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STUDIES ON THE REPRODUCTIVE ORGANS OF RED ALGAE

III. On the Structure and Development of Female Organs in *Schizymenia Dubyi*, *Gymnogongrus flabelliformis* and *Rhodymenia pertusa*

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Schizymenia Dubyi (CHAUV.) J. AG.

The reproductive organs of the Japanese red alga which has been referred to this species have already been observed by Okamura (1933) who gave illustrations of tetrasporangia scattered in the frond cortex, a four-celled carpogonial branch and a gonimoblast in its early stage of development.

The writers collected fertile female specimens of this alga in Oshoro Bay, Hokkaido, on July 22, 1958, and could trace to some extent the development of the cystocarp as described below.

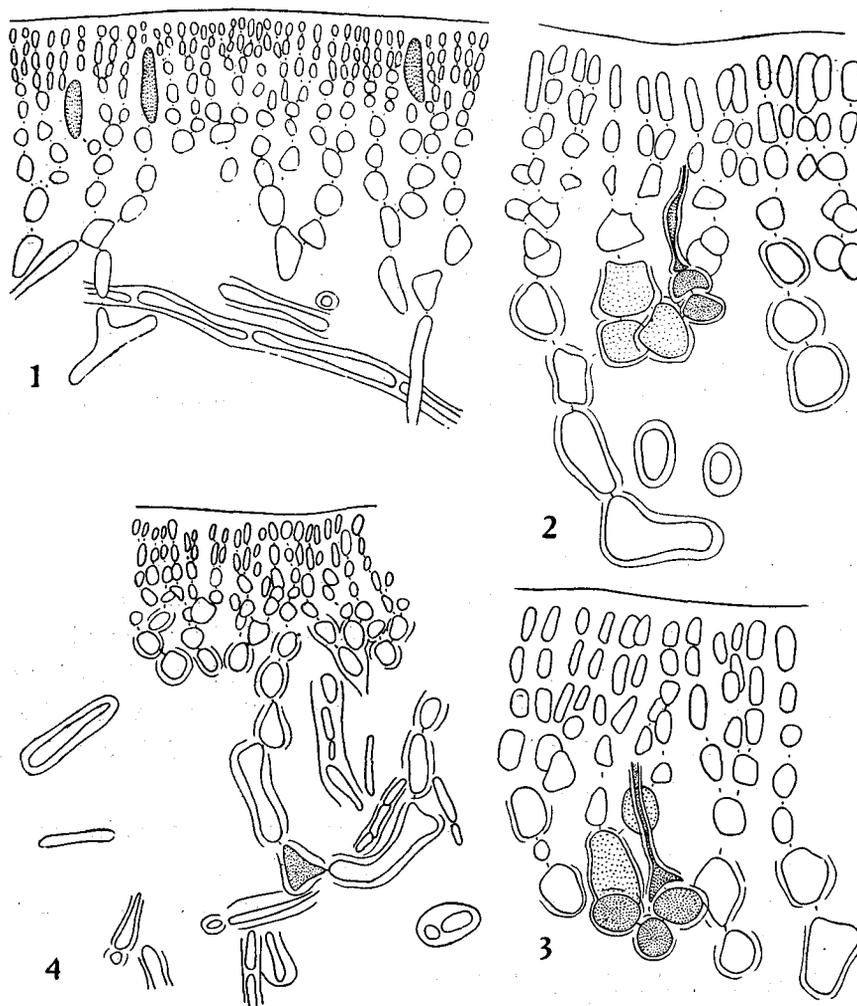
The carpogonial branch is formed on an inner cell of the cortex; it is usually composed of three cells, but rarely four, though Okamura (1933) described and figured four-celled ones only. The supporting cell and its neighbouring few cells are larger than other cortical cells and are so rich in protoplasm before fertilization that they are well stained with cotton blue and make an investigator's search for a carpogonial branch in a section rather easy even under low magnification.

The auxiliary cell, rich in protoplasm, is an intercalary cell of a cortical cell-branch situated apart from that bearing a carpogonial branch; thus a procarp is not formed. Carpogonial branches and auxiliary cells are found occurring in a fertile tissue fairly abundantly.

After fertilization, the first gonimoblast cell is cut off from the auxiliary cell outwardly, and the cortical cells in the neighbourhood of the auxiliary cell become rich in protoplasm. A mature gonimoblast consists of several gonimolobes, and all of the gonimoblast cells develop into carposporangia.

The cystocarp is embedded in the frond tissue beneath the cortex, with no special surrounding tissue, at maturity sometimes occupying the medulla and very slightly upheaving one or both surfaces of the frond. The carpospores are liberated from an aperture formed through the cortical tissue just above the cystocarp. No antheridium has yet been observed in the present alga, though it has been observed by Kylin (1930) in his *Schizymenia pacifica*.

