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## CONTRIBUTIONS TO THE KNOWLEDGE OF GRACILARIACEAE FROM JAPAN

### I. Critical Notes on the Structure of *Gracilaria Textorii* (SURINGAR) J. AG.

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*Gracilaria Textorii* was first described from Japan by Suringar in 1867 under the name *Sphaerococcus* (*Rhodymenia*) *Textorii* in his "Index praecursorius Algarum Japonicarum". Okamura (1900) gave a detailed account of the plant, illustrating the structure of its cystocarp and tetrasporangium. On the other hand, *Gracilaria Vivesii* was described by Howe in 1911 in his "Phycological studies V. Some marine algae of lower California, Mexico", on the basis of an antheridial specimen and a sterile one obtained at La Paz, Baja California, Feb. 28, 1911 by G. J. Vives. In 1924 Setchell and Gardner added *G. Vivipara*, *G. sinicola*, and *G. Johnstonii* to the list of foliate *Gracilaria* from the Gulf of California, but they were subsequently shown by Dawson (1944) to be identical with each other and to be united under the name of *G. Johnstonii*. Afterward, Dawson (1949) studied *G. Vivesii* and synonymized *G. Johnstonii* under that species. At the same time he recognized, comparing his observations with Okamura's figures (1900), that *G. Vivesii* agreed very closely with *G. Textorii* in the habit of frond, in the presence of nutritive filaments in cystocarps, and in the semi-nemathecial structure of cortex in tetrasporic plants. So he suspected the identity of the two species, but could not settle the problem for lack of knowledge on antheridia of *G. Textorii*.

In November, 1954, the writer was able to collect many specimens of *G. Textorii* in the vicinity of Oshoro Marine Biological Station, Hokkaido University. They were found to include rather many individuals of male plant. This is believed to be the first discovery of the male plant of the present species from Japan.

Comparing the external and internal structures of the specimens of *G. Textorii* in the writer's hand with the illustrations of *G. Vivesii* given by Howe and Dawson, the writer could find no essential difference between them. The frond of *G. Textorii* appears occasionally to be somewhat more delicate, more proliferous, and more finely dissected than that of *G. Vivesii*. However, such differences may reasonably be considered as local.

So the writer was driven to the conclusion that *Gracilaria Textorii* and *G. Vivesii* are one and the same species.

Here the writer proposes to give a description of *G. Textorii* based on the specimens now at hand from various localities in Japan.

***Gracilaria Textorii* (Suring.) J. Ag.**

Index praecurs. Alg. Japon., 1867, p. 4; Id., *Sphaerococcus* (*Rhodymenia*) *Textorii*

*Suring.*, Alg. Jap., 1870, p. 36. *Gracilaria Textorii* (SURING.) J. AGARDH, Spec. Alg., III, 1. Epicr., 1876, p. 426; De Toni, Phyc. Jap. Nov., 1895, p. 27 n. 52; Id., Syll. Alg. IV, 1900, p. 449; Okam., Alg. Jap. Exsic. no. 13, 1899; Id., Illust. mar. alg. Jap., 1900. *Gracilaria Vivesii* HOWE, Phyc. Stud. V, 1911, p. 503-505; Dawson, Stud. Northeast Pacif. Gracilariaceae, 1949, p. 34-36. *Gracilaria Johnstonii* SET. et GARD., Mar. alg. exped. Calif. Acad. Sci. Gulf Calif. in 1921, 1924; Dawson, Mar. Alg. Gulf Calif., 1944. *Gracilaria sinicola* SET. et GARD., loc. cit., 1924. *Gracilaria vivipara* SET. et GARD., loc. cit., 1924.

Japanese name: *Kaba-nori*.

Hab.: Growing on rocks and stones at or below low-water mark. In Oshoro Bay, growing abundantly on the rocks, often preferring sheltered places, usually about 30-60 cm below water surface, associated with other algae such as *Sargassum confusum*, *Lomentaria catenata*, *Gymnogongrus flabelliformis*, *Chondrus armatus*, *Champia parvula*, etc. It seems to mature in autumn, as found in Oshoro Bay.

