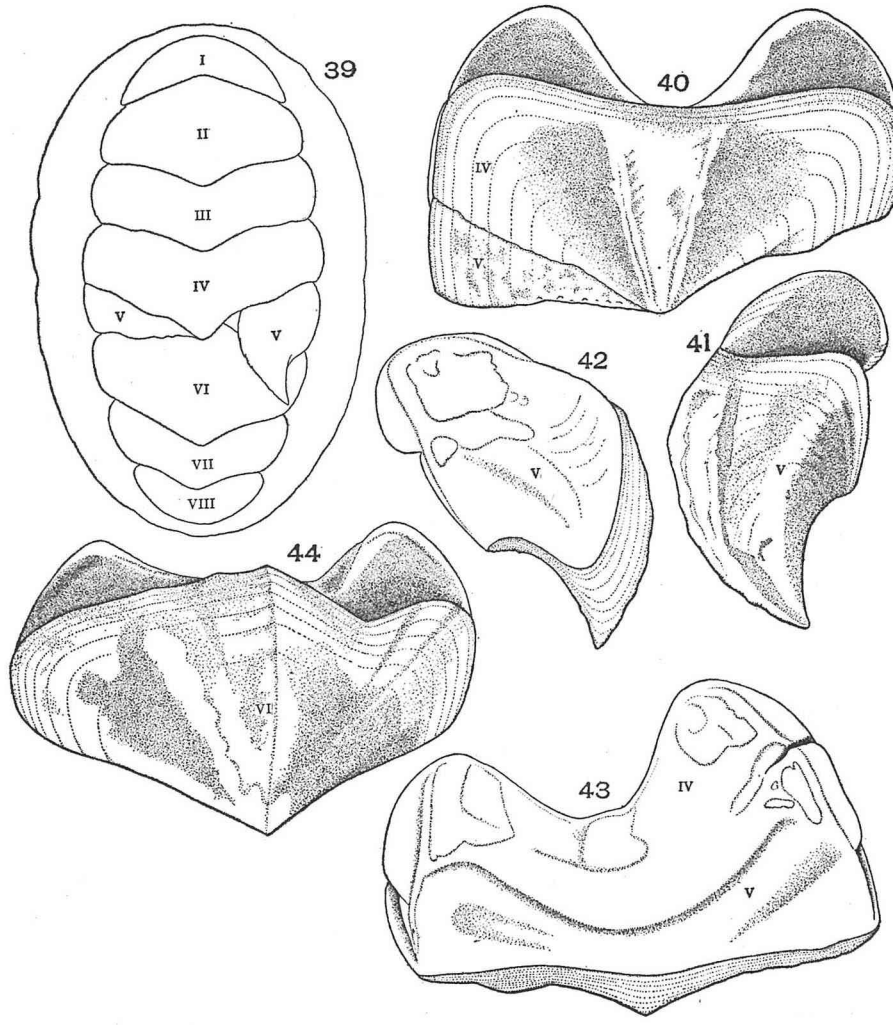


Fig. 39. *Liolophura japonica*, specimen No. 8, with a split valve. (× 1.7) 40, 43. Dorsal and ventral views of valve IV/V. 41, 42. Dorsal and ventral views of the right half of valve V. 44. Dorsal view of valve VI.

the longest, and apparently that of m. pallii interior, while the inner two are smaller and irregular, and may be m. latero-pedalis anterior.

No marked modification is seen on the posterior half of this valve, the valve callus and the posterior reversed area of the tegmentum being almost normal.

The right half of valve v

a) Dorsal view (fig. 41)

Quite unlike the left half of valve v, the right half is represented by an independent half valve, which is very characteristic in shape.

The outline of this valve is roughly square, with the posterior margin pulled strongly backward, the anterior margin being nearly straight, and narrower than half the width of the ordinary shell-plate. This margin is slightly produced at the left corner, while the opposite corner is more angulate than usual; the right lateral margin is nearly straight and perpendicular to the anterior margin. The left lateral margin, which corresponds to the median axis of the shell-plate, is extremely elongated and produced behind, smoothly arcuating outwards. The posterior margin is sinuated, but almost axially directed, though ordinarily it is parallel to the anterior margin. Each of these margins forms a beak behind, which is produced in a peculiar manner to the outside.

The sutural lamina, though nearly normal in its axial length, is much narrowed. On the right side, the sutural lamina projects beyond the tegmentum, quite contrary to the normal case. Probably it has been shifted to the right beyond the tegmentum, on account of some amount of suppression exerted on the left side by the foregoing valve.

b) Ventral view (fig. 42)

The ventral side is as abnormal as the dorsal side. The insertion-plate, though somewhat peculiar, differs little from the normal one. The right lateral margin, or the area of attachment of m. lateralis longitudinalis, is much more shortened axially than in the usual specimen. Though the side slit and eaves are very inconspicuous, the muscle impressions of the sutural lamina are nearly normal. The slit-ray and the valve callus, though quite obsolete, are directed backward to the beak. The inner and the posterior margins are covered widely by the reversed area of the tegmentum, as if these margins were the posterior margin of the normal shell-plate. This is a quite unusual feature in this specimen, and may be related to the abnormal development of the inner margin.