Incidentally, it may be worth mentioning that the gland cells scattered in the superficial tissue of the present alga do not show the protein reaction when treated with Millon's reagent or potassium iodide iodine solution as do the gland cells of *Turnerella*

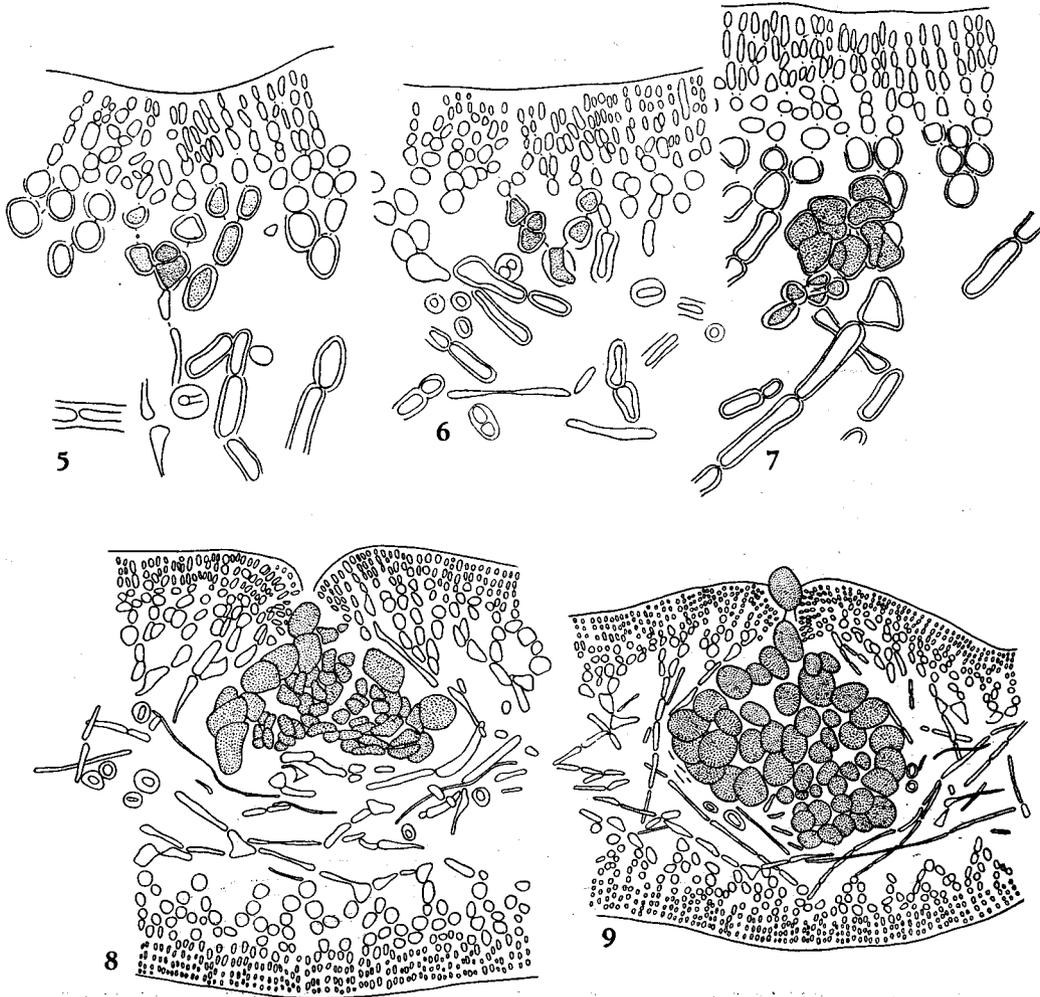


Figs. 1-4. *Schizymenia Dubyi* (CHAUV.) J. AG.: 1, section of thallus showing three gland cells; 2, section through fertile part of female thallus showing a three-celled carpoogonial branch; 3, four-celled carpoogonial branch; 4, auxiliary cell. - Figs. 1, 3 $\times 440$; Figs. 2, 4 $\times 800$

Mertensiana (POST. et RUPR.) SCHM. or the giant cells in the inner tissue of *Cirrulicarpus Gmelini* (GRUN.) TOKIDA et MASAKI. (Cf. Tokida and Masaki, 1956, 1957).

Gymnogongrus flabelliformis HARV.

The present species has been known to bear at maturity two to four cystocarps arranged in one row on the terminal and subterminal segments of the frond. Antheridia and tetrasporangia have not been observed to date in this species. A cross section of the



