# THE SYSTEMATIC STUDY OF THE JAPANESE PROTOFLORIDEAE

BY

TAKESI TANAKA

## CONTENTS

PLATES I-XXIII AND FIGURES 1–41.

# I. INTRODUCTION

The Bangioideae or Bangiales was established as one of the classes of the *Rhodophyceae* by FR. SCHMITZ in 1897. Afterward HARALD KYLIN (1937) divided this class into two orders, namely Porphyridiales and Bangiales. Lately the systematic arrangement was attempted by H. SKUJA in 1939, in which he divided this class into four orders, Porphyridiales, Goniotrichales, Bangiales and Compsopogonales. And also he revised this Bangioideae under the name of Protoflorideae in accodance with the opinion of ROSENVINGE (1909).

From the phylogenetic point of view, many works of THURET (1855 and 1863), COHN (1867), BORNET et THURET (1876), BERTHOLD (1882), BENNET (1887), SCHMITZ (1867), SETCHELL and GARDNER (1920), ISHIKAWA (1921), OLTMANNS (1922), KYLIN (1937 and 1939), TILDEN (1933 and 1935) and SKUJA (1939) etc. may be mentioned. Among these authors, the opinions of COHN, ISHIKAWA, KYLIN, TILDEN, and SKUJA seem to be very convincing to the writer. But as at present it is almost impossible to establish a complete phylogenetic system of Protoflorideae, the present writer here followed for convenience SKUJA's system of Protoflorideae (1939) except the order Bangiales; his system is as follows;

Class Protoflorideae
- Order I. Porphyridiales
  - Family 1. *Porphyridiaceae*
    - *Porphyridium ; Vanhoeffenia ; Chroothece ; Rhodospora ; Cyanoderma.*
- Order II. Goniotrichales
  - Family 1. *Goniotrichaceae*
    - *Asterocytis ; Goniotrichum.*
  - Family 2. *Phragmonemataceae*
    - *Phragmonema ; Kueuckeria ; Kyliniella.*
- Order III. Bangiales
  - Family 1. *Bangiaceae*
    - *Erythrotrichia ; Bangia ; Bangiopsis ; Porphyra.*
  - Family 2. *Erythropeltidaceae*
    - *Porphyropsis ; Erythrocladia ; Neevea ; Erythropeltis ; Conchocelis.*
- Order IV. Compsopogonales
  - Family 1. *Compsopogonaceae*
    - *Compsopogon.*

For some years the present writer has been studying systematically the Japanese species of Protoflorideae under the direction of Professor YUKIO YAMADA in the Botanical Institute, Faculty of Science, Hokkaido University. In treating this group the inner characters, especially the shape of the chromatophore in the vegitative cells, the presence of central pyrenoid and the difference of the division mode of reproductive bodies, as well as the outer characters were used. The total number of species of Protoflorideae treated in the present paper, is thirty-nine, belonging to the ten genera, and five families and four orders.

The materials used for study belong mostly to the herbarium of Hokkaido University, which include the specimens of Professor YUKIO YAMADA, the herbarium of the late Dr. KINTARÔ OKAMURA, and the present writer's own collection.

The writer wishes to express his most cordial thanks to his teacher, Professor YUKIO YAMADA under whose valuable guidance and constsnt encouragement the present work has been completed. Thanks are also due to Mr. SEINAI YAMAMOTO, the Dean of this Faculty of Fisheries, Kagoshima University, for his kind advices and encouragement throughout the present work.

The expenses incurred in collecting the material used for the present study were covered by a grant from the Japan Society for the Promotion of Scientific Research, and by a subsidy from the Department of Education, for which the writer expresses here his sincere thanks.

Furthermore, for the expenses incurred in his work, the writer is also indebted to the Nitto Fishing Company, and expresses his cordial thanks to the Director, Mr. SUEKITI SITITA of the Company. Thanks are also due to Prof. SABURO UEDA, the Tokyo University of Fisheries, who gave valuable suggestions and kindly allowed the writer to examine his specimens. The writer is also much obliged to Dr. MASAZI NAGAI, late Dr. TIYOITI KANDA, Dr. YOSITERU NAKAMURA and Dr. YOSIKAZU OKADA, who allowed the writer to use their specimens.

Furtermore, the present writer is obliged to Prof. JUN TOKIDA, Department of Agriculture, Hokkaido University, Dr. TORAITIRO KINOSHITA, Hokkaido Regional Fisheries Research Labolatory.

## II. AN ANALYTICAL KEY TO THE ORDERS, FAMILIES AND GENERA OF JAPANESE PROTOFLORIDEAE

Order I. Porphyridiales KYLIN

Multiplication by vegetative cell division.

Family *Porphyridiaceae* SKUJA

Each vegetative cell containing stellate chromatophore and central pyrenoid. Cells unicellular, aggregate into gelatinous colony

.....Genus *Porphyridium*.

Order II. Goniotrichales SKUJA

Multiplication arising without cell-division.

Family 1. *Goniotrichaceae* SKUJA

Each vegetative cell containing stellate chromatophore and central pyrenoid.

a) Gonidia naked .....Genus *Goniotrichum*.

b) Gonidia provided with cell-membrane

..... Genus *Asterocytis*.

Order III. Bangiales Schmitz

Frond consisting of one kind of cells; monospore arising by division (or also without division) from an ordinally vegetative cells or cut off by a curved wall in a vegetative cells.

Family I. *Bangiaceae* FR. SCHMITZ

Chromatophore stellate and a central pyrenoid within it.

Subfamily 1. *Erythrotrichieae* ROSENVINGE

Monospore cut off by an oblique wall in a vegetative cells.

Frond erect, filiform ..... Genus *Erythrotrichia*.

Subfamily 2. *Bangieae* ROSENVINGE

Monospore arising by division (or also without division) from an ordinally vegetative cells.

a) Frond filiform ..... Genus *Bangia*.

b) Frond flat ..... Genus *Porphyra*.

Family 2. *Erythropeltidaceae* SKUJA

Chromatophore parietal laminate, without or rarely with a central pyrenoid; monospore cut off by an oblique wall in a vegetative cells.

a) Frond consisting of creeping ramified filament, more or less confluent to a monostromatic disc ..... Genus *Erythrocladia*.

b) Frond at first cushion shaped, later becoming vescicular and ultimately rupturing and becoming an expanded monostromatic plane ..... Genus *Porphyropsis*.

c) Frond consisting of creeping filaments, more or less net-like ..... Genus *Colaconema*.

Order IV. *Compsopogonales* SKUJA

Frond consisting of two kind of cells; monospore cut off by an oblique wall in a vegetative cells.

Family *Compsopogonaceae* SCHMITZ

Chromatophore parietal laminate, without a central pyrenoid.

Frond filiform or cylindrical ..... Genus *Compsopogon*

## III. ENUMERATION OF THE SPECIES AND FORMS

### Order. 1. Porphyridiales

### Family *Porphyridiaceae*

### *Porphyridium* NAEGELI, 1849

Frond forming a thin, gelatinous, blood-red layer, of indefinite extent; cells usually spherical or oblong, each surrounded by an individual gelatinous sheath; chromatophore star-shaped with a central pyrenoid; reproduction by cell division.

#### *Porphyridium cruentum* (AGARDH) NAEGELI

Fig. 1.

Gatt. einzell. Alg. (1849) p. 139, t. IV; RABENHORST, Flora Europea Algarum aquae dulcis et submarinae (1846–'68) p. 397; KIRCHNER, Algenflora von Schlesien (1878) p. 111; SCHNETZLER, Ueber *Porphyridium cruentum* (1878); COOKE, British Freshwater Algae (1882 '84) p. 13, t. 5, f. 6; SCHMITZ, Chromatophoren der Algen (1882) p. 180, fig. 23; BORZI, Noterelle algologische; *Porphyridium cruentum* NAEGELI (1891); GAIDUKOV, Zur Morphologie und Physiologie der Algen. *Porphyridium cruentum* NAEG. (1899); ÔNO, Sinsennippon Shokubutu-zusetu, vol. 2, no. 4 (in Japanese) (1901) pl. 75; DE TONI, Syll. Alg., IV (1905)

p. 1869, V (1907) p. 697; BRAND, Ueber das Chromatophor und die systematische Stellung der Blut Algen (*Porphyridium cruentum*) (1908), Ueber Beurteilung des Zellbaues kleinen Algen mit besoderen Hinweise auf *Porphyridium cruentum* NAEGELI (1917); TILDEN, Minnesota Algae (1910) p. 297, pl. 20, Fig. 23; KUFFERATH, Note sur la physiologie et la morphologie de *Porphyridium cruentum* NAEG. (1913); WEST, Algae (1916) p. 40, p. 422; STAEHELIN, Zur cytologie und Systematik von *Porphyridium cruentum* NAEG. (1917); LEWIS and ZIRKLE, Cytology and systematic position of *Porphyridium cruentum* NAEG. (1920) p. 333-340, pl. 20-21; BORESCH, Die wasserlöslichen Farbstoffe der *Schizophyceen* (1921); GEITLER, Ueber einige wenig bekannte Suesswasserorganismen mit rot oder blaugrünen Chromatophoren. Zugleich ein Beitrag zu Kenntnis pflanzlicher Chromatophoren (1924) p. 357-375, figs. 1-11; FRITSCH, A treatise on the British Freshwater Algae (1927) p. 431, fig. 181, E; DANGEARD, Sur la mobilitè de certaines du *Porphyridium cruentum* NAEG. (1930); OKAMURA, Sôrui keitôgaku (in Japanese, 1930) p. 285, pl. 378, Nippon Kaisosi (in Japanese) (1936) p. 370, pl. 167; SMITH, Freshwater Algae of the United States (1933) p. 125, fig. 79; VISCHER, *Porphyridium cruentum* NAEG. (1934), Zur Morphologie, Physiologie und Systematik der Blutalge, *Porphyridium cruentum* NAEG. (1935); KOBAYASHI and WATARI, Microphytographs of Lower Plants, V (in Japanese, 1934) p. 657; KYLIN, Anatomie der *Rhodophyceae* (1937) p. 39, fig. 15, C-E.

*Palmella cruentum* AGARDH, Syst. Alg. (1824) p. 15; KUETZING, Tab. Phyc., I (1845-'49) t. 15, fig. II, Spec. Alg. (1849) p. 212; MENEGHINI, Monograph. Nostochinearum Italicarum (1946) tab. IV, fig. 1; HASSELL, Brit. Freshwater Alg. (1852) p. 308, t LXXX, fig. 5.

*Tremella cruentum* ENG., Bot. Tab. (1800); GREVILLE, Scott. Cryptog. Flora (1823-'29) p. 205.

Japanese name. *Tinorimo.*

Hab. Very widely distributed in Japan.

Distribution. Europe; America; Asia. Very common in the World.

Frond mass slimy to gelatinous, blood-red, on damp soil and on moist walls, cells approximately spherical, 7–16 $\mu$ in diameter, each cell surrounded by gelatinous sheath, containing star-shaped chromatophores and central pyrenoid within it; nucleus exceedingly small, consisting of a single eccentric granule surrounded by a clear space; reproduction by cell division.