Locality: Yanagihara, Takahama, Minatoyama, Mitsugahama, Ehime Pref., Shikoku; Kurihama, Misaki, Kanagawa Pref.; Kominato, Chiba Pref.; Himi, Toyama Pref.; Oshoro, Hokkaido. Rather common along the Pacific and Japan Sea coasts of the warmer part of Honshu, also found along Shikoku and Kyushu coasts.

Plants foliose, caespitose, rising from a common scutate disc, with a short subcylindrical stipe, soon expanding into the cuneate base of frond, irregularly dichotomously to flabellately lobed with broad linear patent segments whose axils are rounded; color dull- or brownish-red to somewhat yellowish or greenish. Frond flat, membranous to thick coriaceous, variable in size and shape, usually 4.7-18.5 cm high and 7-45 mm broad under the dichotomies when mature, with rounded or somewhat attenuated apices; thickness of frond is also variable, young plants being quite thin (240  $\mu$ ), while old ones may be as much as 750-875  $\mu$  thick; margins smooth and entire, occasionally slightly undulate, normally non-proliferous but sometimes with more or less simple or branched proliferations; apical segments, 0.5-7 mm broad below the apex, sometimes end in blunt or ligulate, or sometimes in acute or bifid apices; in other cases, terminal segments are much slenderer and more pale in color than the remaining portion, being divided repeatedly in dichotomous manner. The following table shows the variability in the external appearance of the present alga.

Table 1. Range of variability in the external appearance of *Gracilaria Textorii* from various localities in Japan

No.	Reproductive phase	Locality	Date of collection	Length	Width	Thick-ness	Color of frond
1	sterile	Takahama	Aug. 13, 1953	4.7cm	9 mm	$\mu$	dull red
2	"	Misaki	Apr. 7, 1944	8	13		yellowish red
3	"	Ao	May 24, 1953	8	25		red
4	"	Oshoro	Nov. 1, 1954	8.2	22	440	pink
5	"	Himi	May 31, 1953	10	13		dull red
6	"	Kawahara	June 10, 1953	10	19		dull red

7	tetrasporic	Takahama	Aug. 16, 1953	6	7		dark red
8	"	Mitsugahama	Aug. 5, 1953	7	8		pale red
9	"	Takahama	Aug. 13, 1953	7	15		dull red
10	"	Oshoro	Nov. 1, 1954	7.6	15	385	pink
11	"	Takahama	Aug. 16, 1953	8	11		red
12	"	Oshoro	Nov. 1, 1954	9	22	630	dark red
13	"	Oshoro	Nov. 1, 1954	9.5	20	560	brownish red
14	"	Akitani	June 6, 1951	9.8	10		pale red
15	"	Oshoro	Nov. 1, 1954	10	14	440	pink
16	"	Oshoro	Nov. 1, 1954	10	25	700	pale red
17	"	Oshoro	Nov. 1, 1954	10.2	21	512	pink
18	"	Oshoro	Nov. 1, 1954	10.3	23	525	brownish red
19	"	Oshoro	Nov. 1, 1954	11	13	385	pink
20	"	Minatoyama	Aug. 22, 1953	11.5	9		yellowish red
21	"	Mitsugahama	July 29, 1953	12	20		red
22	"	Kurihama	June 7, 1951	15	23		dull red
23	"	Kurihama	June 7, 1951	18	36		dull red
24	"	Kurihama	June 7, 1951	18.5	35		dull red
25	cystocarpic	Mitsu	Aug. 21, 1953	7.5	9		pale red
26	"	Takahama	Aug. 21, 1953	8.5	9		dull red
27	"	Oshoro	Nov. 1, 1954	8.5	18	700	brownish red
28	"	Takahama	Aug. 21, 1953	9	9		purplish red
29	"	Takahama	Aug. 18, 1953	9.5	13		slightly greenish red
30	"	Misaki	May 7, 1944	10	12		yellowish red
31	"	Oshoro	Nov. 1, 1954	10.5	12	700	pink
32	"	Oshoro	Nov. 1, 1954	11	20	700	dark red
33	"	Yanagihara	Aug. 12, 1953	12	8		greenish red
34	"	Himi	June 7, 1953	12	15		dull red
35	"	Oshoro	Nov. 1, 1954	12.6	18	680	dull red
36	"	Kominato	May 2, 1950	13	22		dull red
37	"	Oshoro	Nov. 1, 1954	15	15	700	greenish red
38	male	Oshoro	Nov. 1, 1954	8.6	20	525	bull red
39	"	Oshoro	Nov. 1, 1954	11	13	440	greenish red
40	"	Oshoro	Nov. 1, 1954	11.4	15	525	dull red
41	"	Oshoro	Nov. 1, 1954	11.5	20	512	dull red
42	"	Oshoro	Nov. 1, 1954	11.5	28	560	brownish red
43	"	Oshoro	Nov. 1, 1954	13	16	525	brownish red