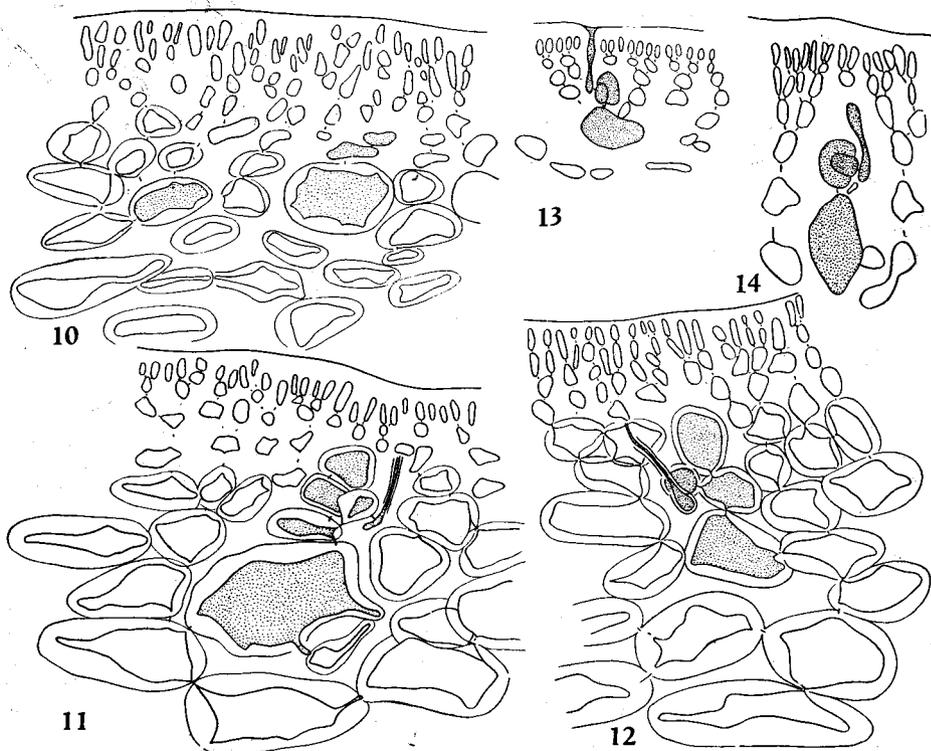
Figs. 5-9. *Schizymenia Dubyi* (CHAUV.) J. Ag. : 5 and 6, the first gonimoblast cell cut off by the auxiliary cell; 7, early stage in development of gonimoblast; 8, section through young cystocarp; 9, section through mature cystocarp. - Figs. 5, 7 $\times 433$; Fig. 6 $\times 366$; Figs. 8, 9 $\times 266$

mature cystocarp has been illustrated by Okamura (1921, 1936), but no one has ever described its development so far as the writers are aware.

The writers were able to make observations on the development of the female reproductive organ as described below using the specimens collected at Tachimachi-misaki, Hakodate, on October 1, 1956.

Carpogonial branches are three-celled. They are formed outwardly from one of the inner cortical cells which had become large and rich in protoplasm. Textfigures 11

and 12 show clearly that the carpogonium is inserted laterally on the second cell of the branch as pointed out by Rosenvinge (1931, p. 519-520) in *Phyllophora membranifolia*; he stated that its carpogonium reminds one of that of *Iridaea cordata*. Similar feature was also observed by the present writers in *Rhodoglossum pulchrum* and *Chondrus ocellatus* f. *crispus* (Textfigs. 13 and 14). This type of carpogonial branch may be a

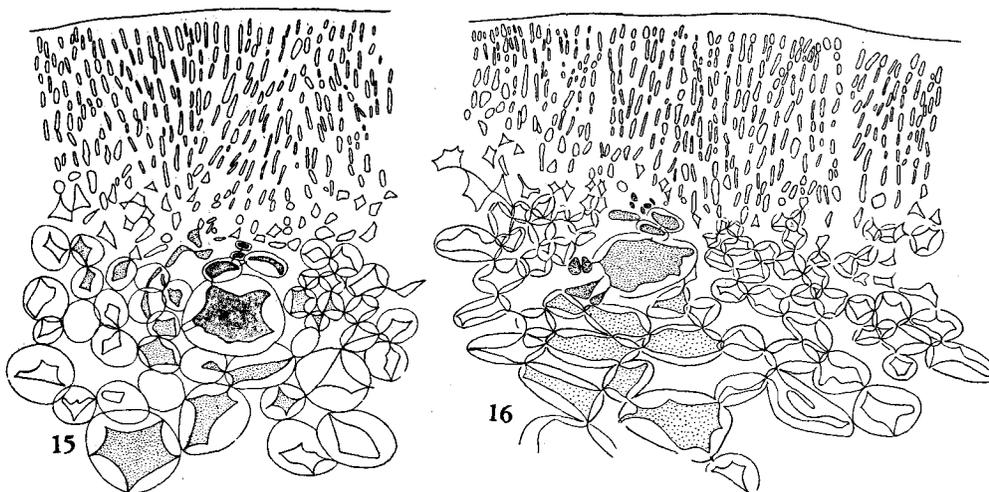


Figs. 10-12. *Gymnogongrus flabelliformis* HARV. : 10, section of thallus showing two supporting cells, one of which has cut off a two-celled initial of carpogonial branch; 11, supporting cell bearing three-celled carpogonial branch, the first cell of which bears a sterile branch of two cells filled with contents; 12, showing a sterile cell on the first cell of three-celled carpogonial branch. Fig. 13. *Rhodoglossum pulchrum* (KÜTZ.) SETCH. et GARDN. : section of thallus showing procarp. Fig. 14. *Chondrus ocellatus* HOLM. f. *crispus* OKAM. : section of thallus showing procarp. - Figs. 10, 11, 12, 14 $\times 433$; Fig. 13 $\times 366$.

characteristic of the Gigartinales. As shown in Textfigures 11 and 12, one or two sterile cells with dense contents are cut off already before fertilization from the first cell of the carpogonial branch. Such sterile cells or cell branches also occur in *Phyllophora membranifolia*. In that species, the first cell of a carpogonial branch gives rise to one or two sterile cells, and the supporting cell of the auxiliary cell gives rise to one sterile

cell branch.