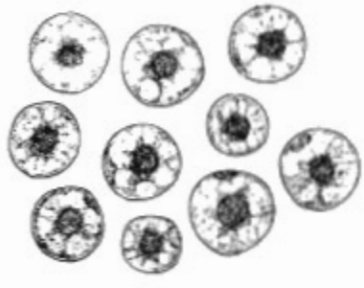


Fig. 1. *Porphyridium cruentum* (AG.) NAEGELI. × 450.

*Porphyridium cruentum* (AGARDH) NAEGELI is one of the unicellular fresh water algae. The plant is slimy to gelatinous, and growing upon damp ground and near base of damp-walls. The widely differing opinions have been held as to its cell structure and its systematic position.

MOLISH (1906), BRAND (1908, and 1917), BORESCH (1921) and many other phycologists have ascertained that the pigment in the chromatophore of the present plant is almost phycoerythrine and not phycocyan. But STAEHELIN (1917) has recently again advovated its inclusion in the *Myxo-*

*phyceae*, but neither his interpretation of the cell-structure, nor his conclusion have found general acceptance.

The present plant was already reported in Japan by ÔNO, OKAMURA and many other Japanese botanists. ÔNO described and delineated this plant in his "Shinsen-nippon Shokubutu-zusetu, vol. 2, no. 4; 1901". The present species appears to be distributed very commonly in Southern and Nouthern parts of Japan.

## Order 2. Goniotrichales
## Family *Goniotrichaceae*
## *Goniotrichum* KUETZING, 1843

Frond filamentous, minute, erect, pseudo-dichotomously or rarely laterally branched, fastened to the substratum by means of a small disc which forms only a single cell; cells usually quadrate with rounded angles or oblong, or barrel-shaped; chromatophore star-shaped with a central pyrenoid; reproduction by the formation of naked monospores with liberated by dissolution of the membrane; colour of the frond purplish red or greenish red.

### Key to the species

I. Filaments of the frond consisting of a single row of cells ..... *G. Alsidii* (ZANARD.) HOWE.

II. Filaments of the frond consisting of more than two rows of cells.
  1) Filaments as a rule unbranched but rarely issuing lateral branches ..... *G. Humphyreyi* COLLINS
  2) Filaments irregularly and dichotomously ramified ..... *G. cornu-cervi* (R.) HAUCK.

### *Goniotrichum Alsidii* (ZANARDINI) HOWE

Figs. 2-3.

Mar. Alg. Peru (1914) p. 75, in BRITTON and MILLSPAUGH's Bahama Flora (1920) p. 553; SETCHELL and GARDNER, Mar. Alg. Revillagigedo Islands Expedition in 1925 (1930) p. 151; INAGAKI, Mar. Red Alg. Oshoro Bay, Hokkaido (in Japan, 1934) p. 12, pl. 5; TSENG, Mar. Alg. Amoy (1936) p. 32, pl. IV, fig. 15; OKAMURA, Nippon-kaisôsi (in Japanese, 1936)p. 369; SEGAWA, Mar. Alg. Susaki, Prov. Izu, and its Vicinity, II (1936) p. 181; TAYLOR, Mar. Alg. Northeastern Coast North America (1937) p. 215, pl. 28, figs. 1-4; YAMADA and TANAKA, Mar. Alg. Island Yonakuni (1938) p. 68; FELDMANN, Les Algues marines côtes Albères RHODOPHYC., IV (1939) p. 256, fig. 3; NAGAI, Mar. Alg. Kurile Islands, II (1941) p. 139, pl. IV, figs. 1-2; TANAKA, The Japanese Species of Protoflorideae, I (in Japanese, 1944) p. 217, pl. 1-2.

*Bangia Alsidii* ZANARDINI, Bibl. Ital., vol. 96 (1839) p. 139.

*Bangia elegans* CHAUVIN, in "Mem. Soc. Linn. Norm., VI (1838) p. 13"; HARVEY, Phyc. Brit., pl. 246; ZANARDINI, Plant in Mari Rubro (1858) p. 87.

*Goniotrichum dichotomum* KUETZING, Tab. Phyc., 3 (1858) p. 27, fig. 1.

*Goniotrichum elegans* (CHAUV.) ZANARDINI, Not. Cell. Mar. (1847) p. 69; FARLOW, Mar. Alg. New England (1881) p. 113; J. AGARDH, Till. Alg. Syst., III (1882) p. 13; DE TONI, Syll. Alg., V (1907) p. 687.

*Goniotrichum ceramicola* KUETZING. Tab. Phyc., 3 (1853) pl. 27, fig. 2.

*Goniotrichum elegans* (CHAUVJN) LE JOLIS, in Alg. Mar. Cherb. (1863) p. 103; BERTHOLD, Bangiaceen Golfes Neapel (1882) p. 26; HAUCK, Meeresalgen (1885) p. 518, fig. 233; COLLINS, Alg. Jamaica (1901) p. 251 Alg. Bermuda (1917) p. 95; KYLIN, Ueber Algenflora Schwedischen Westküste (1907) p. 114, Mar. Red Alg. Biological station Friday Harbor, Wash. (1925) p. 6, fig. 1, a–b, Verzeichnis einig. *Rhodophyc.* Südafrica (1938) p. 3, Californishe *Rhodophyc.* (1941) p. 3; ROSENVINGS, Mar. Alg. Denmark, 1 (1909) p. 75, figs. 15-16; BOERGESEN, Mar. Alg. Danish West Indies, II (1915) p. 4, fig. 2, Mar. Alg. Canary Islands, *Rhodophyc.*, III (1927) p. 10, fig. 4, Some Indian *Rhodophyc.* Presidency Bombay, III (1933) p. 113; YENDO, Notes Alg. New Japan, III (1915) p. 105; WEBER VAN BOSSE. Liste Alg. Siboga, II (1921) p. 187; HAMEL, Floridées France, Bangiales (1924) p. 448, fig. 7a; DE TONI, Syll. Alg., VI (1924) p. 23; NEWTON, Handbook British Seaweeds (1931) p. 246, fig. 150; SINOVA, Alg. Novorossijsk mer Noire leur utilisation (1935) p. 82, Alg. de la mer du Japon (1940) p. 45; LEVRING Zur Kenntn. Algenf. Norwegischen Westküste (1937) p. 78.

*Porphyra elegans* CROUAN, "Fl. Finist. (1867) p. 132, pl., 10, fig. 73".

Japanese name. *Benimidoro.*

Hab. Ponape, Carolline Island; Kashôtô, Formosa; Yonakuni Island, Ryûkyû; Makurazaki and Kosikizima, Satuma Prov.; Amakusa, Higo Prov.; Nomosaki, Hizen Prov.; Susaki, Izu Prov.; Enoshima, Zusi and Hayama, Sagami Prov.; Fukaura, Mutu Prov.; Oshoro, Suttu, Muroran, Hakodate and Akkesi, Hokkaido; Bayôtô, Moppo and Fusan, Corea; Kurile Islands.

Distribution. Very widely distributed in the world.

Frond epiphytic, filamentous, minute, solitary, ca. 0.5–3 mm high, attached to the other algae by means of a small disc formed by the basal cell, pseudo-subdichotomously much branched, 12–48 $\mu$ broad in the lower branches, but 8–20 $\mu$ broad in the upper ones; cells almost uniseriate but rarely 2–3 seriate, suboblong to short disc-shaped, 7–18 $\mu$ wide, 5–15 $\mu$ long, containing a stellate chromatophore and a central pyrenoid within it; colour of the frond violet red or lilac.

The present species is always epiphytic upon other algae, e.g. *Sargassum*, *Polysiphonia*, *Sphacelaria*, *Gloiosiphonia*, *Ceramium*, etc. and seems to be rather common. The filaments consist mostly of a single row of cells, but several specimens have filaments which are consisted of more than a single cell at the same revel. According to ROSENVINGE's discription (l.e.) this was caused not by longitudinal walls by displacement of the cells. But the writer has observed, as already mentioned and figured by BOERGESEN (1916), this transversal multiplication of the cells is certainly due to longitudinal division of the cells. The ramification is already described in detail by ROSENVINGE; it takes place in a manner reminding one of the so called false branching of *Asterocytis* or *Scytonemataceae*.

The length of the vegetative cells is rather often variable; most of the length is shoter than breadth, but often there are those ones which are longer than broad.

According to SCHMITZ (1894, p. 718 and p. 314), monospore is produced by the ordinally cells, and cell content is condensed and liberated as a naked spore.

The writer has fortunately ovserved the monospore-formation. The monospore are almost spherical and naked, about 9–18 $\mu$ in diameter. In using ZANARDINI's name for the present species the writer has followed to HOWE and INAGAKI (l.c.). The present species is very commonly found in the waters of both the Pacific and Japan Sea.

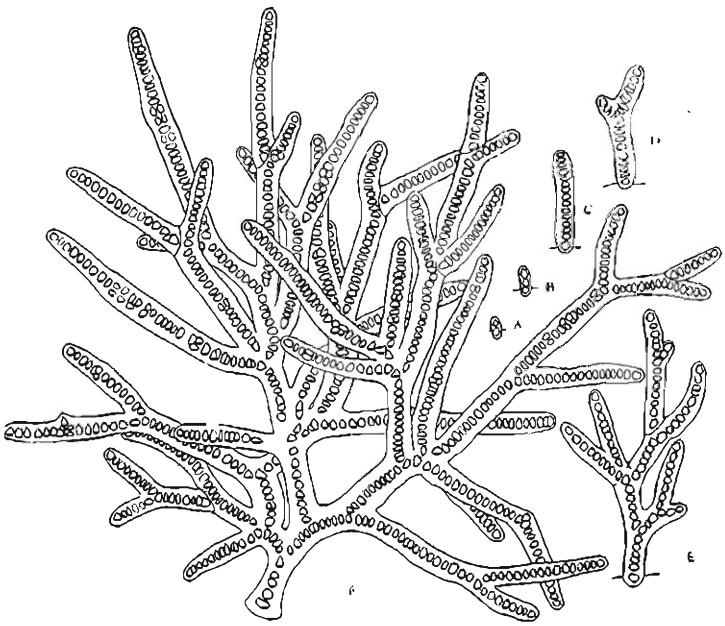


Fig. 2. *Goniotrichum Alsidii* (ZANARDINI) HOWE.
A - F: Various stages of the plants. × 125.