Specimens except from Oshoro can not be exactly measured as they are dried materials.

FronD internally consisting of a prominent cellular medulla of large (230-400  $\mu$  in diam.) thin-walled (5-9  $\mu$  thick) cells, which are colorless in content; cortex normally made of a pigmented single layer of more or less anticlinally elongated cells, which in older parts become two-layered, measuring 5-10  $\mu$  long, 4-6  $\mu$  broad in transverse section, and 4.3 $\mu$ ×4.3 $\mu$  to 5.4 $\mu$ ×6.5 $\mu$  as seen from surface; subcortical layers of somewhat larger cells, containing more or less Floridean starch grains which

are 3-5  $\mu$  in diam. The transition from the large medullary cells to the small cells of the cortex is abrupt. Colorless hairs occasionally present on frond surface, measuring up to 320  $\mu$  long and 6  $\mu$  thick. Surface jelly thin. Tetrasporangia are densely scattered over both surfaces of the frond except the apical and the lowermost portions, ovate to elongate in shape, attaining  $22\mu \times 13\mu$ - $35\mu \times 28\mu$  in transverse section and  $8.5\mu \times 8.5\mu$ - $40\mu \times 22\mu$  in surface view, cruciately divided. They are bright red in color.

Sexual plants are heterothallic.

Cystocarps are hemispherical or almost globular, up to 1660  $\mu$  in diam., ostiolate, densely scattered over both surfaces of frond. Pericarp is thick, being constructed of many layers of cells, which are anticlinally elongated. The development of the gonimoblast results in the formation of a parenchymatous, subspherical, narrow-based dome, sometimes called placenta, nearly filling the cystocarpic cavity and keeping connection with the pericarp by means of numerous nutritive filaments. These nutritive filaments are irregularly shaped, 105-180  $\mu$  long, 10-20  $\mu$  broad. Outermost cells of the pericarp are red in color, 9-15  $\mu$  long, 6-9  $\mu$  broad, while inner ones are yellowish in color or almost colorless.

Carpospores are spherical or slightly elongated in shape, measuring  $13\mu \times 9\mu$ - $28\mu \times 22\mu$ , having a red chromatophore in the central portion.

Male frond is sometimes distinguishable by its pale red color from others. Antheridia are borne abundantly all over the surfaces of frond, in superficial shallow saucer- or cup-like cavities or pits, 20  $\mu$  wide, 17  $\mu$  deep, surrounded by modified, pigmented cortical cells. Antheridial pits are formed at first solitarily, but later become confluent. Within the pits are found clusters of antheridial branches transformed from cortical cells. Spermata are colorless, globular, mostly 2-3  $\mu$  in diam. as seen from surface.

The plant is coriaceous and brittle while fresh, but becomes tenacious upon drying. A fully grown plant adheres imperfectly to paper in drying.