The supporting cell of the carpogonial branch functions as the auxiliary cell, so the procarp is formed in the present species as in the typical members of the Gigartinales. After fertilization the auxiliary cell gives rise laterally and inwardly to several protrusions from which the gonimoblast cells are cut off. At this stage, the procarp is surrounded by vegetative cells filled with contents and the cortex above the procarp is remarkably thickened by cell divisions. Textfigure 15 shows a female organ at an early post-fertilization stage, and Textfigures 16 and 17 those at more advanced stages in which



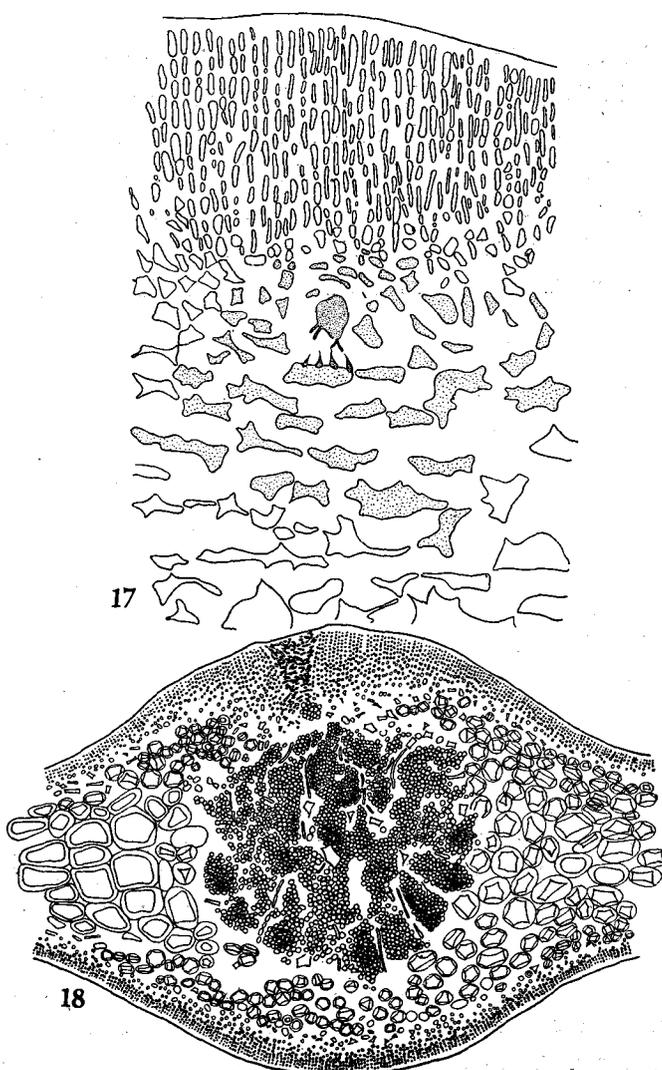
Figs. 15-16. *Gymnogongrus flabelliformis* HARV.; 15, section through procarp just after fertilization, showing its neighboring cells and early stage in development of pericarp; 16, primary gonimoblast cells cut off by auxiliary cell or supporting cell of carpogonial branch. - Figs. 15, 16 $\times 266$

gonimoblast cells are already formed. All the gonimoblast cells develop into carposporangia. The cystocarp is embedded in the frond tissue, with no special surrounding tissue, occupying the medulla and slightly upheaving usually one surface of the frond but sometimes both surfaces. The thickened superficial cell layers function as the pericarp which has an aperture at its center. The aperture is formed by the collapse of the tissue and serves as a passage for the liberation of carpospores (Textfig. 18). Okamura's figures (1921, pl. 182, figs. 13, 14) show a slit-like carpostome on both surfaces of a cystocarp.

As described above, the structure and development of the female reproductive organ in *Gymnogongrus flabelliformis* coincide well with those hitherto reported in other related genera, showing the characteristics of the Phylloporaceae. (Cf. Kylin, 1932, p. 68).