Valve vi (fig. 44)

This valve, though apparently without any relation to the monstrosity of the shell-plates described above, is somewhat modified. The median axis is shifted a little to the right, where it is prominently carinated. The left part of the tegmentum is smoothly inclined, while the right part is reflected sharply downwards. The anterior margin is deeply sinuated at about the middle of the right half, so that the proximal part of the right

sutural lamina is exposed irregularly. This is due to the abnormal development of the right half of the foregoing valve, which is produced backward and suppresses the growth of the tegmentum. But these abnormalities on the right half of the tegmentum have no direct effect on the articulamental structure.

The monstrosity of this apecimen is caused by the longitudinal splitting of valve v, which may have occurred in an earlier stage of development, and by the coalescence of the left half of this valve with the preceding valve, the right half being left independent. Hence, the reduction of the shell-plate is scarcely noticed in this specimen, which has a normal length of body instead of being axially shortened.

Discussion

Abnormal specimens of chitons are rather rare, yet records of their occurrence are by no means scarce. The occurrence of 6- or 7-valved chitons was noted as early as at the time of Linné (Pilsbry, 1892). Since then, numerous cases[1] have been reported in various species of this group. Rather recently, Pelseneer (1919, '20, '23) and Hoffmann (1930) have given a general review of the abnormality in question. I should like to deal with the matter more fully from the teratological point of view.

1. Classification of abnormality

The abnormal cases described above may be classified as follows:

a. Hypomerism (Nos. 1 and 2)
b. Coalescence (Nos. 3—7)
c. Splitting (No. 8)

a) Hypomerism, or the complete absence of a certain number of shell-plates. Here the imbricated series of plates is regulated so finely in the subsequent development that in its general features the specimen looks apparently normal. This is a case of "meristic variation in linear series," as it is called by Bateson (1894). So far as I am aware, nothing is known about the regenerating power of the shell-plates of chitons; it is likely, however, that the abnormality may be brought about by the complete atrophy of one or more rudiments of shell-plates in an early embryonic stage, and by the subsequent regulative change of the remaining plates. Specimens No. 1 (7-valved) and No. 2 (6-valved) described above, belong to this category.

The reduction may affect various numbers of shell-plates; in fact,

1. See p. 58.

specimens with 7 to 3 valves are known, though a 4-valved one has not yet been recorded.

b) Coalescence—or the atrophy of a certain area of a shell-plate, and coalescence of that plate with the adjacent plate. There are various degrees of reduction of the shell-plate, and of the coalescence too. Thus, in Nos. 3 and 4 of the specimens described above, the tegmental area of the fused valve is only a little longer than that of a normal plate, but in No. 5 the left lateral area alone is attached to the tegmentum of the abnormal valve, and in No. 6 the anterior 5/6 of the tegmentum has atrophied. On the other hand, in specimen No. 7, one shell-plate covers another partially, and coalesces with it only weakly, so that the growth of the tegmentum of the covered valve is somewhat inhibited, while the articulamentum of both the shell-plates has developed almost in an ordinary manner. In general the double nature of a coalesced plate tends to be retained much better in the articulamentum than in the tegmentum.

c) Splitting. In specimen No. 8 in the above descriptions, one of the shell-plates is divided into two halves by a median longitudinal fissure, and one of them coalesces with the preceding valve, the other being left independent. No quantitative loss of shell-plate is here seen ; but the monstrosity probably originated in an early embryological period, as is suggested by the completeness of the coalescence of one half and the perfect isolation of the other of the valve affected.

According to Strohl's (1929) classification of the teratological types, the above three kinds correspond to :

hypomerism — " Partialorganismen " in die Gruppe " Defekte "
coalescence — " Verwachsungen " in die Gruppe " Exzesse "
splitting——— " Spaltbildungen " in die Gruppe " Defekte ".

This classification is applicable to all known cases of abnormality in chitons ; but it should be noticed that coalescence is not always a change to a plus direction, because it is in almost all cases accompanied by some amount of defective development of the shell-plate.

The various types of the malformation given above suggest a fundamental difference in their origin, but we meet with abnormalities which are difficult to assign to any of these types. For instance, in the case of specimen No. 3, the double nature of valve III/IV is clearly shown in the right side only, while on the opposite side the fusion of the valve is nearly complete, so that, if the former had coalesced like the latter, the specimen would have been just like a regular 7-valved one, and hardly distinguishable from a hypomeric specimen. On the other hand, the tail valve of specimen No. 2 (a 7-valved *Acanthochiton*) shows a different irregularity ;

in it, the valve is apparently of a compound nature corresponding with valves VII and VIII of a normal specimen. This fact suggests, in spite of the valve being entirely free from any trace of fusion, a coalescence between the two hindmost shell-plates after some injury. In specimen No. 8, as has already been mentioned, the malformation implies both splitting and coalescence. Thus, it seems probable that the distinction among those types can be attributed to the difference in the degree of atrophy and coalescence of the shell-plate.