In conclusion, the writer wishes to express his hearty thanks to Prof. Jun Tokida for his kind guidance. Sincere thanks are also due to Dr. E. Y. Dawson in the Allan Hancock Foundation, University of Southern California, for his kindness in giving the writer a large set of valuable material from his collection of the northeast Pacific Gracilariaceae and many copies of his publications, as well as for his useful informations and helpful suggestions. The writer is also thankful to Prof. S. Ueda and Mr. Y. Sakai for their assistance in various ways. The expense for pursuing the present study was partly defrayed by a Grant in Aid for Miscellaneous Scientific Research from the Ministry of Education.

#### Summary

1. In this paper is reported the discovery of male plant of *Gracilaria Textorii* in Oshoro Bay, Hokkaido.

2. After comparing the antheridial and other structures of *G. Textorii* with those of the Californian *G. Vivesii*, the writer came to the conclusion that they are one and the same species as has been suspected by Dawson (1949).

3. A thorough description of *G. Textorii*, including a table showing the range of variability in the external feature, is given on the basis of numerous Japanese specimens from various localities.

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#### Explanation of plates

##### Plate I. *Gracilaria Textorii* from Oshoro Bay

- Fig. 1. Transverse section through a sterile frond × 420  
Fig. 2. Surface view of tetrasporangial sori × 420  
Fig. 3. Transverse section through a tetrasporangial sorus × 420  
Fig. 4. Surface view of an antheridial frond showing only tips of modified cortical cells × 420  
Fig. 5. Surface view of an antheridial frond showing confluent antheridial sori among large cortical cells × 760  
Fig. 6. Transverse section through antheridial sori showing superficial, slightly depressed, antheridial pits × 760

##### Plate II. *Gracilaria Textorii* from Oshoro Bay

- Fig. 1. Vertical section through a mature cystocarp × 48  
Fig. 2. Detail in the enlargement and ramification of the fusion cell, seen as if dissected away from surrounding cells × 420  
Fig. 3. Carpospores showing a stellate central body × 420  
Fig. 4. Part of section through pericarp showing anticlinally elongated cortical cells × 420  
Fig. 5. Nutritive filaments showing various shapes × 420

Plate III. *Gracilaria Textorii* from Oshoro Bay

- Fig. 1. Habit of a mature tetrasporic plant × ca. 1/2  
Fig. 2. Habit of a mature cystocarpic plant × ca. 1/2  
Fig. 3. Habit of a mature antheridial plant × ca. 3/4