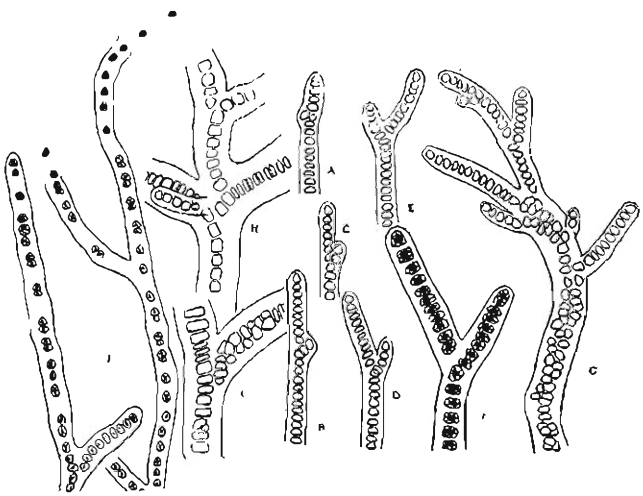


Fig. 3. *Goniotrichum Alsidii* (ZANARD.) HOWE.
A-J: Various stages of the ramified filaments. ×210, G: ×180. J: Parts of the filaments with the naked akinetes. ×210.

## *Goniotrichum Humphreyi* COLLINS

Fig. 4.

In Phyc. Bor. Amer., no. 421 (1898) Exsicc., Alg. of Jamaica (1901) p. 251, Alg. of Bermuda (1917) p. 95; TANAKA, The Japanese Species of Protoflorideae (1944) p. 82, text-figs. 4-5.

*Bangiopsis subsimplex* (non SCHMITZ) BOERGESEN, Mar. Alg. Danish West Indies, *Rhodophyc.*, III (1915) p. 10, figs. 5-6.

Japanese name. *Nise-usikenori.*

Hab. Satoura, Awa Prov.

Distribution. West Indies; Florida.

Frond caespitose, minute, filamentous, darkish purple or purplish red, ca. 1.5 mm high and 15-70 $\mu$ in diameter, almost unbranched but rarely irregularly ramified, fastened to the substratum by the basal cell (often few cells) which forms an irregular small disc; no rhizoidal filaments issuing from lower most cells; cells irregularly arranged somewhat near the peripheral portion in transverse section, almost rounded polygonal or hemispherical, or often crescent shaped, ca. 6-10 $\mu$ in diameter, containing a stellate, red-violet chromatophore and a central pyrenoid within it; reproductive organ unknown.

The plant was found on rocks or *Sargassum* forming more or less small tufts. The base of the frond consists of an enlargement of the lower most end of the basal cell (often few cells), forming a small disc.

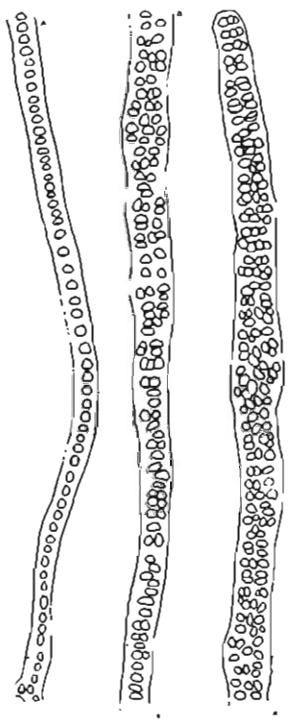


Fig. 4.
*Goniotrichum Humphreyi* COLLINS.
ca. × 250.

When young the frond is filamentous being composed of a single row of cells. The cells of the monosiphonous portion are disc-shaped, their length being much shorter than the breadth. In the somewhat older filaments the cells now and then being to be divided by longitudinal or more or less oblique walls. The division of the cells is rather irregular. The filaments are, as a rule, unbranched, but now and then short branches are given off from the thicker part. There branches are commonly short, proliferation-like, consisting of a single or a few rows of cells.

The cells of the filaments are irregular, rounded polygonal or hemispherical in shape, about 6-10 $\mu$ in diameter. These are irregularly arranged and often two or three are gathered. Among them crescent-shaped cells are often observed. A transverse section of the frond shows that the cells are arranged

somewhat near the peripheral part. The cells contain a star-shaped chromatophore with a central pyrenoid. The colour of the frond is somewhat darkish purple or purplish red. This alga was collected only once by Mr. Y. UZIKE from Satoura, Awa Prov., in August, 1941, in the littoral zone. Unfortunately the writer has not seen yet any reproductive organ.

*Goniotrichum Humphreyi* COLLINS has been established by COLLINS in Phyc. Bor. Amer., no. 421 (1898) Exsicc., in which he given figures and descrived it. Later this species was reported from Florida by the same author (1917). In 1915, BOERGESEN reported a species from St. Croix, West Indies nearly related to *G. Humphreyi* under the name of *Bangiopsis subsimplex* (MONT.) SCHMITZ. The material at hand agrees well with the specimens of *G. Humphreyi* in Phyc. Bor. Amer., no. 421, determind and distributed by COLLINS, and also agrees well with the description and figures of *Bangiopsis subsimplex* from Danish West Indies, given by BOERGESEN. The arrangement of the cells as well as the shape and size of our specimens are, however, slightly different from those of Jamaican specimen. In the Jamaican plant the cell arrangements is not so dense as that of our plants.

In general apperance, the present species has much resemblance to genus *Bangia*, but it differs from the latter by the want of rhizoidal filaments at the base and by the common presence of proliferation and especially by the rather irregular cell-division. The cells of the frond in *Bangia* is divided by radial walls and these, as the result of it, are generally wedge-shaped.

## *Goniotrichum cornu cervi* (REINSCH) HAUCK

Fig. 5.

Meeresalgen (1885) p. 519; DE TONI, Syll. Alg., V (1907) p. 688; HOWE, Mar. Alg. Peru (1914) p. 76; KYLIN, Mar. Red Alg. in the Vicinity of Biological Station, Friday Harbor, Wash. (1925) p. 6, fig. 1, c--e; HAMEL, Flor. de France, Bangiales (1924) p. 450, fig. VI, c--d; NEWTON, Handbook British Seaweeds (1931) p. 246; FELDMANN, Alg. Mar. côto de Albéres (1930) p. 257; SEGAWA, New or Noteworthy Alg. from Izu (1941) p. 257, fig. 5; TANAKA, The Japanese Species of Protoflorideae, 1 (in Japanese, 1944) p. 222, figs. 4–5.

*Stylonema cornu cervi* REINSCH, "Gontrib. (1875) p. 40, t. 15".

*Goniotrichum dichotomum* BERTH. (non KUETZING) *Bangiaceen* des Golfes von Naepel (1882) p. 26.

Japanese name. *Kazuno-hosinoito.*

Hab. Susaki, Izu Prov.; Hayama and Misaki, Sagami Prov.

Distrib. Mediterranean Sea; Adriatic Sea; Atlantic Ocean.

Frond epiphytic, erect, minute, ca. 1 mm high, 30–80 $\mu$ broad, irregularly 3–5 times dichotomously ramified, fastened to the substratum by the basal cell which forms an irregularly lobed disc; branches very patent with almost rounded axils, forming cervis-horn shaped, cells of the basal disc usually larger and longer than the other vegetative ones, ca. 10 $\mu$ in diameter; cells mostly hemispherical quadrate with rounded angles, ca. 7-8 $\mu$ in diameter, but at times longer or shorter than the diameter, arranged more or less irregularly longitudinal cross rows; chromatophore star-shaped with a prominent pyrenoid; monospore formed by the immediate transformation of vegetative cells, naked

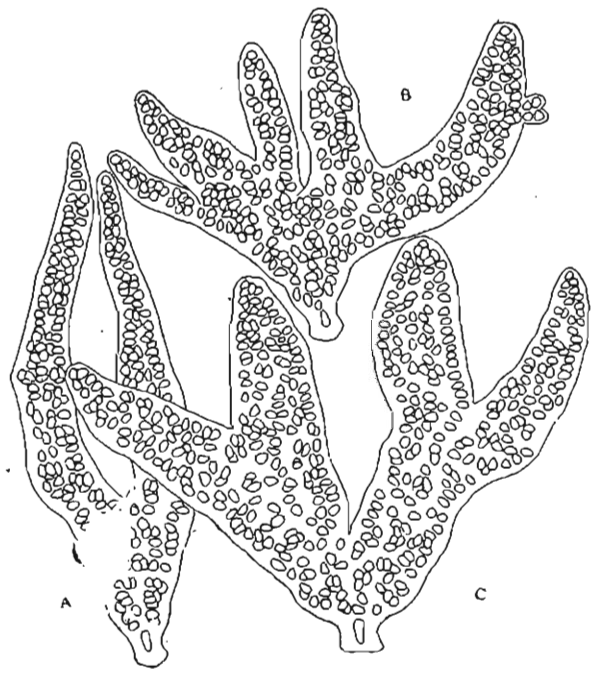



Fig. 5. *Goniotrichum cornu cervi* (REINSCH) HAUCK.
A - C: Three ramified plants. × 210.

and containing dense contents, ca. 6-9 $\mu$ in diameter; colour of the frond lilac or feebly bluish red.

The present species is epiphytic upon other algae, e.g. *Hypnea*, *Spermothamnion*, *Callophyllis*, *Polysiphonia* etc. The plant reaches a length of up to 1 mm. In the broadest part, the number of vertical septa in each joint of median part of the frond, may be 5-6 in surface view, and their breadth is 30-80 $\mu$. The cells in the basal disc is comparatively large and oblong. The apex of the branches is more or less obtuse and gradually tapering. The most characteristic feature of the present plant is the dichotomous ramification, which indicate at once the present species.

In general appearance, the materials at hand, agree with a description of *Goniotrichum cornu cervi* (REINSCH) HAUCK given by HAUCK, except only the shape of branches. The branches of our Japanese specimens are a little more thicker than European plant and generally obtuse at the apex of the branchlets.

## *Asterocytis* Gobi, 1879

Frond epiphytic, erect, filamentous, reddish blue-green, arising from a convex lobed hapteron, pseudo-dichotomously much branched; cells arranged in a single row in thick gelatinous matrix of the filaments, suboblong to short disc-shaped, containing stellate chromatophore and a central pyrenoid within it; asexual reproduction by the formation of akinetes; sexual reproduction unknown.

## *Asterocytis ornata* (C. AGARDH) HAMEL

Fig. 6.

Floridées de France, II (1924) p. 451, figs. b-d; BOERGESEN, Mar. Alg. Canary Islands, *Rhodophyc.*, III (1927) p. 11, Mar. Alg. Iranian Gulf (1939) p. 102; FELDMANN, Alg. Mar. de la côtes des Albères (1939) p. 257, fig. 4; LEVRING, Stud. u. Algenveg. von Blekinge, Suedschweden (1940) p. 71, TANAKA, The Japanese Species of Protoflorideae (1944) p. 79, text-figs. 1-2.

*Conferva ornata* C. AGARDH, Syst. Alg. (1824) p. 104.

*Hormospora ramosa* THWAITES in HARVEY's Phyc. Brit., pl. 213

*Goniotrichum ramosa* (THWAITES) HAUCK, Meeresalg. (1855) p. 519.

*Goniotrichum caerulescens* ZANARDINI, Icon. Phyc. Adri., III (1871) p. 67, Tab. 96, B.

*Callonema smaragdinum* REINSCH, Rech., p. 41.