***Rhodymenia pertusa* (POST. et RUPR.) J. AG.**

The structure and development of the female organ in this species have been studied in detail by Sjöstedt (1926) with material from California. His observations were con-



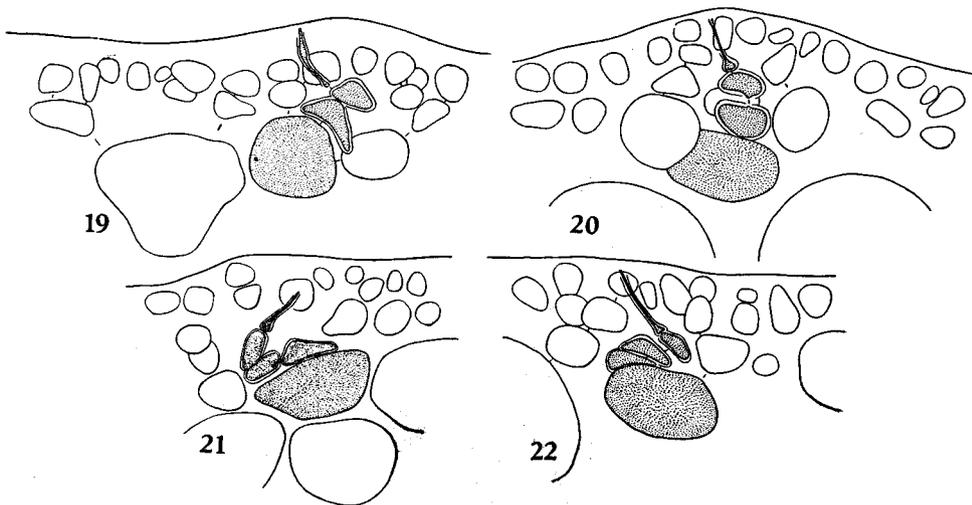
Figs. 17-18. *Gymnogongrus flabelliformis* HARV.: 17, early stage in development of gonimoblast and its neighboring vegetative cells filled with protoplasm; 18, section through a nearly matured cystocarp showing carpostome in the process of formation. - Fig. 17 $\times 270$; Fig. 18 $\times 70$

firmed by Kylin (1930) with material from Friday Harbor. Recently Sparling (1957) reported her observation on the carpogonial branch of *Rhodymenia pertusa* made with materials from Puget Sound, Esquimalt and Robben Island, stating that the carpogonial branch consists of four distinct units instead of being composed of only three cells as described by Sjöstedt and Kylin. However, she has left for future study the question whether the fourth unit is a trichogyne separated from the carpogonium or whether it is

no other than the carpogonium itself.

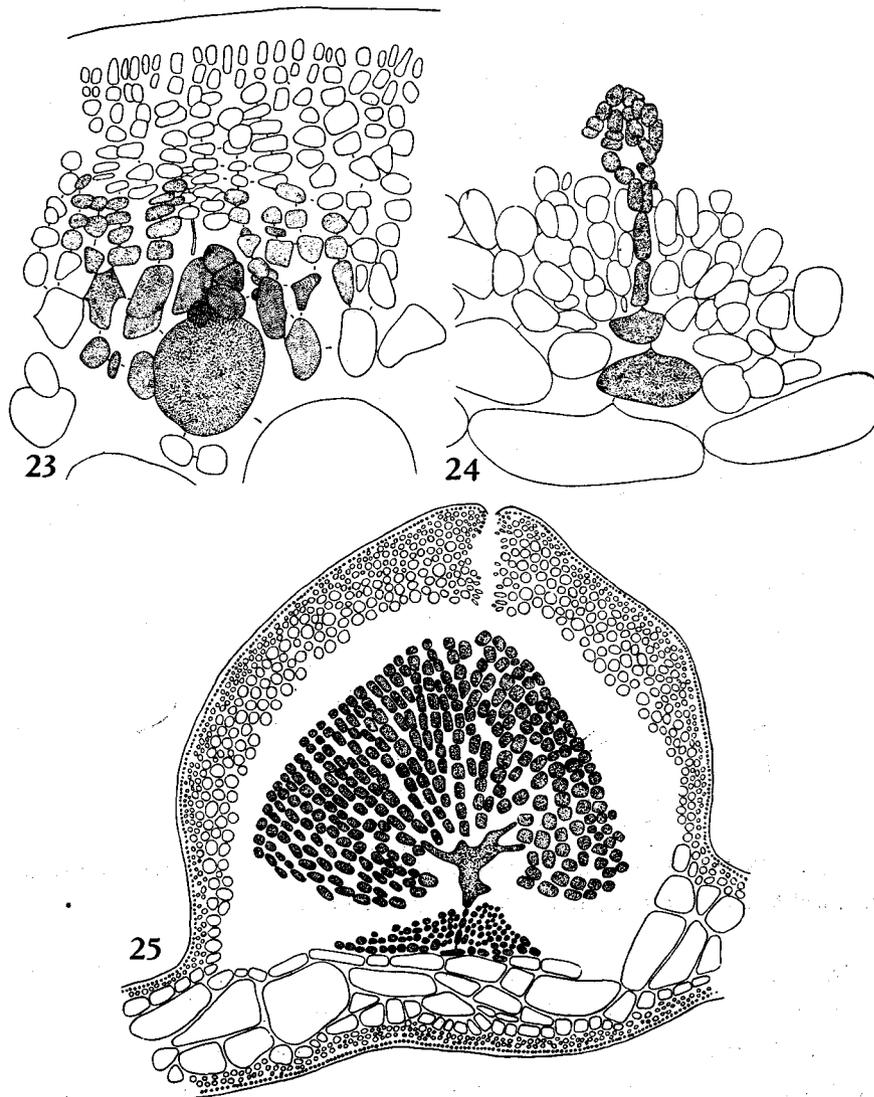
The writers studied female specimens of this species collected at Usu, Prov. Iburi, on April 1, 1942, at Nanaehama, Hakodate, on May 7, 1955, and May 10, 1956, and in Hakodate Harbor on March 8, 1956. The results obtained coincide well in general with those of the above mentioned investigators as described below.