2. Abnormality of shell-plates

a) Size of shell-plates

If reduction occurs in the number of shell-plates, compensatory growth occurs in the remaining plates. For example, in specimens Nos. 1, 2 and 6 (all of them *Acanthochiton rubrolineatus*), each valve is longer and wider than that of a normal specimen. Though in the three malformed specimens of *Placiphorella stimpsoni*, the shell-plate is nearly as wide as a normal one, in specimen No. 3 one shell-plate, and in No. 4 two shell-plates, behind the coalesced valve, are elongated in a striking manner so that the total length of the serial valves is almost the same as in the normal specimen. This is also the case with specimen No. 8 of *Liolophura japonica*, in which shell-plate VI following the split plate is elongated axially. But in the same species, No. 7 (coalescence in the lowest degree) shows no noticeable elongation of each valve, and each shell-plate except the coalesced one is separated from the adjacent plate so uniformly that the whole series of the valves attains a normal length. In general, a uniform enlargement of the shell-plate occurs in a hypomeric specimen, while in the cases of coalescence and splitting, the loss in the total length of the shell-plates is compensated to some extent by the axial elongation of one or more shell-plates which follow the malformed one. It is interesting to note, in the latter two cases, that the shell-plates in front of the abnormal one do not take part in the compensatory growth of the valve, so that the head valve is almost always free from any abnormality, at least in the specimens dealt with here. This compensatory elongation of the valve may be seen also in the figures given by previous authors, e. g. in a 6-valved *Ischnochiton conspicuus* (Dall, 1925), a 5-valved *Chiton pellisserpentis* (Iredale, 1908), a 3-valved *Ischnochiton contractus* (Sykes, 1900); in the last mentioned case, especially the tail valve is markedly extended.

b) Coalescence

In the specimens with coalesced shell-plates described above (Nos.

3—7), the coalescence is more complete in the tegmentum than in the articulamentum, viz. the fusion apparently advances from the dorsal to the ventral direction. This fact suggests the presence of some relation between this change and the development of the shell-plates ; according to Hammarsten and Runnström (1925), the appearance of the tegmentum in the larval period antedates that of the articulamentum.

3. Relation between the abnormality of shell-plates and other morphological characters

a) Body length

If the shell-plate has undergone hypomerism, the body is usually shortened at the same time. This fact has been pointed out by Pelseneer (1919, '20). It seems significant that the body length as well as the outline of the whole body, is closely correlated with the number of the existing shell-plates. Although the reduction in the length of the body is not always proportional to the number of shell-plates which have atrophied, however, the general tendency may be perceived from the data given in Table 1.

Table 1.

The relative length of abnormal chiton specimens, in comparison with that of normal ones. (* shows coalescence)

Species	No. of valve	Ratio (length x : breadth 10)		Author
		abnormal	normal	
Acanthochiton rubrolineatus No. 1	7	14 : 10	17 : 10	Taki
„ „ No. 2	6	18 : 10	17 : 10	„
Placiphorella stimpsoni No. 3	7*	15 : 10	13 : 10	„
„ „ No. 4	7*	13 : 10	13 : 10	„
„ „ No. 5	7*	13 : 10	13 : 10	„
Acanthochiton rubrolineatus No. 6	7*	16 : 10	17 : 10	„
Tonicia undulata[1]	7	20 : 10	22 : 10	Pelseneer, 1920
Lepidochiton cinereus[2]	7	14 : 10	16 : 10	Pelseneer, 1919, '20
„ „	7	15 : 10	16 : 10	„
„ „	6	13 : 10	16 : 10	„
„ „	6	11 : 10	16 : 10	Pelseneer, 1923
Plaxiphora ovata	6	15 : 10	12 : 10	(Iredale, 1908)
Ischnochiton conspicuus	6	18 : 10	22 : 10	(Dall, 1925)
Chiton pellisserpentis	5	14 : 10	15 : 10	(Iredale, 1908)
Ischnochiton contractus	3	14 : 10	21 : 10	(Sykes, 1900)

1. This species belongs to the section *Onithochiton* of this genus.
2. = *Chiton* (*Boreochiton*) *marginatus*.

The phylum Mollusca, as is generally accepted, is characterised by its non-metameric structure. If some similarity to metamerism is to be perceived at all, however, it would be in the Polyplacophora[1], and particularly in the arrangement of :

A. Shell-plates (including muscular and nervous structures, etc.);

B. Girdle : i. in colouration ;

ii. in pore-tufts or sutural hairs on the intersegmentum ;

C. Ctenidia ;

D. Auriculo-ventricular communications of the heart.

In some groups of chitons the girdle is tessellated, or banded across the area adjacent to each median valve. No information is given in the works of previous authors about the relationship between the hypomerism of the shell-plate and the colour band. My materials, described above, do not give much help in this point, but it seems probable that the colour band becomes less than usual in accordance with the number of the plate (cf. fig. 1, in Pelseneer, 1919).

The auriculo-ventricular communications also tend to be reduced in number in the hypomeric specimen (Pelseneer, 1919); but no definite information has been obtained as to this point from the present material.

b) Bundle of spicules

The girdle of all species of the genus *Acanthochiton* is armed with 9 pairs of bundles of calcareous needles around the shell, of which 7 pairs are placed regularly on both sides of the intersegmentum. This arrangement is practically constant in the normal specimen. In the abnormal specimens of *Acanthochiton rubrolineatus* at my disposal, both No. 1 (7-valved) and No. 2 (6-valved) are provided with a pair or two fewer spicule-bundles than the usual number. This fact suggests that the spicule-bundles have a close relationship with the formation of the shell-plate. It is readily understandable, therefore, that even in the same species, a specimen such as No. 6, in which the shell-plates are reduced in number by coalescence, should bear the pore-tufts in the usual number.