*Asterocytis ramosa* (THWAITES) GOBI in Arbeiten St. Petersb. Naturf. Gesellsch., Bd. X (1877) p. 85; SCHMITZ, in Engler u. Prantl's Natur. Pflanzenfam., Teil 1, Abteil. 2 (1897) p. 314; WILLE, Algolog. Notizen, III. *Asterocytis ramosa* (THW.) GOBI (1900) p. 7, Taf. I, Figs. 8-14; DE TONI, Syll. Alg., V (1907) p. 690; ROSENVINGE, Mar. Alg. Denmark, Pt. 1 (1909) p. 77, fig. 17; BOERGESEN, Mar. Alg. Danish West Indies, *Rhodophyc.*, II (1916) p. 3, fig. 1; HOWE, in Britton and Millspaugh's Bahama Flora (1920) p. 554; ELENKIN et STARK, De *Asterocytis ramosa* (THWAITES) GOBI caeterisque speciebus hujus generis Notula (1923); TAYLOR, Mar. Alg. Florida (1928) p. 132, pl. 20, figs. 1-2, Mar. Alg. Northeastern North Amer. (1937) p. 214; LAKOWITZ, Algenf. gesamt. Ostsee (1929) p. 301, fig. 41; NEWTON, Handbook British Seaweeds (1931) p. 247, fig. 151; LEVRING, Zur Kenntn. Algenf. norwegisch Westküste (1937) p. 78; SINOVA, Les Alg. de la mer Japon (1940) p. 45.

Japanese name. *Tamatunagi*.

Hab. Palau, Caroline Islands; Kashoto and Bokotō, Formosa; Miyakozima and Isikakizima, Ryūkyū; Makurazaki, Satuma Prov.; Tomioka, Hizen Prov.; Ozika, Gotō Islands; Hinomisaki, Izumo Prov.; Osima, Etizen Prov.; Wagu, Sima Prov.; Saroma Lake, Hokkaido.

Distribution. Mediterranean Sea; Atlantic Ocean; Sweden; Iranian Sea; Florida; West Indies; Japan Sea.

Frond Epiphytic, erect, filamentous, ca. 1.5 mm long, 12-18 $\mu$ broad, attached to the substratum by means of a somewhat hemispherical hapteron, pseudo-dichotomously or rarely laterally much branched; cells usually elliptical or somewhat globular, ca. 10-18 $\mu$ broad and 8-20 $\mu$ long, arranged in single row in the gelatinous matrix of the filaments; cell wall about 6 $\mu$ thick, especially thickened in the lower parts of the filaments; chromatophores stellate, containing a large prominent pyrenoid; akinetes often oblong or ellipsoidal, ca. 10-13 $\mu$ in transverse diameter up to 18 $\mu$ in length, containing dense granular contents, librated by a lateral pore in the wall of the filaments; colour of the frond light or dull blue-green.

This species is always epiphytic upon other algae, e.g. *Sphacelaria*, *Dasya*, *Champia parvula*, *Digenea simplex*, *Hypnea charoides*, *Gracilaria confervoides*, *Chondrus*, and many others. The plant attains a length of at least 1.5 mm.

The filaments are below up to 18 $\mu$ thick, above they become gradually thinner and are at the summit 12 $\mu$ thick.

The frond is subdichotomously much branched and the mode of ramification reminds one of the so-called false branching of *Goniotrichum Alsidii* (ZANARD.) HOWE. The cells are usually oblong or elliptical, often $1\frac{1}{2}$ times as long as broad, sometimes shorter, nearly globular; they are about 10-18 $\mu$ broad and 8-20 $\mu$ long. The chromatophore, as is well known, is star-shaped with a central pyrenoid. The akinetes escape through a hole in the membrane of the filaments. They are often oblong, sometimes also globular or ellipsoidal, measuring 10-13 $\mu$ in diameter, up to 18 $\mu$ in length, and have very dense granular contents. The membrane of the akinetes is very thick, about 2-3 $\mu$. The colour of the frond is blue-green.

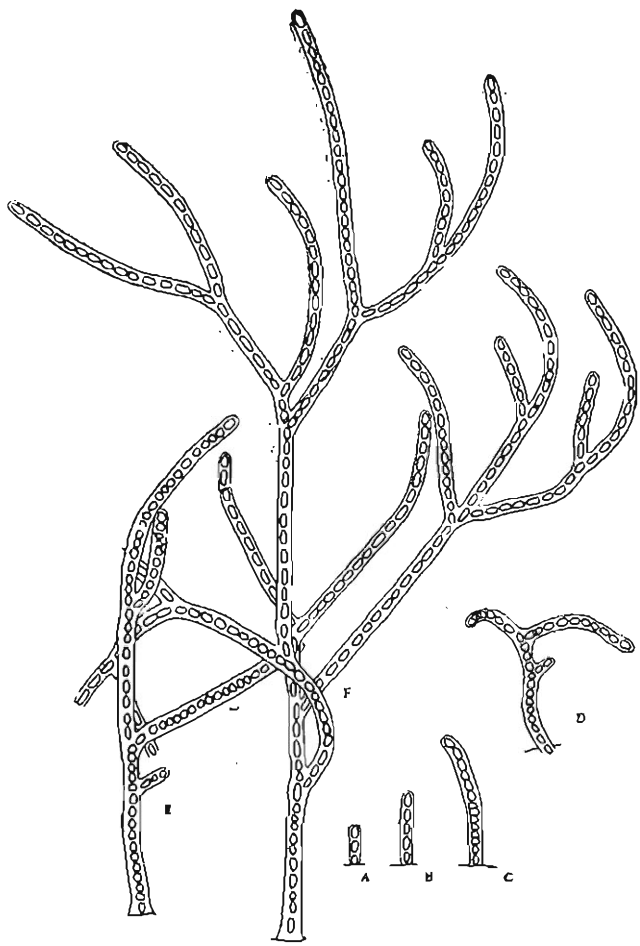



Fig. 6. *Asterocytis ornata* (C. AGARDH) HAMEL.
A-F: Various stage of the plants. × 135.

In general appearance, *Asterocytis ornata* seems to show some resemblance to *Goniotrichum Alsiedii* (ZANARD.) HOWE, but the former differs from the latter in the following points; The present species seems to grow, as a rule, in brackish water, as already noted by several authors, while *Goniotrichum Alsiedii* (ZANARD.) HOWE in water of high salinity. Furthermore, *Asterocytis ornata* differs from *Goniotrichum Alsiedii* on account of blue-green colour, in the presence of akinetes (ROSENVINGE l.c.).

As to the reproduction, this plant has been examined in detail by WILLE (1900, l.c.), ROSENVINGE (l.c.), BOERGESEN (l.c.), and by HAMEL (1924, l.c.). In our specimens, the writer has the chance of finding, several times, vegetative filaments in which the most part of the cells were transformed to akinetes. They were collected in summer (July-August). The present alga is widely distributed and more common around Japan, and found in shallow brackish waters.

### *f. simplex* (LAKOWITZ) HAMEL

Floridèes de France, II (1924) p. 452. Fig. VI, E; TANAKA, The Japanese Species of Protoflooridea (1944) p. 82, Text-fig. 3.

*Asterocytis ramosa* (THWAITES) GOBI *f. simplex* (LAKOWITZ) ROSENVINGE, in Mar. Alg. Denmark, I (1909) p. 77; LAKOWITZ, Algenf. gesamt, Ostsee (1929) p. 302, fig. 411.

*Goniotrichum simplex* LAKOWITZ, Algenf. Danziger Bucht (1907) p. 80; DE TONI, Syll. Alg., VI (1924) p. 23.

Japanese name. *Ito-tamatunagi*.

Hab. Palau, Caroline Islands; Bokoto and Kashotō, Formosa; Makurazaki and Kosikizima, Satuma Prov.; Tomioka and Hutae, Hizen Prov.

Distrib. Denmark; Baltic Sea; Mediterranean Sea.

Frond epiphytic, minute, erect, unbranched, usually up to 720 $\mu$ in length, 7–9 $\mu$ broad; cells globular or ellipsoidal, ca. 5–9 $\mu$ in diameter; chromatophore star-shaped with a central pyrenoid; reproductive organ unknown; colour light blue-green.

The present froma has been observed upon *Sphacelaria* and *Hypnea charoides* LAMX. growing on *Sargassum* and others. The filaments are as a rule unbranched and reach a length of about 720 $\mu$ and a breadth of about 7–9 $\mu$. The cells of the filaments are usually about as long as broad or somewhat longer. The wall of the cells are rather thick, about 1.5 $\mu$. The present forma has been found only in shallow and somewhat brackish waters.

## Order 3. Bangiales
## Family 1. *Bangiaceae*
## Subfamily 1. *Erythrotrichieae*

### *Erythrotrichia* ARESCHOUG, 1850

Frond erect, filiform, purplish red, epiphytic, usually unbranched, attached to the substratum by short rhizines from the basal cell, or suborbicular disc, monosiphonous or polysiphonous; cells usually ovoid or quadrate with rounded angles, containing star-like or parietal chromatophores; asexual reproduction by monosporangia formation in a vegetative cells, monospore isolated from

the spore mother cell by an oblique wall; sexual reproduction by antheridia and carpogonia; antheridia minute, pale, produced from the vegetative cells; carpogonia formed by the immediate transformation of vegetative cells, cystocarp containing of few carpospores.

### Key to the species

Vegetative cell of the frond containing a star-shaped chromatophore and a central pyrenoid within it ..... **Subgen. *Stelliplastida*** TANAKA

1. Frond consisting of a single row of cells ..... *E. carnea* (DILLW.) J. AG.
2. Frond consisting of more than single row of cells
   a) Filaments of the frond consisting of bisiphonous ..... *E. biseriata* TANAKA
   b) Filaments of the frond consisting of quadrasiphonous ..... *E. reflexa* (CROU.) THURET

Vegetative cell of the frond containing a parietal or band-shaped chromatophore without central pyrenoid or an obsuure pyrenoid ..... **Subgen. *Parietaliplastida*** TANAKA

1. Primary basal disc absent ..... *E. parietalis* TANAKA
2. Primary basal disc present.
   a) Basal creeping portion of the frond filamentous, with a free end ..... *E. incrassata* TANAKA
   b) Basal creeping portion of the frond suborbicular, disc shaped, without a free end ..... *E. japonica* TOKIDA

## Subgenus *Stelliplastida* TANAKA

### *Erythrotrichia carnea* (DILLWYN) J. AGARDH

Fig. 7.