Plate IV. *Gracilaria Textorii* from Kurihama

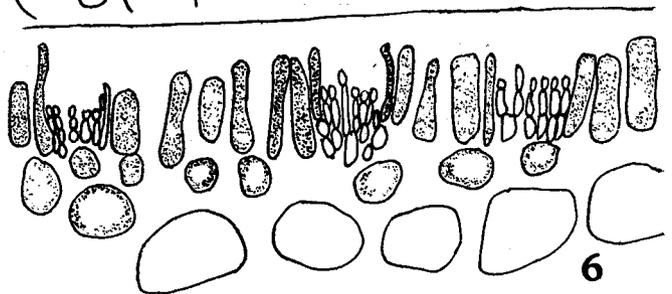
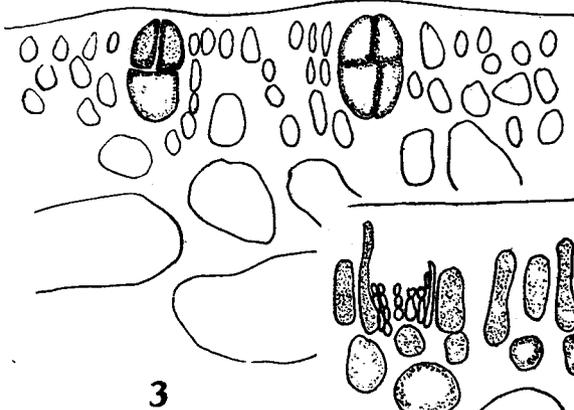
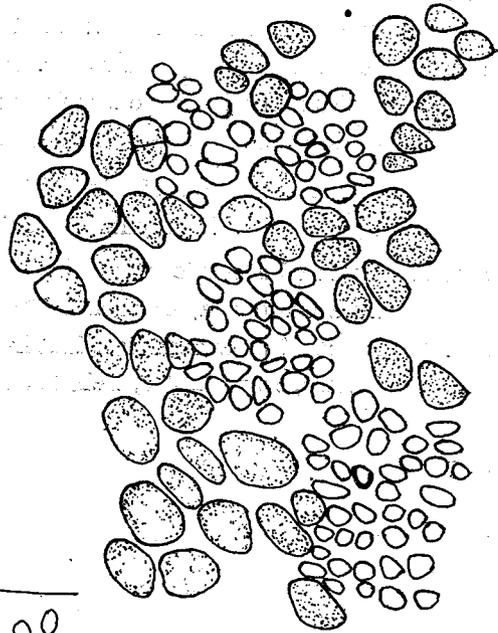
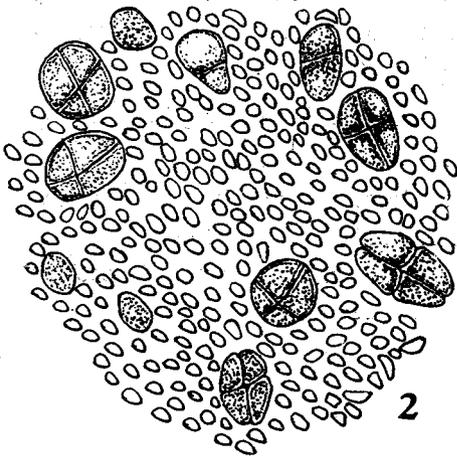
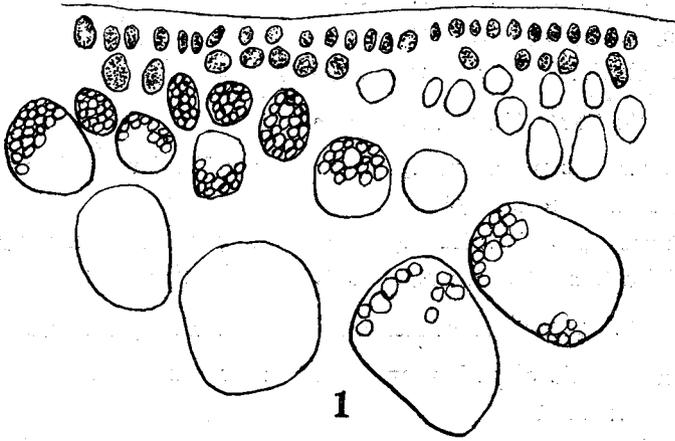
- Fig. 1. Habit of a young tetrasporic plant having typical shape; Kurihama, Kanagawa Pref., June 7, 1951 × ca. 3/4  
Fig. 2. Habit of a mature tetrasporic plant having broad frond provided with many finely dissected proliferations; Kurihama, June 7, 1951 × ca. 2/3