In the younger specimens of the genus *Placiphorella* the sutural position of the girdle is provided with a conspicuous hair, which by later growth becomes quite obsolete, so that I was unable to find any relationship between this and the reduction of the shell-plates.

c) Number of ctenidia

Pelseneer (1919, '20) noticed that in a specimen with hypomeric shell-plates the number of ctenidia tends to decrease, though the reduc-

1. Pelseneer (1899) called this resemblance " pseudo-metamerisation ".

tion does not necessarily go hand in hand in those two organs. However, so far as my teratological examples are concerned, the fact is not so plain, and the reverse is often met with. For example, in specimens Nos. 1 and 2 (hypomerism) at least, it is hardly possible to find any tendency to reduction of the ctenidial number. This is partly due to the difficulty in estimating the number of ctenidia in a specimen of corresponding size[1], and partly to its high variability. But from the data available (Table 2) I am inclined to believe that the ctenidium may develop normally without any connection with the hypomerism of the shell-plate.

Table 2

Ctenidial number in abnormal and normal specimens. (* shows coalescence)

Species	No. valve etc.	Number of ctenidia			Author
		Abnormal specimen	Normal specimen		
			range	mean	
		r. l.			
Acanth. rubrolineatus No. 1	7	27/24	22~28	24	Taki
„ „ No. 2	6	18/16	17~19	—	„
Plac. stimpsoni No. 3	7*	25/23	21~24	—	„
„ „ No. 4	7*	25/27	21~24	—	„
„ „ No. 5	7*	22/23	21~24	—	„
Acanth. rubrolineatus No. 6	7*	37/38	32~37	—	„
Liol. japonica No. 7	7*	53/56	——	ca. 50	„
„ „ No. 8	splitting	58/55	——	ca. 50	„
Tonicia undulata	7	31/31	31~34	—	Pelseneer, 1919
Lepidochiton cinereus	7	14/15	——	17	Pelseneer, 1923
„ „	7	17/17	——	17	„
„ „	7	17/18	——	17	„
„ „	6	15/14	——	17	„
„ „	6	15/13	——	17	Pelseneer, 1919

3. Occurrence of abnormality

a) The number of abnormal shell-plates

In the case of hypomerism we are unable to say which of the shell-plates has atrophied. With regard to this, Pelseneer (1919) suggested a possible origin of a hypomeric specimen as follows: "L'existence de sept valves au lieu de huit, dans quelques adultes isolés, pourrait peut-être s'expliquer par le fait que, dans le développement, les sept valves antérieures apparaissent ensemble, bien avant que la huitième se constitue: celle-ci avorterait plus facilement que d'autres dans certains cas. Mais

1. Snyder and Crozier (1922) have shown in chitons an increase of ctenidia with growth.

cette sorte d'explication n'est plus valable pour des hypomères à six ou à trois valves" (p. 42). It is embryologically known that the anterior 7 rudiments of shell-plates appear first while the 8th rudiment is formed much later (Heath, 1899; Hammarsten and Runnström, 1925). So that this explanation of Pelseneer seems plausible[1].

On the other hand, in the cases of coalescence and splitting, we see that all of the valves are liable to monstrosity, or the occurrence depends entirely on chance[2] (Table 3).

Table 3

The number of coalesced valves.

Species	Coalesced valves	Author
Acanthopleura granulata	I/II	Berry, 1925
Chiton olivaceus (a)	II/III	Maluquer, 1915
Acanthochiton rubrolineatus, No. 6	II/III	Taki
Placiphorella stimpsoni, No. 4	II/III/IV	„
Callochiton platessa	III/IV	Oliver, fide Hoffmann, 1930
Placiphorella stimpsoni, No. 3	III/IV	Taki
Liolophura japonica, No. 7	III/IV	„
Placiphorella stimpsoni, No. 5	IV/V	„
Liolophura japonica, No. 8	IV/V	„
Lepidochiton cinereus	VI/VII (2 cases)	Pelseneer, 1920; 1923
Chiton olivaceus (b)	VI/VII	Maluquer, 1915
Chiton tuberculatus	VII/VIII (2 cases)	Crozier, 1919
Lepidochiton cinereus	VII/VIII	Pelseneer, 1923

b) Frequency of occurrence of malformed chiton specimens

It is generally supposed that the malformed chiton specimen is of rather rare occurrence. Among the abnormal specimens at my disposal, 5 out of 8 cases belong to the type of coalescence, so that coalescence seems to occur more frequently than a regular hypomerism or a splitting. Pilsbry (1892) says likewise: "Most seven-valved specimens are due to the soldering together of two valves in consequence of some injury. This is not uncommon, a number of cases having come under my observation. Individuals actually seven-valved are known to occur, although they are far from common" (p. xiii). Nothing definite is known as to

1. It seems not improbable that 6-, 5- or 3-valved specimens are the result either of complete atrophy of a number of rudiments of the shell-plate or of coalescence of them in an earlier stage.