Till. Alg. System., VI (1883) p. 15, t. 1, figs. 8–10; ROSENVINGE, Mar. Alg. Denmark, 1 (1909) p. 69, fig. 8; BOERGESEN, Mar. Alg. Danish West Indies, II (1915) p. 7, Mar. Alg. Easter Island (1924) p. 268, A list Mar. Alg. Bombay (1935) p. 41, Some Mar. Alg. Ceylon (1936) p. 79, Contrib. South India mar. Algal Flora, 1 (1937) p. 28, Mar. Alg. Iranian Gulf (1937) p. 101; COLLINS and HERVEY, Alg. Bermuda (1917) p. 94; HOWE, in BRITTON's Flora Bermuda (1918) p. 510, in BRITTON and MILLSPAUGH's Bahama Flora (1920) p. 553; WEBER VAN BOSSE, Liste Algues Siboga, II (1921) p. 188; DE TONI, Syll. Alg., VI (1924) p. 14; TAYLOR, Mar. Alg. Florida (1928) p. 133, Mar. Alg. Northeastern Coast North America (1937) p. 217, Figs. 13–15; FELDMANN, Contrib. Flora Algologique Marine de l'Algerie (1931) p. 233; NEWTON, British Seaweeds (1931) p. 242, fig. 147; YAMADA, Notes Some Japanese Alg., VI (1935) p. 28; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 375, fig. 181; YAMADA and TANAKA, Mar. Alg. in the Vicinity Akkesi Mar. Biological Station (1944) p. 67; TANAKA, Species of *Erythrotrichia* from Japan (1) (1951) p. 97, fig. 1.

*Erythrotrichia ceramicola* (LYNGBYE) ARESCHOUG, Phyceae Scandinavicae (1850) p. 210; LE JOLIS, Liste Algues Mar. de Cherbourg (1880) p. 103, pl. III, 1–2; BERTHOLD, *Bangiaceen* des Golfes von Neapel (1882) p. 25; SCHMITZ, in

Engler-Prantl's Naturlichen Pflanzenfam., I, Teil, Abt. 2, s. 313, fig. 194, a–b; DE TONI, Syll. Alg., IV (1897) p. 24; BOERGESEN, Mar. Alg. Faeröes (1902) p. 349; KYLIN, Stud. ueber Algenflora Schwedischen Westküste (1907) p. 107; LAKOWITZ, Algenflora gesamt. Ostsee (1929) p. 302, fig. 412.

*Conferva carnea* DILLWYN, Brit. Confervae (1809) pl. 84.

*Bangia carnea* (LYNGBYE) CHAUVIN, Recherches sur l'Organisation, la fructification de plusieurs generes d'Algues avec la description de quelques especes inedites (1842); HARVEY, Meeresalg. Deutschlands und Oesterreiches (1885) p. 22, fig. 1, a–b.

*Conferva ceramicola* LYNGBYE, Tentamen Hydrophytologicae Danicae (1819) p. 144, pl. 48, D.

Japanese name. *Hosinoito.*

Hab. Naha, Ryūkyū; Kosikizima, Satuma Prov.; Amakusa, Higo Prov.; Nomosaki, Hizen Prov.; Takamatu, Sanuki Prov.; Irakozaki, Mikawa Prov.; Hayama, Zusi and Enosima, Sagami Prov.; Onagawa, Rikuzen Prov.; Hakodate, Muroran, Suttu, Oshoro, Rumoe, Akkesi and Rausu, Hokkaido; Moppo and Bayoto, Corea.

Distribution Denmark; Indian Ocean; Pacific Ocean; Atlantic Ocean; Japan Sea.

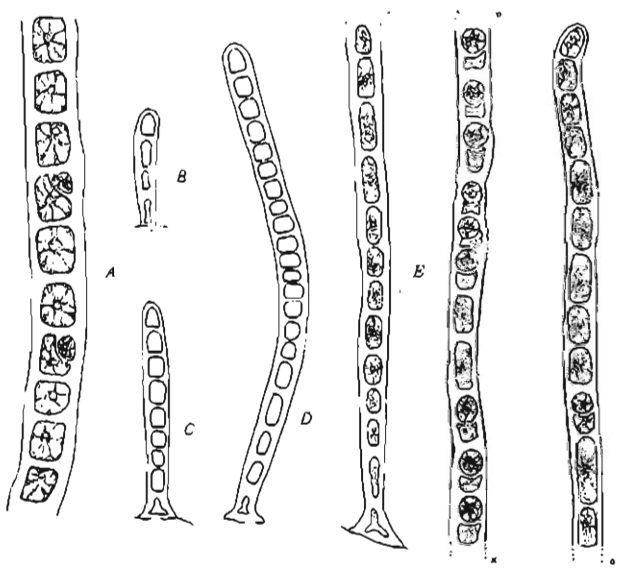



Fig. 7. B-E: *Erythrotrichia carnea* (DILLW.) J. AG. *f. tenuis* TANAKA
B-D: Young plants. ×300. E: Mature plant with monosporangia. ×300.
A: *Erythrotrichia carnea* J. AG. Part of the filament with monosporangia. ×300.

Frond filamentous, minute, erect, simple, epiphytic, solitary or 2–3 aggregate, 0.5–2 cm high, 12–27 μ thick, consisting of a single row of cells, attached to the host plant by means of the basal cell which gives off short ramified rhizines radiating in all directions on the surface of the host plant; cells of the filaments

mostly quadrate with rounded angles, usually slightly longer than broad, 14–30 x 12–27 $\mu$ as long as or often longer, containing a clear, star-shaped chromatophore with a large central pyrenoid; cell wall about 3–4 $\mu$ thick, gelatinous especially in the lower portion of the frond; monosporangia cut off by an oblique wall at the upper end of the vegetative cells; monospore nearly globular, ca, 5–10 $\mu$ in diameter, containing granular contents; colour of the frond light purplish red.

### *f. tenuis* TANAKA

Fig. 7.

The Japanese Species of Protoflorideae (1944) p. 92, Text-fig. 13, Species of *Erythrotrichia* from Japan (1) (1951) p. 98.

Japanese name. *Hosc-hosinoito.*

Hab. Yonakuni Island, Miyakozima and Naha, Ryūkyū; Makurazaki and Kosikizima, Satuma Prov.; Nomosaki, Hizen Prov.; Hukae, Gotō Island; Takamatu, Sanuki Prov.; Hinomisaki, Izumo Prov.

Distrib. Endemic.

Frond erect, epiphytic, simple, ca. 1.5 mm high and 9–12 $\mu$ thick; monosporangia almost spherical or subglobose, ca. 12 $\mu$ in diameter.

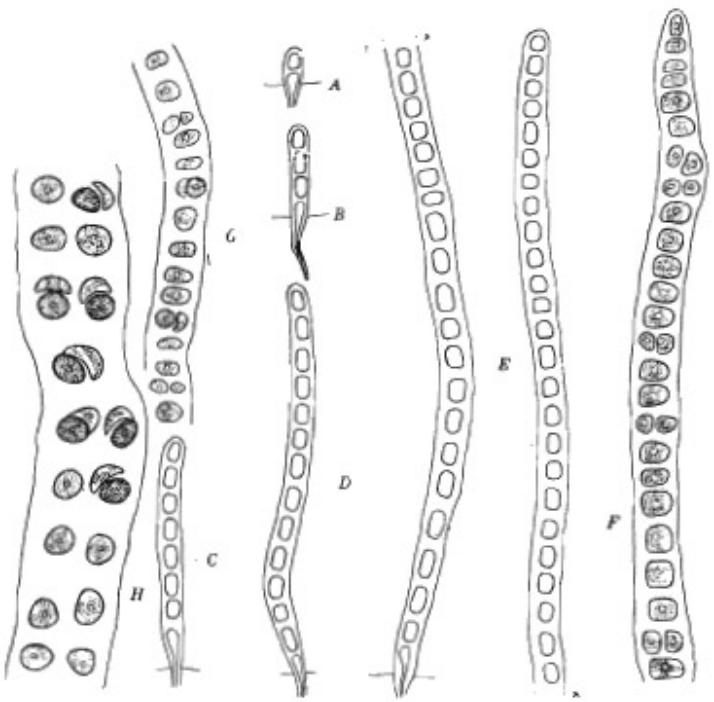



Fig. 8. *Erythrotrichia biseriata* TANAKA.
A-E: Various stages of the plants. ×450. F: Upper part of a filament. ×450. G-H; Parts of the filaments with monosporangia. G: ×450, H: ×600.

## *Erythrotrichia biseriata* TANAKA

Fig. 8.

The Japanese Species of Protoflorideae (1944) p. 86, fig. 8, Species of *Erythrotrichia* from Japan (1) (1951) p. 99.

Japanese name. *Hime-ribon.*

Hab. Hatidyō Island; Kashoto, Formosa.

Distrib. Endemic.

Frond epiphytic, minute, usually up to 1 mm in length; basal cell usually linear-elongate and slender, different from the other cells, about 8 $\mu$ in diam., and about 25 $\mu$ long, penetrating vertically through the cortical cells of the host plant; filaments suberect, 10-27 $\mu$ in diam., composed of 15-60 cells in a series, monosiphonous when young and throughout life in lower part, but often gradualllly becoming bisiphonous by longitudinal division in upper parts; cells usually slightly shorter than broad, rarely as long as broad, mostly quadrate with rounded angles, 10-22 × 8-15 $\mu$; cell wall about 3-4 $\mu$ thick, gelatinous especially in bisiphonous portions; chromatophore star-shaped with a large central pyrenoid; spore-mother cells crescent-shaped; monosporangia ovate, 6-8 X 5-7 $\mu$ in upper part of the frond. Colour of the frond purplish red.

## *Erythrotrichia reflexa* (CROUAN) THURET

Fig. 9.

HAMEL, Floridées de France (1924) p. 288, fig. 1, 4; ROSENVINGE, Mar. Alg. Denmark, Pt. 1 (1931) p. 613, figs. 611-613; DANGEARD, Sur quel. *Erythrotrichia* et *Erythrocladia* (1932) p. 146, fig. 2; LEVRING, Zur Kenntn. Algenf. norwegischen Westküste (1937) p. 79; FELDMANN, Alg. Mar. de la Côtes des Alberès *Rhodophyc.*, IV (1939) p. 251; TANAKA, The Japanese Species of Protoflorideae (1944) p. 87, Text-fig. 9-10, Species of *Erythrotrichia* from Japan (1) (1951) p. 99.

*Bangia reflexa* CROUAN, Alg. Mar. Finistère, III (1852) n. 394; HAUCK, Meeresalg. Deutsch. u. Oester. (1884) p. 22.

*Porphyra reflexa* CROUAN, Florule du Finistère (1867) p. 132, pl. 10, fig. 73.

Japanese name. *Yumigata-hosinoobi.*

Hab. Oshoro, Muroran and Suttu, Hokkaido; Asamusi and Fukaura, Mutu Prov.

Distrib. Norway; Denmark; Mediterranean Sea.

Frond filamentous, minute, epiphytic, purplish red, solitary or somewhat caespitose, attaining a length of 1-3 mm and a maximum width 18-70 $\mu$, tapering very gradually to the base and a little gradually to the apex, monosiphonous when young, but becoming quadrasiphonous eventually in the outer portion by two successive longitudinal cell divisions, slightly curved, attached to the other algae by means of a basal cell; cells of the filaments usually quadrate with rounded angles, ca. 10-20 $\mu$ in diam., slightly longer than the diameter, containing a star-shaped chromatophore with a central pyrenoid and long, simple or dichotomously branched arms bent along the valuted outside of the cells; monosporangia cut off by longitudinal or somewhat oblique walls from the cells at the polysiphonous portion of the frond; monospore usually spherical or ovate, ca. 15 $\mu$ in diameter; carpogonia forming immediate transformation of vegetative cells, constricted, 30-60 $\mu$ in diameter, darkish purple, cystocarps of about 4-8 carpospores; antheridia unknown.