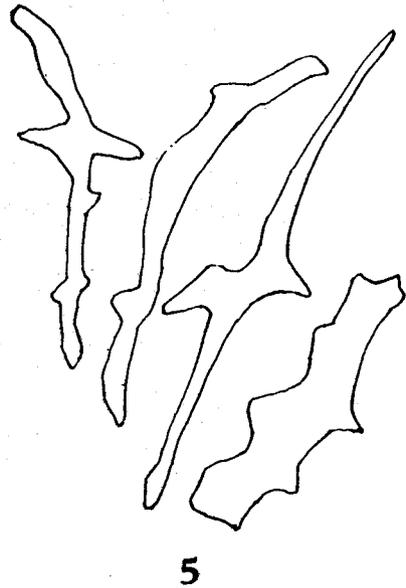
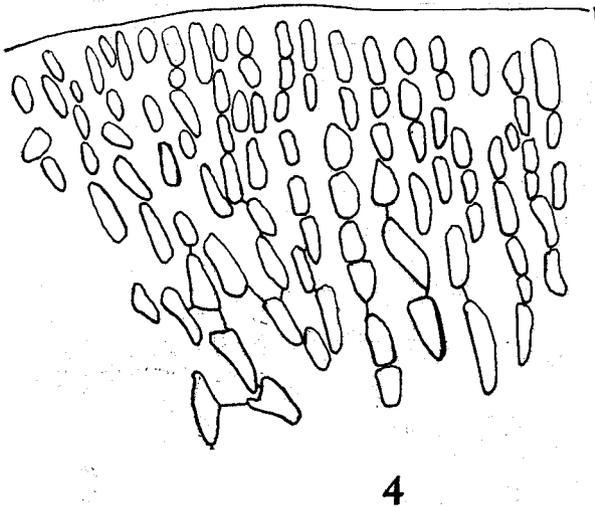
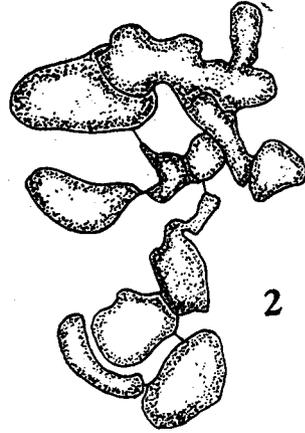
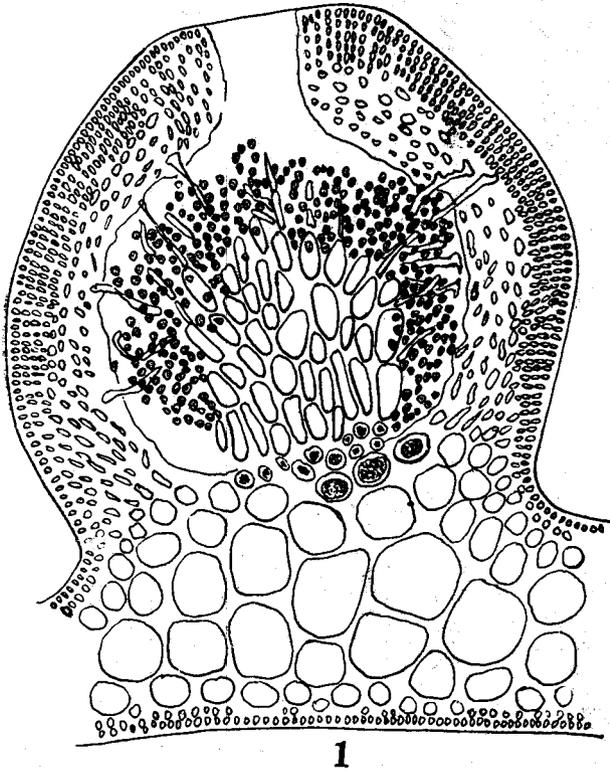
Plate V. *Gracilaria Textorii* from Kurihama and Bahia Agua Dulce

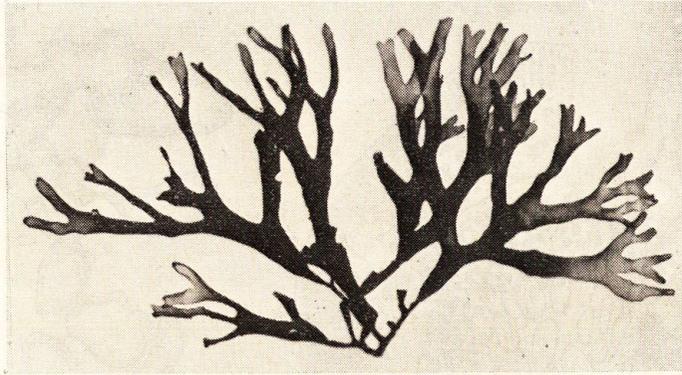
- Fig. 1. Habit of a mature tetrasporic plant having abundant proliferations; Kurihama, June 7, 1951 × ca. 1/2  
Fig. 2. Habit of a young tetrasporic plant showing typical mode of branching of a medium sized and slender frond; Bahia Agua Dulce, Isla Tiburon, Gulf of California, Dawson 877, Feb. 21, 1946 × ca. 3/5