2. Pelseneer's view (1923) is untenable as to this point; he says, "Quand une valve de *Chiton* se réduit et disparaît en partie, c'est la septième; c'est-à-dire que si un *Chiton* ne présente que sept valves, la dernière peut être le résultat de la soudure des septième et huitième originelles" (p. 70).

how scarce such abnormality is, but I have gathered some recorded cases for future reference in Table 4.

Table 4

Frequency of occurrence of malformed chiton specimens.

Species	No. of cases and abnormality	No. of individuals	Author
Mopalia ciliata	2 (7-valved)	many thousands	Pilsbry, 1892
Chiton tuberculata	2 (coalesced)	over 2,100	Crozier, 1919
Lepidochiton cinereus	1 (coalesced) 3 (7-valved)	several hundreds	Pelseneer, 1920
" "	1 (7-valved) 1 (6-valved)	ca. 300	Pelseneer, 1919
Placiphorella stimpsoni (Nos. 3 & 4)	2 (coalesced)	ca. 40	Taki
Squamopleura curtisiana[1]	1 (7-valved)	16	Iredale, 1910

c) Summary of known cases of hypomeric and coalesced chiton specimens

Cases of hypomerism as well as of coalescence of the shell-plates are tabulated below. In this list all the families[2] of the Polyplacophora are represented, except the Lepidopleuridae, a family comprising small, rare, deep-sea forms.

Seven-valved specimens (* shows coalescence)

Family Lepidochitonidae

1.	*Tonicella lineata* (Wood)	Packard, 1918
2.	*Lepidochiton cinereus* (Linné)[3]	Iredale, 1910
*3–6.	*Lepidochiton cinereus* (Linné)[4]	Pelseneer, 1920
*7–11.	*Lepidochiton cinereus* (Linné)	Pelseneer, 1923
12.	*Nuttallina californica* (Nuttall)	Baily, 1907
13.	*Callochiton laevis* (Montagu)[5]	Montagu, fide Pelseneer, 1919
14.	*Callochiton laevis* (Montagu)	Jeffreys, fide Oliver, 1921
15.	*Callochiton platessa* (Gould)	Oliver, 1921

Family Mopaliidae

16, 17.	*Mopalia ciliata* (Sowerby)	Pilsbry, 1892
*18–20.	*Placiphorella stimpsoni* (Gould)	Taki

1. =*Sclerochiton*.
2. Thiele's classification (1929) is adopted here.
3. =*Craspedochiton*.
4. *Chiton* (*Boreochiton*) *marginatus*.
5. Montagu named a 7-valved specimen " *Chiton septemvalvis*" (fide Pilsbry, 1892).

	Family Cryptoplacidae	
*21, 22.	*Acanthochiton rubrolineatus* (Lischke)	Taki
	Family Ischnochitonidae	
23, 24.	*Ischnochiton* sp.	Iredale, 1910
	Family Chitonidae	
25.	*Chiton tuberculatus* Linné	Linné, fide Oliver, 1921
*26, 27.	*Chiton tuberculatus* Linné	Crozier, 1919
*28, 29.	*Chiton olivaceus* Spengler[1]	Maluquer, 1915
30.	*Chiton tricostalis* Pilsbry	Bednall, 1897
31.	*Squamopleura curtisiana* (E. A. Smith)	Iredale, 1910
*32.	*Liolophura japonica* (Lischke)	Taki
*33.	*Acanthopleura granulata* (Gmelin)	Berry, 1925
34.	*Tonicia undulata* (Quoy et Gaimard)[2]	Pelseneer, 1919
35.	"*Chiton*" sp.	Quoy et Gaimard, fide Pelseneer, 1919

Six-valved specimens

	Family Lepidochitonidae	
1.	*Tonicella rubra* (Linné)[3]	Blaney, 1904
2, 3.	*Lepidochiton cinereus* (Linné)	Pelseneer, 1919; 1923
	Family Mopaliidae	
4.	*Plaxiphora matthewsi* Iredale	Matthews, fide Bednall, 1897
5.	*Plaxiphora ovata* (Hutton)	Iredale, 1908
	Family Cryptoplacidae	
6.	*Acanthochiton rubrolineatus* (Lischke)	Taki
	Family Ischnochitonidae	
7.	*Ischnochiton conspicuus* Pilsbry	Stearns, 1901
8.	*Ischnochiton conspicuus* Pilsbry	Dall, 1925
9.	*Ischnochiton* sp.	Dall, 1903

Five-valved specimens[4]

	Family Lepidochitonidae	
1.	*Lepidochiton cinereus* (Linné)	Jeffreys, fide Oliver, 1921

1. To each of these two coalesced specimens, Maluquer has given the name of *Chiton olivaceus* Spengler, aberr. *septemvalvis*, var. ex-forma *major-rubra* et *major-viridis*.

2. This species belongs to the section *Onithochiton*.

3. = *Trachydermon ruber*.

4. Though the record of a 5-valved *Chiton aereus* (Iredale, 1908) is referred to by Hoffmann (1930), I cannot find it in the paper cited.