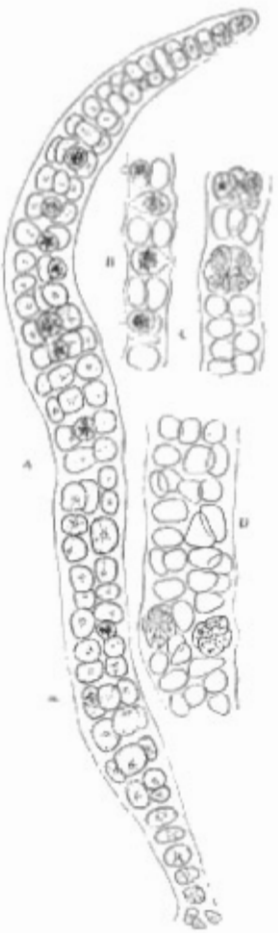


Fig. 9. *Erythrotrichia reflexa* (CROUAN) HAMEL.
A: Mature plant with monosporangia. m: monosporangium. ×210.
B: A part of female filament with fertilization tübes. ×210.
C-D: A part of female filament with cystocarps. ×210.

## *Subgenus Parietaliplastida* TANAKA

## *Erythrotrichia parietalis* spec. nov.

Text-fig. 10.

Frons epiphytica, caespitosa vel solitaria, minuta ad 2 mm alta; cellula basali singula lineali-elongata et gracilenta, raro dichotoma, in cortice hospitis penetraliter immersa; filamentis suberectis, diam. 15–24 $\mu$, uniseriatis, in parte superiore raro biseriatis; cellulis optica quadrato-orbicularibus, 6 - 12 × 8 - 22 $\mu$; chromatophoris parietali-laminatis, unum pyrenoide magnum centrali non ostendentibus, monosporangiis ovatis vel globosis, ca. 12 $\mu$ in diam., in parte superiore filamentorum evolutis; sporocarpiis e transformatione immediata cellularum vegetativarum formantibus, in plerumque 2 carpospores divisis; colore fusco-purpureo.

Japanese name. *Itoribon.* (*n.n.*)

Hab. Takamatu, Hyūga Prov. Growing on *Grateloupia filicina* (WULF.) AG.

Frond epiphytic, solitary or caespitose, usually up to 2 mm in length, lowermost basal cells usually linear-elongate and slender, often branched, penetrating vertically through the cortical tissue of the host plant; filaments suberect, 15-24 $\mu$ in diam., usually monosiphonous when young and throughout life in lower part, but rarely becoming bisiphonous by longitudinal division in upper parts; cells usually slightly shorter than broad, rarely as long as broad, mostly quadrate with rounded angles, 6 - 12 × 8 - 22 $\mu$; cell wall rather thin; but gelatinous especially in the lowest basal portion of the frond; chromatophore parietal-laminate, without central pyrenoid; monosporangia spherical or ovate, about 12 $\mu$ in diam., in upper part of the frond; cystocarps producing a hyaline protuberance in the surface of the frond, fertilized carpogonia of almost two carpospores; colour of the frond purplish red.

The present species was found growing on *Grateloupia filicina*, forming more or less small tufts. This plant is microscopic, but its presence may be recognized with the naked eye, since it gives the host a reddish mottled appear-

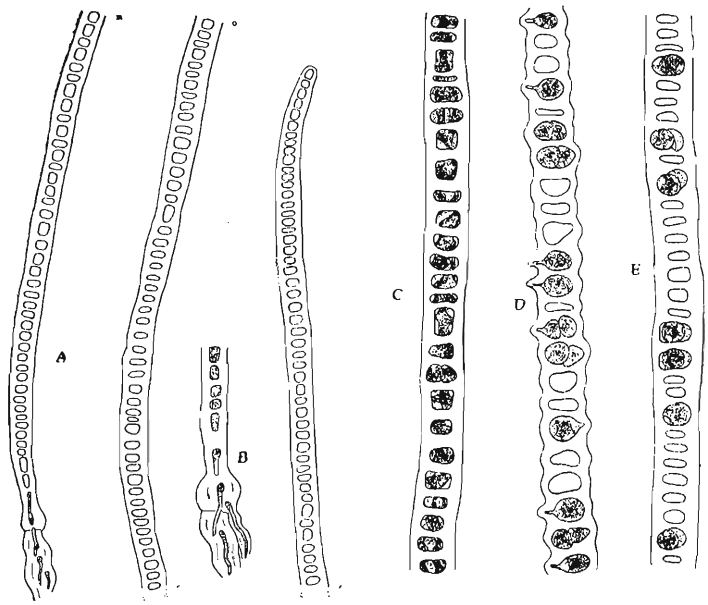



Fig. 10. *Erythrotrichia parietalis* TANAKA. A: Habit of the plant. ×200. B: Lower part of the frond. × 300. C: Upper part of the filament. × 300. D: A part of a female filamant with fertilization tubes. × 300. E: A part of the filament with monosporangia. ×300.

ance. The lower most cell of the filament is slender and has rather thick wall. In the basal structure, this plant is some related to *E. biseriata*, but this is quite different from it in other respects. At first, the filaments consist of a single row of cells. The cells of the upper part of the filaments are rarely divided by longitudinal walls into two cells.

In general appearance, the present species closely resembles to *E. carnea*, but the shape of chromatophore of this plant is apparently different from that of *E. carnea*. The chromatophore of vegetative cells is not stellate, unlike the case of *E. carnea*, *E. biseriata*, etc., but keeps more or less parietal-laminate condition, without central pyrenoid.

## *Erythrotrichia incrassata* TANAKA

The Japanese Species of Protoflorideae (1944) p. 89, figs. 11–12.

Japanese name. *Isoribon.*

Hab. Suttu, Hokkaidō.

Distrib. Endemic.

Frond epiphytic, caespitose, mostly about 5 mm high, attached to the substratum by somewhat expanded basal filaments; basal creeping filaments irregularly ramified and more or less fused together into a basal parenchymatous disc, basal disc unistratose, cells of the basal disc usually subquadrate, 12–25 $\mu$ in diam.; erect filaments monosiphonous when young and throughout life in the lower parts, soon becoming polysiphonous above by longitudinal or vertical

division of the cells, remaining often two layers of cells; ribbon-shaped regions of the frond attain a width of 75–150 $\mu$, and a thickness of 20–35 $\mu$; cells of the erect filaments mostly quadrate with rounded angles, 15–27 × 12–20 $\mu$, but at times slightly longer or shorter than the diameter, arranged more or less irregularly in longitudinal and cross rows; cell wall very thick, about 4–6 $\mu$ thick; chromatophore lamina shaped nearly filling the cell, with an obscure central pyrenoid; spore mother cell often crescent-shaped; monosporangia ovate, 8–12 $\mu$ in diameter, on the erect filaments of the frond. Colour of the frond purplish red.

The present species was found upon *Grateloupia filicina* and *Sargassum* sp. associated with *Rhodochorton* sp. The primary basal filaments were monosiphonous, but soon ramified radiating in all directions, and the filaments then fuse together in the central part. Thus there is formed an irregular disc. A great number of erect filaments are given off from the peripheral parts. At first the erect filaments are monosiphonous, then the breadth and thickness gradually increase upwards, longitudinal and transverse divisions begining at the upper part of the filaments. The number of vertical cell rows in surface view may amount to eight in the broadest part of the frond. The transverse sections of the erect filaments in different stages show almost two layers of cells. Among abundant materials at hand some ramified specimens were rarely observed. The monosporangia occur only upon the ribbon-shaped erect frond, and not in the basal filaments. The specimens have monosporangia in the month of April.

In general appearace, the present species closely resembles *E. japonica* TOKIDA, but the development and building up the basal disc of this species is apparently different from those of *E. japonica*. In *E. japonica* the basal part of the thallus is a small suborbicular, and polystromatic disc. It has a continous margin, showing a marginal growth and not a free end. But we are unable to find such habits in our plants as mentioned above. Furthermore *E. incrassata* differs from *E. japonica* by its thicker thallus and its somewhat irregular arrangement of the cells.

## *Erythrotrichia japonica* TOKIDA

Figs. 11 – 12.

Phycolog. Observ., IV (1938) p. 218, fig. 5.

*Bangia ciliaris* (non CARM.) YENDO, Notes on Algae new to Japan, IV (1916) p. 51; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 377.

Japanese name. *Hosino-obi*.

Hab. Cape Inubō, Boshu Prov.; Abu, Awa Prov.; Hayama, Sagami Prov.; Esasi and Suttu, Hokkaidō.

Distrib. Endemic.

Frond erect, caespitose, epiphytic, attached to the substratum by means of a well developed basal disc, basal disc suborbicular or oblong, attaining often a diameter of about 150 $\mu$, showing no free end at the marginal portions, monostromatic when young, but older ones having a continous margin and becoming irregularly distromatic in the central parts; marginal cells of the basal disc at first cuneate and often emerginate or furcate, becoming mostly oblong

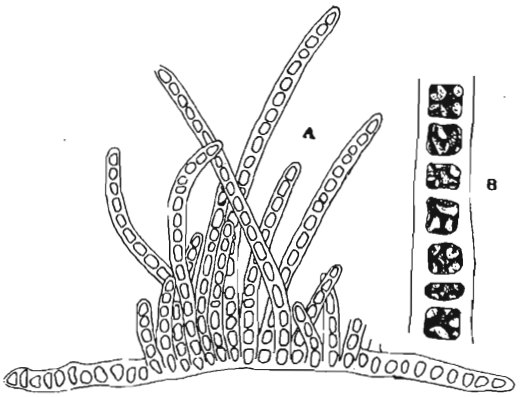



Fig. 11. *Erythrotrichia japonica* TOKIDA.
A: Habit of sketch of young fronds. × 110.
B: A part of the single row of cells. × 400.

or linear-oblong and 12–32 × 6–12 $\mu$, those of central portions irregularly quadrate, ovoid or suborbicular in surface view, about 18 $\mu$ in diameter; erect frond ribbon-shaped, attaining a length of ca. 3 cm long, and a maximum width of about 150 $\mu$, 8–16 cells in width, tapering very gradually to the base and a little less gradually to the apex; cells of the erect filaments at first quadrate-oblong or discoid, finally ovoid and mostly ca. 8–15 $\mu$ in diameter; chromatophore more or less stellate lamina shaped, nearly filling the cell, with an obscure central pyrenoid; monosporangia ovoid forming either on the basal disc or on the erect frond, up to 10–15 $\mu$ in diameter; colour of the frond purplish red.