The carpogonial branch is formed on one of the innermost cells of the cortex and consists of three or four cells. Thus the writers believe that they could confirm the presence of four-celled carpogonial branches in this species as suspected by Sparling.



Figs. 19-22. *Rhodymenia pertusa* (POST. et RUPR.) J. AG.: 19 and 20, procarp with a three-celled carpogonial branch; 21 and 22, four-celled carpogonial branch. - Figs. 19-22 $\times 666$.

Before fertilization, both the carpogonial branch and the supporting cell were filled with contents, but the auxiliary cell could not be distinguished morphologically from other vegetative cells. After fertilization the auxiliary cell and its mother cell become rich in protoplasm, and the former increases its size so much that one can easily recognize it as an auxiliary cell. The two-celled auxiliary cell branch stands together with the carpogonial branch on the same supporting cell (Textfig. 23). The fusion of carpogonial cells and the cutting off of a connecting cell from the carpogone that had fused with the hypogynal cell were observed by Sparling in *Rhodymenia pseudopalmata* (LAM.) SILVA but not in *Rh. pertusa*. The writers did not succeed in observing them in their material. The gonimoblast cells are cut off from above the auxiliary cell. The cortical cells that are situated above the neighbourhood of the fertilized procarp divide repeatedly and consequently the cortex increases in thickness. These cortical cells become connected laterally with each other. The inner cells of the cortical cell rows become rich in protoplasm; they are later left at



Figs. 23-25. *Rhodymenia pertusa* (POST. et RUPR.) J. AG.: 23, procarp after fertilization and its surrounding tissues; 24, young stage in development; 25, vertical section through a mature cystocarp. - Fig. 23 $\times 400$; Fig. 24 $\times 320$; Fig. 25 $\times 60$

the bottom of the cystocarpic cavity when the latter is formed by a rupture at the basal part of the considerably thickened cortex. The gonimoblast cells are almost wholly converted into carposporangia, which are grouped in a mature cystocarp into a few masses according to their developmental stages as illustrated by Sparling in *Rh. pseudopalmata*. Textfigure 25 shows a section of a mature cystocarp through a group of fully matured

carposporangia only. It also shows at the center of the base of the cystocarp a large irregularly branched cell which was presumably formed by the fusion of early gonimoblast cells. This kind of irregular cell which was illustrated by Okamura (1907, pl. 21, fig. 7) as "Stielzelle" in *Rh. pertusa*, is not mentioned at all by other workers in *Rhodymenia* species, if "the outgrowing, club-shaped gonimoblast" figured by Sjöstedt (1926, p. 34, fig. 21 C) does not contain within it an initial of such "Stielzelle." It may be worth while to make mention of the existence of a large irregular cell in the center of a young gonimoblast in *Faucheia Freyeana* SETCH., a member of the Rhodymeniaceae, as one can see in a figure by Sjöstedt (1926, fig. 18 C).

Summary

The results of the writers' present study were not fully satisfactory, but they are reported in this paper in order to add some data to knowledge on the Japanese plants of the species in question. The carpogonial branches in both *Schizymenia Dubyi* and *Rhodymenia pertusa* were revealed to consist of three or four cells. The procarp and the development of gonimoblasts in *Gymnogongrus flabelliformis* were first described here.