Plate VI. *Gracilaria Textorii* from Bahia de Los Angeles and  
Ensenada Bocochoibampo

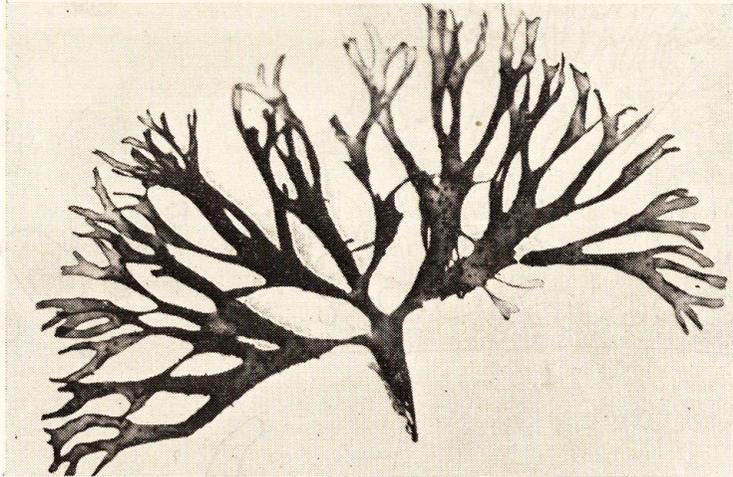
- Fig. 1. Habit of a sterile plant having broad frond; Bahia de Los Angeles, Gulf Baja California, Dawson 1335, Apr. 11, 1946 × ca. 1/2  
Fig. 2. Habit of an antheridial plant having typical shape; Ensenada Bocochoibampo, Sonora, Dawson 455, Feb. 12, 1946 × ca. 2/3