Family Chitonidae

2. *Chiton pellisserpentis* Quoy et Gaimard — Iredale, 1908

Three-valved specimens

Family Ischnochitonidae

1. *Ischnochiton contractus* (Reeve) — Sykes, 1900

Family Cryptoplacidae

2. *Cryptoplax striata* (Lamarck) — Henn, 1894

From the foregoing enumeration we can safely conclude that the frequency of the occurrence of malformation decreases with the number of affected shell-plates. Some of these records are too brief to enable us to determine to what type of malformation they belong[1]. However, if we take all of the cases with the shell-plates less than the usual number, regardless of their origin, whether hypomerism or coalescence, it is obvious that 7-valved specimens occur most commonly while the 3-valved ones are extremely rare. The relationship may be shown with a J-shaped curve (fig. 45).

No. of valve	3	4	5	6	7	8
Frequency	2	0	2	9	35	∞

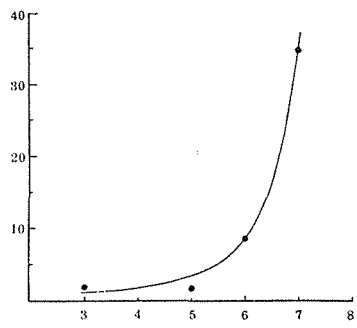


Fig. 45. Frequency of occurrence of specimens with fewer shell-plates than the usual number. Ordinate—frequency; abscissa—number of shell-plates.

If the meristic variation in the number of shell-plates of chitons occurs in an ordinary manner, e. g. as in the ray number of certain starfishes, or in the number of radial canals of a certain Hydromedusa[2], its frequency can be expressed by a normal curve of distribution with the number 8, the normal number of shell-plates, as its mode. But no case with hypermeric (supernumerary) shell-plates is yet known (cf. Pelseneer, 1919). This peculiar type of frequency curve is to be regarded as due to an extreme skewness, represented only by the negative half of a normal curve. In other words, the possible occurrence of the abnormality of the valve in chitons, in so far as is known at least, is restricted

1. For instance, in a case observed by Crozier (1919, text-fig. 2, 3), the coalescence is only visible on a narrow area of the articulamentum, whereas the tegmental surface is apparently as perfect as in a normal valve. The coalescence of this specimen, therefore, was revealed only by the disarticulation of the shell-plates.

2. Vernon, 1903, p. 90.

within either a congenital loss of the rudiment of the shell-plate or a subsequent union between the overlapping plates.

Summary

1. Eight specimens with abnormal shell-plates collected in the Japanese seas are described, with special reference to the nature of the malformation.

2. These abnormalities of the valve may be classified into three types, namely, a) hypomerism, b) coalescence, c) splitting, according to the possible origin of their malformation.

3. By hypomerism is meant the complete reduction of the number of shell-plates to 7, 6, 5, etc., with a subsequent regulation of form among them. Specimens Nos. 1 and 2 here described, as well as the rather regular 7-, 6-, 5- (or 3-) valved specimens belong to this type.

4. The term coalescence is applied to the change in which a shell-plate is partly atrophied, and fuses with other plates. This type of valve monstrosity is rather commonly met with, and includes specimens Nos. 3–7 of my examples.

5. The case in which a certain shell-plate is divided into two by a fission is called splitting. In this case there is no quantitative loss of the shell-plate, so that the degree of malformation in this type is the lowest of all the types. It is not always possible to give a clear demarcation among these three types, owing to the occurrence of transitory forms.

6. In the hypomeric case, almost all the shell-plates, and in the case of coalescence one or more valves following the coalesced one, take part in the compensatory enlargement or elongation of the shell-plate. The coalescence of the valve is likely to take place from the tegmentum downward to the articulamentum, which fact agrees with the earlier appearance of the former than the latter in the larval period.

7. Specimens with hypomeric shell-plates tend to decrease in their body length, while the number of ctenidia is scarcely correlated with the hypomerism. On the other hand, the spicule-bundles in *Acanthochiton* decrease in number in accordance with the number of the shell-plate (specimens Nos. 1 and 2).

8. The malformation of valves is recorded in almost all families of the Polyplacophora. Also any of the shell-plates is liable to coalescence.

9. Cases with hypomeric as well as coalesced shell-plates are enumerated and their frequency is plotted on a graph. The latter shows an extreme skewness, and may be regarded as a hypomeric half of a normal curve.

No case of hypermerism in the number of shell-plates has ever been reported in chitons.

References

(Original papers inaccessible to me are marked with an asterisk.)

BABA, K. 1929. Anatomy of some Japanese Chitons (in Japanese). Dôbutsugaku-Zasshi, vol. 41, p. 108–121.

BATESON, W. 1894. Materials for the Study of Variation. London.

BEDNALL, W. T. 1897. The Polyplacophora of South Australia.
Proc. Malac. Soc. London, vol. 2, p. 154.

BERRY, S. S. 1925. On an abnormal specimen of the chiton, *Acanthopleura granulata*.
Ann. Mag. Nat. Hist., ser. 9, vol. 16, p. 173–175, pl. 12.

CROZIER, W. J. 1918. Growth and duration of life in *Chiton tuberculatus* Linn.
Proc. Nat. Acad. Sci., vol. 4, p. 322–325.

—— 1918 *a*. Growth of Chiton in different environments.
Ibid., vol. 4, p. 325–328.