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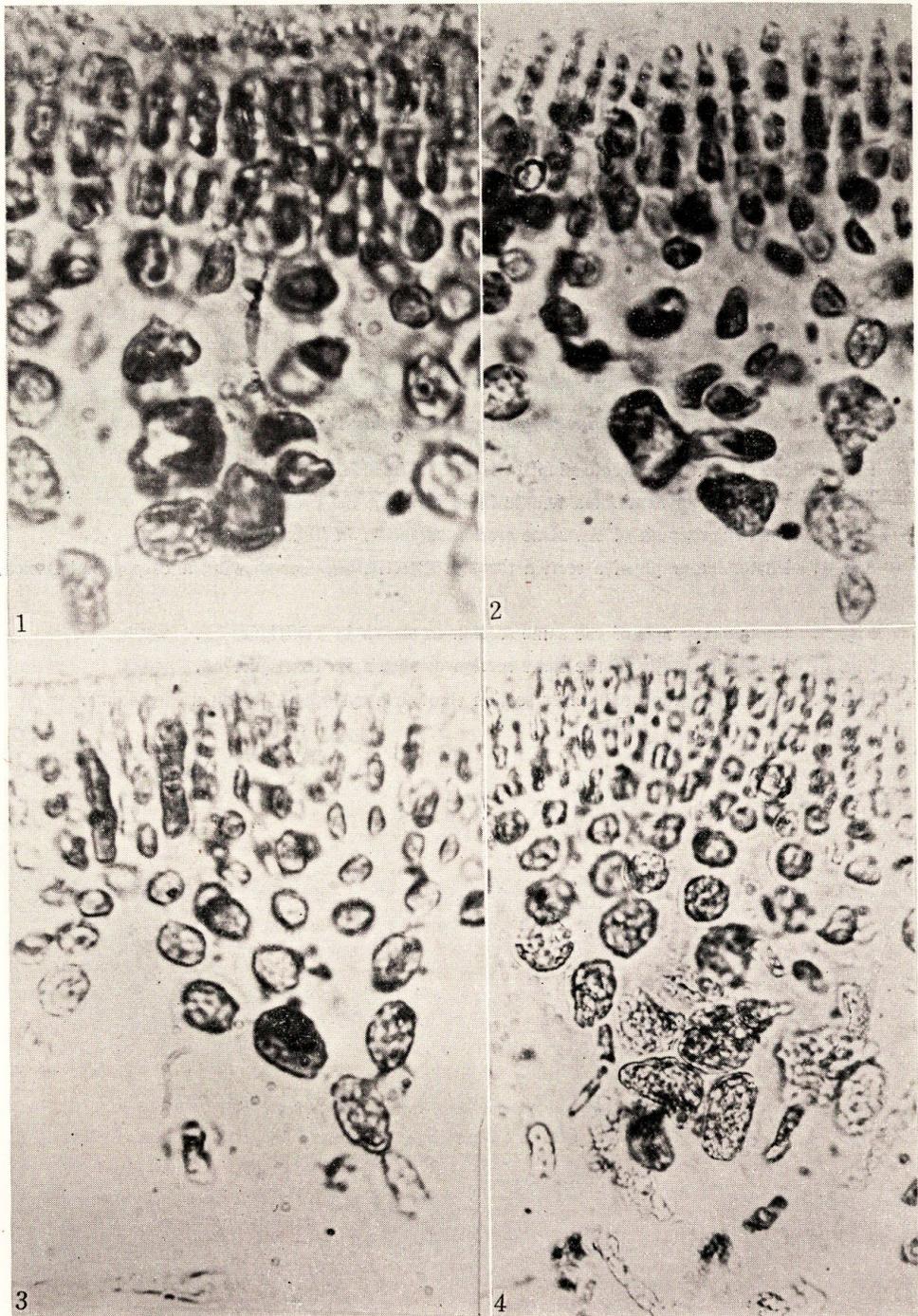
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EXPLANATION OF PLATES

PLATE I

Schizymenia Dubyi (CHAUV.) J. AG.

- Fig. 1. Photomicrograph to show a three-celled carpogonial branch in the same section as shown in Textfigure 2. $\times 1330$
- Fig. 2. Photomicrograph to show a four-celled carpogonial branch. $\times 1330$
- Fig. 3. Photomicrograph to show an auxiliary cell and two gland cells. $\times 1330$
- Fig. 4. Photomicrograph to show an early developmental stage of the gonimoblast. $\times 1330$