The present species was found growing on *Hizikia fusiformis* (HARV.) OKAMURA and *Sargassum* sp. The monosporangia are produced either upon the basal disc or upon erect frond. In general appearance, this species is most nearly related to *Erythrotrichia incrassata* TANAKA. In arrangement of the cells as well as the size and the location of monosporangia, shape of monospore, *E. japonica* shows a great similarity to *E. polymorpha* HOWE. But as already described by TOKIDA, the frond of *E. japonica* TOKIDA is somewhat greater in diameter as well as in the number of cells of pedicels as composed with those of *E. polymorpha* HOWE. Furthermore, the basal disc of the species is smaller than that of *E. polymorpha*. The materials from Esasi and Suttu, Hokkaido have more or less larger frond and well developed basal disc than those of cotype specimens from Inubō, Bōshu Prov., but they are not so sufficiently different as to justify their separation as the distinct species.

## *Subfamily* 2. *Bangieae*

### *Bangia* LYNGBYE, 1819

Frond filamentous, erect, simple, purplish red or darkish red, cylindrical or irregularly constricted, attached to the substratum by means of rhizines, which grow downwards from the lower cells in the common outer-wall; filaments at first consisting of a single row of cells, later becoming polysiphonous by long-

itudinal as well as transverse divisions of the cells; chromatophore stellate, with a central pyrenoid; monosporangia formed by the direct transformation of vegetative cells; dioecious or monoecious; spermatangia formed from vegetative cells by repeated cell-divisions; carpogonia formed by the immediate transformation of vegetative cells; cystocarp producing more than eight carpospores.

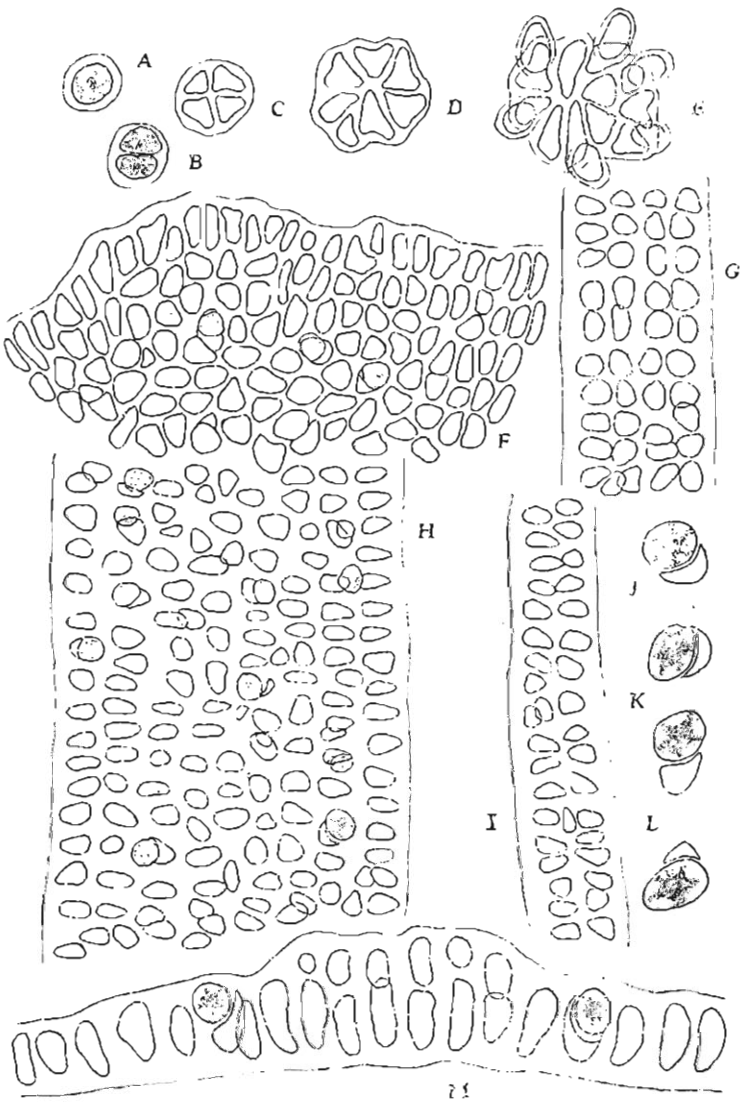



Fig. 12. *Erythrotrichia japonica* TOKIDA. A-D: The basal disc in various stages of development. ×420. E: Small disc bearing the first cells of the erect filament. ×420. F: Portion of well developed basal disc bearing spores. ×420. G, I: Portion of an erect frond, showing the arrangement of the cells. ×420. J-L: Four spores formed in the disc. ×550. M: Transverse section of the basal disc, bearing spores. ×420.

## Key to the species

I. Marine algae.
  1) Frond large and reaches a height of 10 cm. ..... *B. fusco-purpurea* (DILLW.) LYN.
  2) Frond slender and not reaches a height of 10 cm.
    a) Frond epiphytic and polysiphonous ..... *B. gloiopeltidicola* TANAKA
    b) Frond growing on rock, usually consisting of a single row of cells ..... *B. Yamadai* TANAKA
II. Freshwater algae ..... *B. atropurpurea* (ROTH) C. AG.

## *Bangia fusco-purpurea* (DILLWYN) LYNGBYE

PL. II, 2.

Hydrophyt. Dan. (1819) p. 83, tab. 24, C; HARVEY, Phyc. Brit. (1846–'51) pl. 96; KUETZING, Phycologia Generalis (1843) p. 249, Spec. Alg. (1849) p. 360, Tab. Phyc., 3 (1853) t. 29, 6; REINKE, Uber die Geschlechtpf. von *Bangia fusco-purpurea* (1878) p. 274; LE JOLIS, Liste Alg. marines Cherbourg (1880) p. 102; BERTHOLD, Fauna und Flora des Golfes von Neapel (1992) p. 23, tab. 1, figs. 12–14; KJELLMAN, Alg. of the Arctic Sea (1883) p. 192; HAUCK, Meeresalg. Deutschlands und Oesterreiches (1885) p. 22, fig. 1, c–e; ROSENVINGE, Gröenlands Havalger (1893) p. 831, Algues d'marines du Gröenland (1894) p. 44, Mar. Alg. Denmark, 1 (1901) p. 56, figs. 1–3; KYLIN, Stud. uber die Algenflora des Schwedischen Westküste (1907) p. 107, Über die Entwicklung. der *Bangiaceen* (1921), Mar. Alg. in the Vicinity of Biological Station at Friday Harbor, Wash. (1925) p. 6, Anatomie der Rhodophyc. (1937) p. 45, fig. 19, F.–N.; COLLINS and HERVEY, Alg of Bermuda (1917) p. 94; HOWE, in BRITTON's Flora of Bermuda (1918) p. 510; OKAMURA, Icones Japanese Algae, 4 no. 5 (1952) p. 87, pl. 171, figs. 6–12, Mar. Alg. Mutu Bay (1927) p. 9; HAMEL, Floridèes de France, Bangiales (1925) p. 35; LAKOWITZ, Algenflora gesamt. Ostsee (1929) p. 296, fig. 402–403; NEWTON, Handbook British Seaweeds (1931) p. 238; INAGAKI, Mar. Red Alg. Osyoro Bay, Hokkaidō and its Adjacent Waters (in Japanese, 1933) p. 11, figs. 3–4; SINOVA, Algues Novoirossijsk Mer Noire leur Utilisation (1935) p. 80, Les Alg. de la mer Japon (1940) p.44, Alg. Commander Islands (1940) p. 203; TSENG, Mar. Alg. from Amoy (1936) p. 33; TAKAMATU, Mar. Alg. Kinkwazan Isl. (1936) p. 56, Mar. Alg. Sanriku Coast, Northeastern Honshu, Japan (1938) p. 102, fig. XIV, fig. 2; LEVRING, Algenflora norwegischen Westküste (1937) p. 89, Stud. Algenveget. Blekinge, Suedschweden (1940) p. 72; TOKIDA, On Some edible seaweeds utilized among a native race "Ami" of Formosa (in Japanese, 1939) p. 1550, fig. 3; TAYLOR, Mar. Alg. Northeastern Coast North America (1939) p. 218, pl. 4, figs. 10–12; FELDMANN, Alg. Mar. de la cotes des Alberes, IV, *Rhodophyc.* (1939) p. 247; TANAKA, On Species of *Bangia* from Japan (1950) p. 167, fig. 3.

*Bangia atropurpurea f. fuscopurpurea* (DILLWYN) J. AGARDH, Till. Alg. Systematik (1882) p. 37; SETCHELL and GARDNER, Alg. Northeastern Coast North America (1903) p. 288.

*Conferva fuscopurpurae* DILLWYN, Brit. Conferva (1809) p. 92.

*Bangia atropurpurea* (ROTH) AGARDH *f. fuscopurpurea* (DILLWYN) LYNGBYE; DE TONI, Syll. Alg., IV (1897) p. 10.

Japanese name. *Usikenori.*

Hab. Commonly distributed in the waters of both the Pacific and Japan Sea, ranging from Formosa to Kurile Islands.

Distrib. Widely distributed in the World.

Frond erect, simple, filamentous, caespitose, 3–15 cm high, 25–75 $\mu$ broad, fastened to the substratum by means of rhizines which grow downwards from the lower cells in the common outer cell wall, at first filaments consisting of a single row of cells, soon becoming polysiphonous above by longitudinal divisions of the cells, later cell dividing the articles into wedge-shaped cells usually quagrate with rounded-angles in monosiphonous part, 15–30 $\mu$ thick, usually about as long as broad or somewhat longer, up to 2–4 times as long, but sometimes as broad as long; chromatophore star-shaped with a cenral pyrenoid; dioecious; male plant yellowish red or light red, cylindrical about 95 $\mu$ broad; female frond darkish red or purplish red, cylindrical and to 100 $\mu$ in width, more or less constricted, arranged several tiers of four each in surface view; colour of the frond purplish red or darkish red, but sometimes yellowish red.

## *Bangia gloiopeltidicola* TANAKA

On Species of *Bangia* from Japan (1950) p. 163, figs. 1-2.

Japanese name. *Funorino-usige.*

Hab. Awano, Nagato Prov.; Takamatu, Sanuki Prov.; Kominato, Bōshu Prov.; Oshoro and Suttu, Hokkaidō.

Distrib. Endemic.

Frond very minute, simple, caespitose, flaccid, epiphytic, growing on the frond of *Gloiopeltis furcata* (FOST. et RUPR.) J. AG., up to 1.5 cm high, attached to the substratum by means of intramatrical rhizoides springing from the lower parts of the filaments; filaments at first composed of a single row of cells which are most quadrate with rounded angles, 10–20 $\mu$ thick, 1–3 times as long as broad, later becoming polysiphonous by transverse divisions, ca. 50 $\mu$ thick, somewhat cuneate and usually arranged radial in transverse sections; chromatophore star-shaped and a central pyrenoid within it; species dioecious; asexual reproduction unknown; antheridia formed vegetative cells by repeated divisions, about 38 $\mu$ thick, yellowish red or light purple; antherozoids in several tiers of four each; carpogonia formed by the immediate transformation of vegetative cells, more or less constricted, ca. 58 $\mu$ thick, cystocarps consisting of more than 16 carpospores; colour of the frond purplish red or somewhat yellowish red.