—— 1919. Coalescence of the shell plates in Chiton.
Amer. Naturalist, vol. 53, p. 278–279.

*DALL, W. H. 1901. Recent works on Mollusks. (3-valved *Ischnochiton*).
Science, n. s., vol. 12, p. 823.

—— 1925. Illustrations of unfigured types of shells in the collection of the United States National Museum.
Proc. U. S. Nat. Mus., vol. 66, no. 17, p. 18, pl. 18, fig. 7.

HAMMARSTEN, O. D & RUNNSTRÖM, J. 1925. Zur Embryologie von *Acanthochiton discrepans* Brown.
Zool. Jahrb., Abt. Anat., vol. 47, p. 261–318.

HEATH, H. 1899. The development of *Ischnochiton*.
Zool. Jahrb., Abt. Anat, vol. 12, p. 567–656, pl. 31–35.

*HENN, A. U. 1894. List of Mollusca found at Green Point, Watson's Bay, Sydney.
Proc. Linn. Soc. New South Wales, vol. 9, p. 165–182, 1 pl.

HENRICI, P. 1912. Über die Muskulatur und Fussdrüsen bei *Tonicella marmorea* (Fabr.)
Arkiv för Zoologi, vol. 7 no. 35, p. 1–17, pl. 1–3.

HIRASE, S. 1927. Amphineura (in Japanese).
Nippon Dôbutsu-Zukan, p. 1499–1503. Tokyo.

HOFFMANN, H. 1930. (Schalenbrüche und Anomalien) in BRONN's Klass. u. Ordn. d. Tierreichs, Bd. 3, Abt. I, Nachtrag II, Polyplacophora, p. 173–174, fig. 94.

—— 1931. Beiträge zur Kenntnis der Chitonen. I. Über die Fortpflanzung und Entwicklung von *Trachydermon cinereus* L.
Zeits. f. Morph. u. Ökol. d. Tiere, vol. 20, p. 719–732.

IREDALE, T. 1908. Notes on some New Zealand marine Mollusca.
Trans. N. Zeal. Inst., vol. 40, p. 375, pl. 31, fig. 2.

—— 1910. Notes on Polyplacophora, chiefly Australasian (Part II).
Proc. Malac. Soc. London, vol. 9, p. 156.

VON KNORRE, H. 1925. Die Schale und die Rückensinnesorgane von *Trachydermon* (*Chiton*) *cinereus* L. und die ceylonischen Chitonen der Sammlung Plate.
Jena. Zeits. f. Naturwiss., vol. 61, p. 469–632, pl. 18–35.

MALUQUER, J. 1915. Amfineures de Catalunya.
Treb. de l'Inst. Catalana d'Hist Nat., 1915, p. 73, pl. 3, fig. 27, 28.

NIERSTRASZ, H. F. 1906. Remarks on the Chitonidae.
Tijschr. Nederl. Dierk. Ver., (2), vol. 10, p. 141–172, pl. 1.
*OLIVER, W. R. B. 1921. Variation in Amphineura.
Trans. N. Zeal. Inst., vol. 53, p. 361.
PACKARD, E. L. 1918. Molluscan fauna from San Francisco Bay.
Univ. Calif. Publ. in Zool., vol. 14, no. 2, p. 292, pl. 34, fig. 3 (7-valved *Tonicella lineata*).
*PELSENEER, P. 1898. Sur la morphologie des branchies et des orifices rénaux et génitaux des Chitons.
Bull. Scient. France et Belg., vol. 31.
—— 1899. Recherches morphologiques et phylogénétiques sur les Mollusques archaïques.
Mém. cour. Acad. Roy. Belg., vol. 57, no. 3.
—— 1919. La métamérie et l'hypomérie chez les Chitons.
Ann. Soc. Roy. Zool. et Malac. Belg., vol. 51, p. 41–43.
—— 1920. Les variation et leur hérédité chez les Mollusques.
Mém. Acad. Roy. Belg., sér. 2, vol. 5, p. 22–24.
—— 1923. Variations dans les Mollusques.
Ann. Soc. Roy. Zool. Belg., vol. 54, p. 68–78.
PILSBRY, H. A. 1892. TRYON'S Manual of Conchology, (1), vol. 14, p. xiii-xiv (Teratology of Chiton); p. 305 (7-valved *Mopalia ciliata*), pl. 64, fig. 67.
PLATE, L. 1898–1902. Die Anatomie und Phylogenie der Chitonen. (Teil A, B, C).
Zool. Jahrb., Suppl. Bd., 4–5.
SAMPSON, L. V. 1894. Die Muskulatur von Chiton.
Jena. Zeits. f. Naturwiss., vol. 28, p. 460–468.
—— 1895. The musculature of Chiton.
Journ. Morph., vol. 11, p. 595–628, pl. 31–33.
SIMROTH, H. 1893. (Schalenbrüche usw. von Polyplacophora) in BRONN'S Klass. u. Ordn. d. Tierreichs, Bd. 3, Abt. I, p. 254, 304.
SNYDER, L. H. & CROZIER, W. J. 1922. Notes on some problems of adaptation. (9) Ctenidial variation in Chiton.
Biol. Bull., vol. 43, p. 246–252.
STEARNS, R. E. O. 1901. An abnormal chiton.
Nautilus, vol. 15, p. 53–54.
STROHL, J. 1929. Missbildungen im Tier- und Pflanzenreich. Versuch einer vergleichenden Betrachtung. Jena.
SYKES, E. R. 1901. Malacological notes. (1. On a three valved *Ischnochiton*).
Journ. Malac., vol. 7, p. 164.
—— 1905. Variation in recent Mollusca.
Proc. Malac. Soc. London, vol. 6, p. 268.
TAKI, ISAO. 1924. Notes on the Chitons found in the littoral of Misaki (in Japanese).
Dôbutsugaku-Zasshi, vol. 36, p. 281–291.
TAKI, Is. & TAKI, Iw. 1928–31. Studies on Japanese Chitons (I–VI). Venus, vol. 1–2.
THIELE, J. 1929. Handbuch der systematischen Weichtierkunde. I. Teil. Jena.
VERNON, H. M. 1903. Variation in animals and plants. London.