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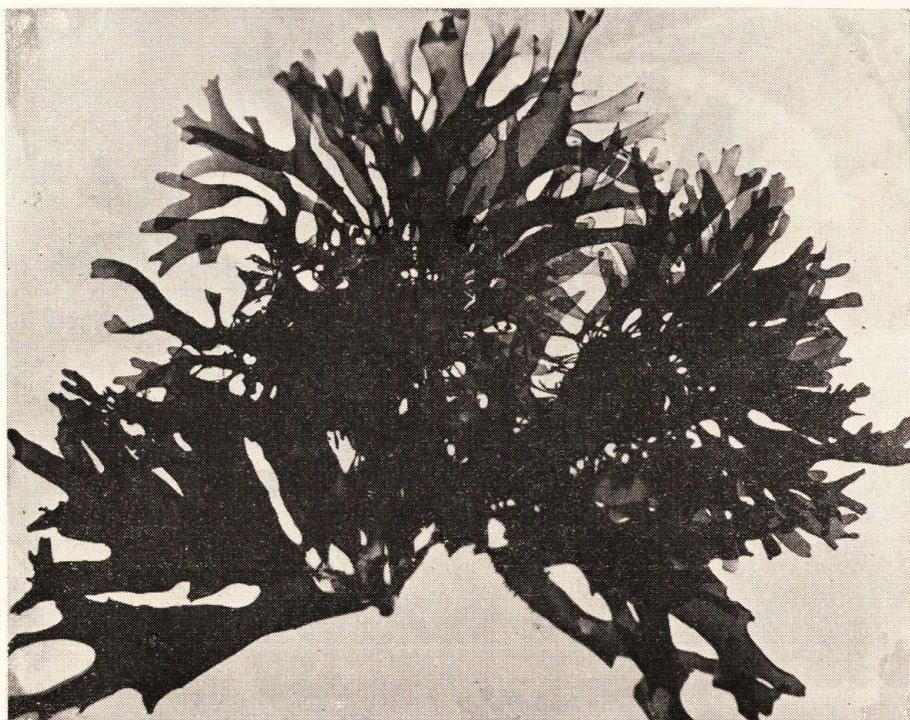
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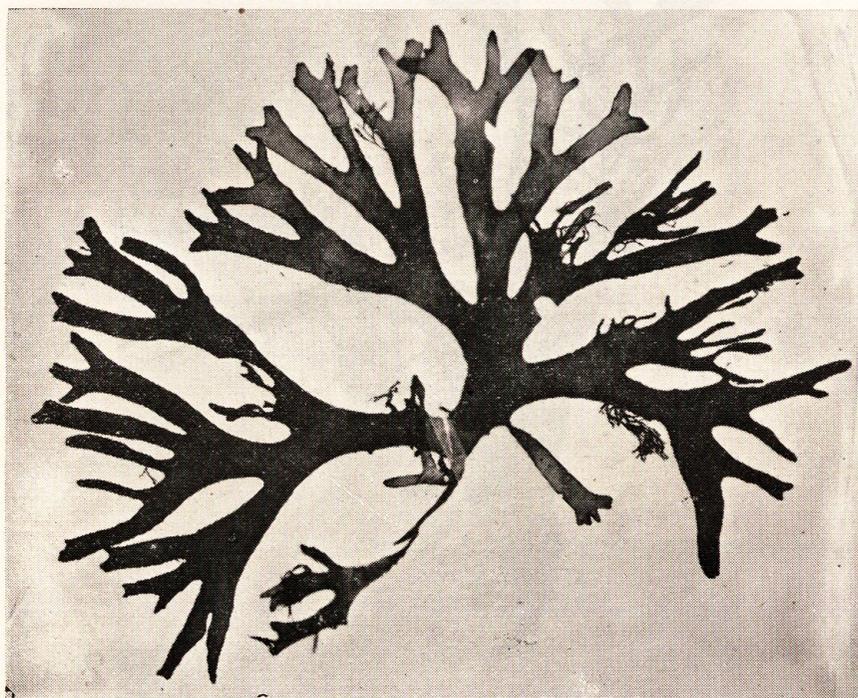
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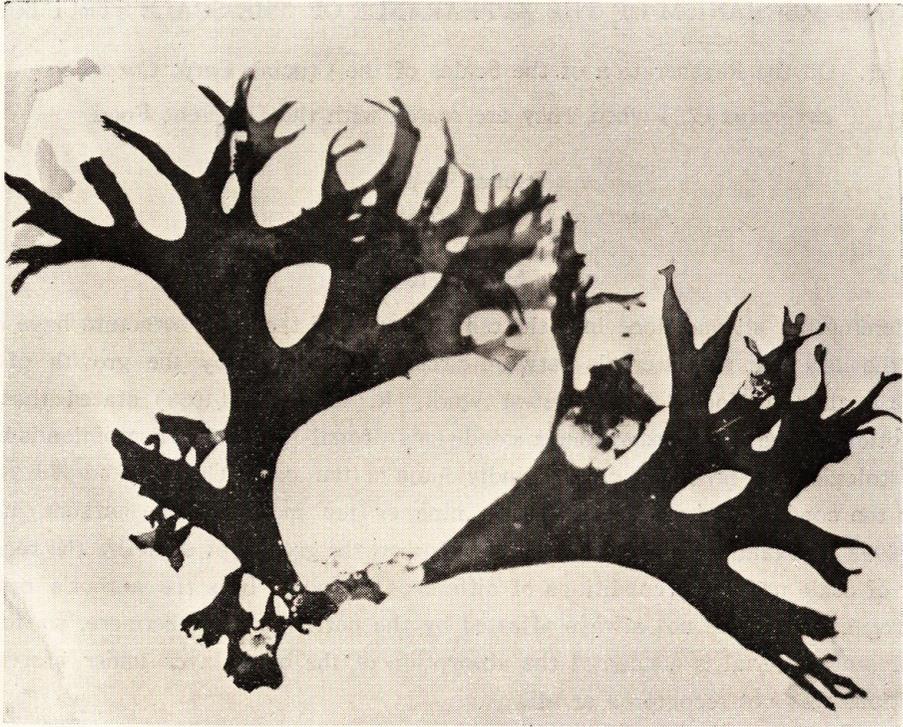
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