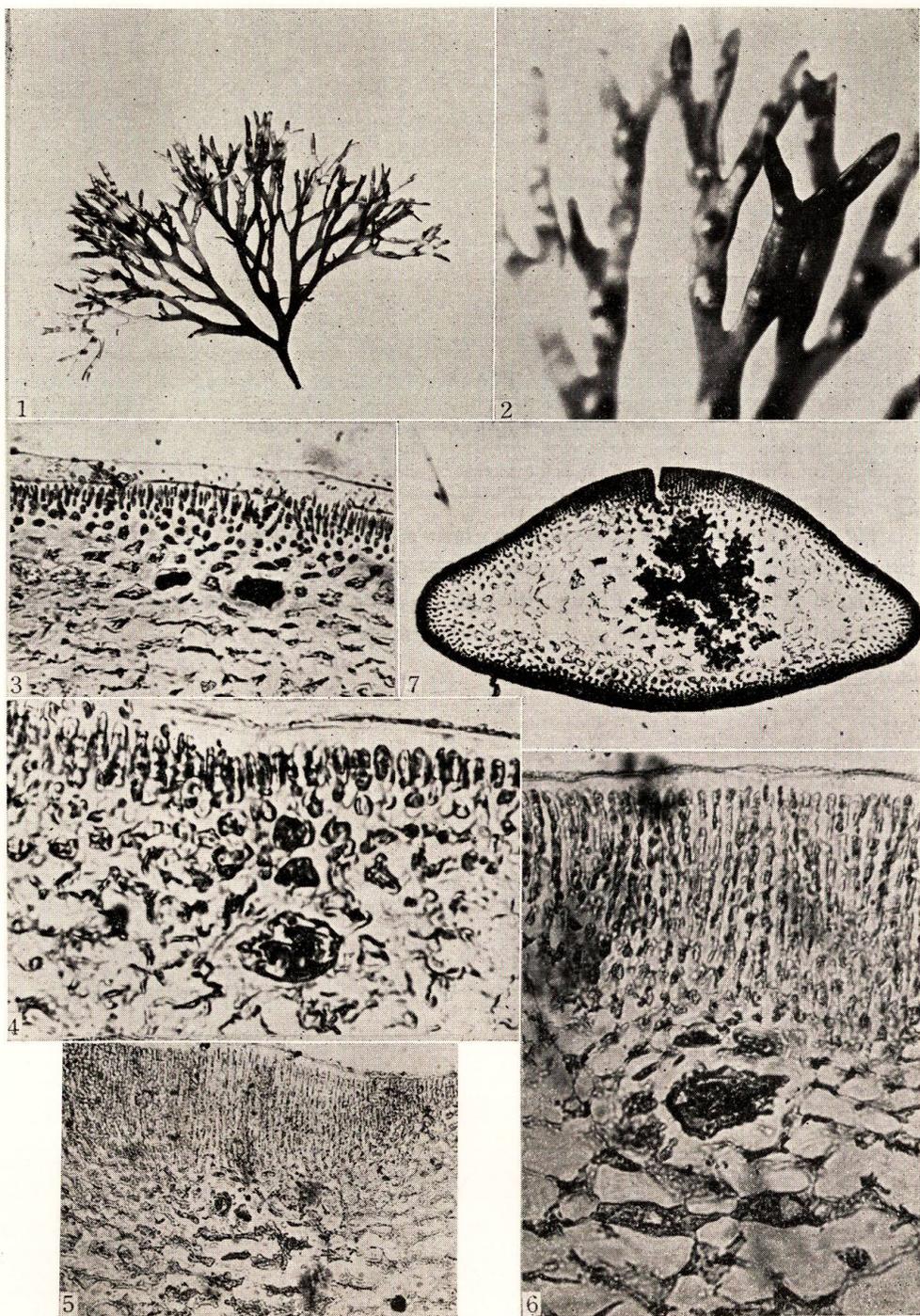


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PLATE II

Gymnogongrus flabelliformis HARV.

- Fig. 1. Habit of a cystocarpic plant collected at Hakodate, Oct. 1, 1956. ×1
- Fig. 2. Terminal segments of a female frond showing the cystocarps. ×5
- Fig. 3. Photomicrograph of the same section as shown in Textfigure 1. ×215
- Fig. 4. Photomicrograph of a section through a fertile segment showing a carpogonial branch.
×600
- Fig. 5. Photomicrograph of the same section as shown in Textfigure 17. ×133
- Fig. 6. Photomicrograph of the same section as shown in Textfigure 16. ×333
- Fig. 7. Photomicrograph of a cross section through a cystocarp bearing a carpostome. ×60



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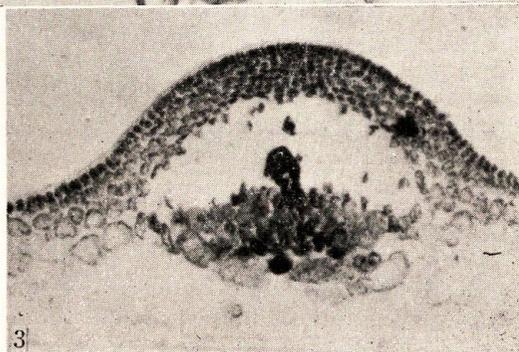
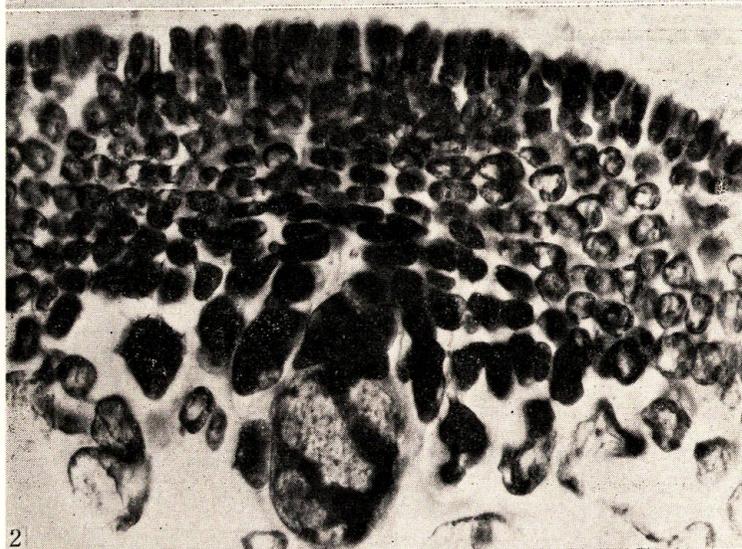
PLATE III

Rhodymenia pertusa (POST. et RUDR.) J. AG.

Fig. 1. Photomicrograph of the same section as shown in Textfigure 19, showing a three-celled carpogonial branch. $\times 1333$

Fig. 2. Photomicrograph of the same section as shown in Textfigure 23, showing a procarp just after fertilization and the cortical tissue markedly thickened. $\times 666$

Fig. 3. Photomicrograph of a vertical section through a young cystocarp, showing "the club-shaped gonimoblast," cystocarpic cavity, and pericarp. $\times 166$



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