Explanation of Plate II

Fig. 1 *Acanthochiton rubrolineatus*, No. 1, a 7-valved specimen.
× 1.5 . . . . . (p. 28)

Fig. 2 *Acanthochiton rubrolineatus*, a normal specimen of nearly the same size with figs. 1 and 3. × 1.5

Fig. 3 *Acanthochiton rubrolineatus*, No. 6, coalescence of valve II/III.
× 1.5 . . . . . (p. 42)

Fig. 4 *Placiphorella stimpsoni*, No. 3, coalescence of valve III/IV.
slightly reduced . . . . . (p. 33)

Fig. 5 *Placiphorella stimpsoni*, No. 4, coalescence of valve II/III/IV.
× 0.9 . . . . . (p. 35)

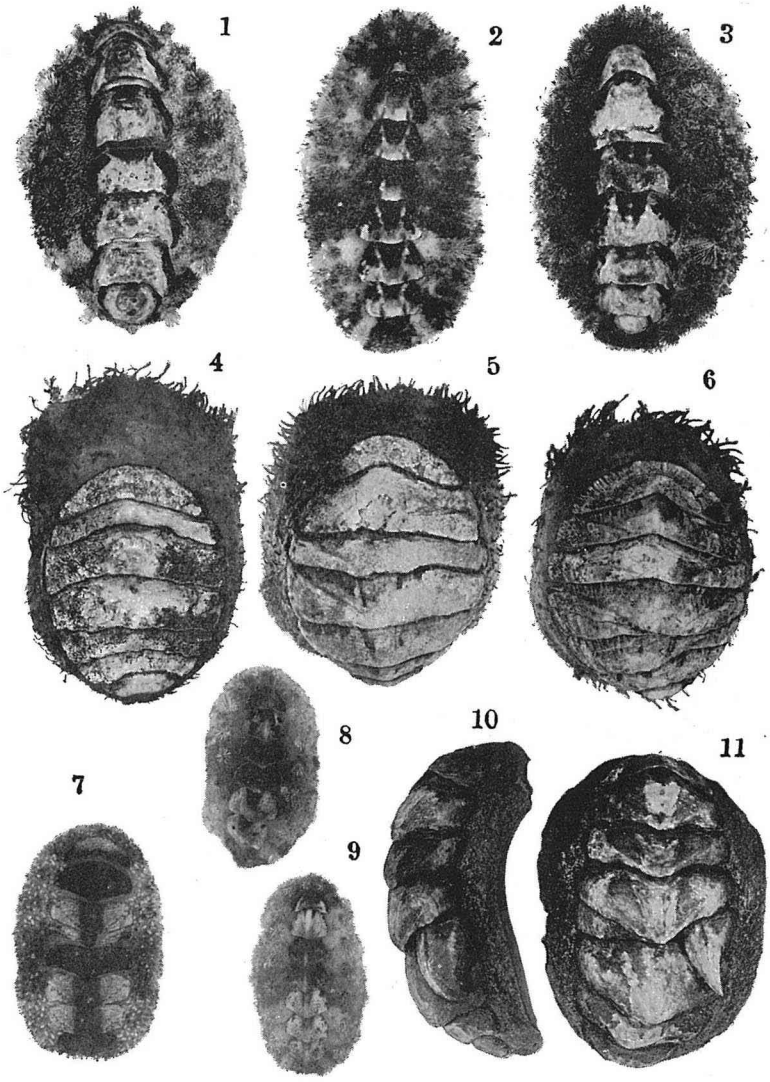
Fig. 6 *Placiphorella stimpsoni*, No. 5, coalescence of valve IV/V.
× 1 . . . . . (p. 38)

Fig. 7 *Liolophura japonica*, No. 7, coalescence of valve III/IV.
× 2.3 . . . . . (p. 45)

Fig. 8 *Acanthochiton rubrolineatus*, No. 2, a 6-valved specimen.
× 3 . . . . . (p. 29)

Fig. 9 *Acanthochiton rubrolineatus*, a normal specimen of nearly the same size as that in fig. 8.
× 3

Figs. 10, 11 *Liolophura japonica*, No. 8, splitting in valve V.
× 1.2 . . . . . (p. 48)



Is. Taki & Iw. Taki photo.