## *Bangia Yamadai* TANAKA

PL. II, 1, and Fig. 13.

The Japanese Species of Protoflorideae (1944) p. 84, Text-figs. 6–7, The species of *Bangia* from Japan (1950) p. 168.

Japanese name. *Hime-usikenori.*

Hab. Bōkotō, Formosa.

Distrib. Endemic.

Frond very small, caespitose, 1.5–2 cm high, attached to the substratum by means of intramatrical rhizoids springing from the lower parts of the filaments; filaments cylindrical, erect, simple, almost uniseriate, but rarely pluriseriate, 15–26 $\mu$ diam., gradually decreasing to about 12 $\mu$ at the upper end; cells quadrate, usually as long as broad or somewhat shorter, rarely $1\frac{1}{2}$–2 times as long, containing stellate chromatophore and a central pyrenoid within it; cell wall very thick, about 5–7 $\mu$ thick, especially thickened in the lower parts of the filaments; species dioecious; antheridia formed from vegetative cells by repeated divisions, about 30 $\mu$ thick, more or less constricted, yellowish red, antherozoids irregularly arranged in four tiers of four each, carpogonia formed by the inmediate trnsformation of vegetative cells, constricted, 30–48 $\mu$ thick, darkish purple, cystocarps of about 8–16 carpospores; colour of the frond purplish red.

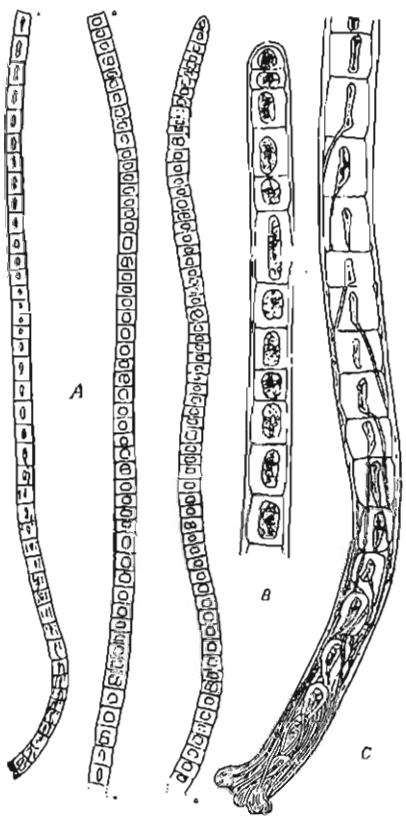



Fig. 13. *Bangia Yamadai* TANAKA.

A: Habit of a plant. × 110.

B: Apex of a filament. × 320.

C: Base of a filament, showing rhizoidal filaments. × 320.

The present species was found growing upon rocks, forming more or less small tufts. The plant is at first a filaments consisting of a single row of cells, and fixed at the base by rhizines which grow downwards from the lower cells in the common outer wall. But later some cells of the filaments divided into two or rarely four cells by longitudinal divisions. This plant was collected by Prof. Y. YAMADA in the month of March, 1941, and in a fructifying condition.

This species is most closely related to *Bangia tenuis* GARDNER, but the former is a little larger and thicker than the latter. Furthermore, the substratum of the plant of *Bangia Yamadai* differs from that of *B. tenuis* GARDNER. This speciesm, also, resembles somewhat *B. compacta* ZANARDINI, but differs from the latter in size and shape of the cells.

## *Bangia atropurpurea* (ROTH) C. AGARDH

Icon. Alg. Europ. (1828) pl. 25; KUETZING, Spec. Alg. (1849) p. 361, Tab. Phyc., 3 (1853) pl. 30, 3; RABENHORST, Fl. Eur. Alg., 3 (1864) p. 398; J. AGARDH, Till. Algern. Syst., 7 (1883) p. 36, pl. 1, figs. 28–33; Wolle, Freshwater Alg. U. S. (1887) p. 55, pl. 67, figs. 9–11; DE TONI, Syll. Alg., 4, sec. 1 (1897) p. 10; HAMEL, Floridées de France (1925) p. 447 fig. IIId; PASCHER and SCHILLER in PASCHER's Suesswasserfl., 11 (1925) p. 158. fig. 12; SCHREIFFEL, *Bangia atropurpurea* (ROTH) AGARDH in Balaton (Plattensee) (1934); WOLOSZYNSKA, *Bangia atropurpurea* (ROTH) Ag. in Polen (1935); OKADA, Note on *Bangia atropurpurea* (ROTH) AG. found in Japan (in Japanese, 1944) p. 201, fig. 1; TANAKA, The species of *Bangia* from Japan (1950) p. 168.

*Conferva atropurpurea* ROTH, Cat. Bot., III (1806) p. 298, pl. 6; DILLWYN, Brit. Conferva (1809) p. 103.

Japanese name. *Tani-usikenori*.

Hab. Amehatake River, Minamikomagun, Yamanasi Prefecture.

Distrib. Europe; America; Japan.

Frond erect, filamentous, 2–4.5 cm high, 20–98 $\mu$, thick, attached to the substratum by means of the rhizoidal filaments which grow downwards from the lower cells in the common outer-wall; monosiphonous when young, later becoming polysiphonous, containing a star-shaped chromatophore and a central pyrenoid within it; cells of the monosiphonous filaments usually quadrate to slightly longer or shorter, 8–20 $\mu$ long and 18–20 $\mu$ thick; mature fructifying filaments usually 6–8 cell-rows in width, ca. 35–50 $\mu$ thick; monospore formed by the direct transformation of vegetative cells; sexual organ unknown; colour of the frond purplish red or purplish brown.

## *Porphyra* C AGARDH, 1824

Frond membranaceous, somewhat gelatinous, expanding above into a narrow or a broad soft slippery blade, monostoromatic or distromatic, attached to the substratum by means of small disc; each cell containing a star-shaped chromatophore and a central pyrenoid within it; monoecious or dioecious; asexual reproduction by monospores involving large continuous area of the frond; sexual reproduction by antheridia and carpogonia; antheridia produced by cell division and conversion of portion of the frond into spermatangial cells; carpogonia

produced from vegetative cells by formation of a short trichogyne extending to the surface of the gelatinous membrane of the thallus.

## Key to the subgenera and species

I. Frond generally monostoromatic ····· Subgenus *Euporphyra* ROSENV.

1) Microscopic spinulate processes on the marginal portion of the frond present.

a) monoecious.

i) Formula of division of sporocarps and antheridia;

♀ 16 $\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$ and ♂ 128 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$

····· *P. Okamurai* UEDA.

ii) ♀ 32 $\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$ and ♂ 64 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{4}\right)$

····· *P. suborbiculata* KJELLMAN.

iii) ♀ 32 $\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$ and ♂ 128 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$

····· *P. crispata* KJELLM.

b) dioecious ····· *P. dentata* KJELLM.

2) Microscopic spinulate processes on the marginal portion of the frond absent.

a) monoecious.

i) Formula of division of sporocarps and antheridia;

♀ 16 $\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$ and ♂ 64 $\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{8}\right)$

····· *P. yezoensis* UEDA.

ii) ♀ 16 $\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$ and ♂ 64 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$

····· *P. seriata* KJELLM.

iii) ♀ 32 $\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$ and ♂ 128 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$

····· *P. ochotensis* NAGAI.

b) dioecious.

i) Formula of divisions of sporocarps and antheridia;

♀ 8 $\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{2}\right)$ and ♂ 128 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$

····· *P. angusta* OKAM. et UEDA.

ii) ♀ 32 $\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$ anb ♂ 128 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$

····· *P. pseudolinearis* UEDA.

c) dioecious or andro-dioecious.

i) Formula of division of sporocarps and antheridia;

♀ 8 $\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{2}\right)$ and ♂ 64 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{4}\right)$

····· *P. tenera* KJELLM.

ii) ♀ $16\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$ or ♂ $32\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$ and ♂ $128\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$ ……*P. crassa* UEDA,

iii) ♀ $32\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$ and ♂ $128\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$ ……*P. umbilicalis* (L.) J. AG.

II. Frond composing of mostly one layer of cell, containing two plastids and in portion often distromatic……Subgenus *Diplastida* TOKIDA.

Formula of division of sporocarps and antheridia;

♀ $8\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{2}\right)$ and ♂ $64\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{4}\right)$ ……*P. Onoi* UEDA.

III. Frond generally distromatic…… Subgenus *Diploderma* (KJELLM.) ROSENVINGE.

a) monoecious.

i) Formula of division of sporocarps and antheridia;

♀ $4\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{1}\right)$ and ♂ $128\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$ ……*P. Tasa* (YENDO) UEDA.

ii) ♀ $16\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$ and ♂ $64\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{4}\right)$ ……*P. bulbopes* (YENDO) OKAM.

iii) ♀ $16\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$ and ♂ $64\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{4}\right)$ ……*P. variegata* (KJELLM.) HUS.

b) dioecious or monoecious.

Formula of division of sporocarps and antheridia;

♀ $8\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{2}\right)$ and ♂ $16\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$ or ♂ $64\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{4}\right)$ ……*P. amplissima* (KJELLM.) SETCH et HUS.

## *Porphyra Okamurai* UEDA

Plate III, 1 and Figs. 14–15.

*Porphyra* of Japan (in Japanese, 1932) p. 14, pl. 1, figs. 9–10, pl. 2, figs. 1–6, pl. 12, figs. 1–2; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 381; TAKAMATU, Mar. Alg. Tsugaru Strait, Northeastern Honshu, Japan (1938) p. 30.

Japanese name. *Kuronori*.

Hab. Oshoro and Suttu, Hokkaidō; Asamusi, Mutu Bay; Widely distributed in Japan Sea of Honshū.

Distrib. Endemic.

Frond membranaceous, monostoromatic, ovate or oblong-ovate, often lanceolate, with a little or not undulate margin, 5–15 cm long, 1.5–5 cm wide, 30–45 $\mu$ thick, stipitate, with rounded cuneate or cordate base; microscopic spinulate processes well-developed; vegetative cells usually ellipsoidal, somewhat irregularly arranged, 16–17 × 20–25 $\mu$ in diameter in surface view, 18 × 27 $\mu$ high and 20 $\mu$ in cross section; surface jelly more or less thick; lower most cells issuing rhizoidal filaments usually oblong-capitate; asexual plant always minute, ca. 0.5–1 cm high, monospores spherical, about 18 $\mu$ in diameter, producing on the marginal portion of the frond; each cells containing a stellate chromatophore and a central pyrenoid within it; monoecious; sporocarps and antheridia in irregular linear patches at the marginal portion; antheridia containing 128 antherozoids, each after having divided according to the formula, 128 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$, sporocarp containing 16 carpospores, each after having divided according to the formula, 16 $\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$; colour of the frond light purplish red or pale violet.

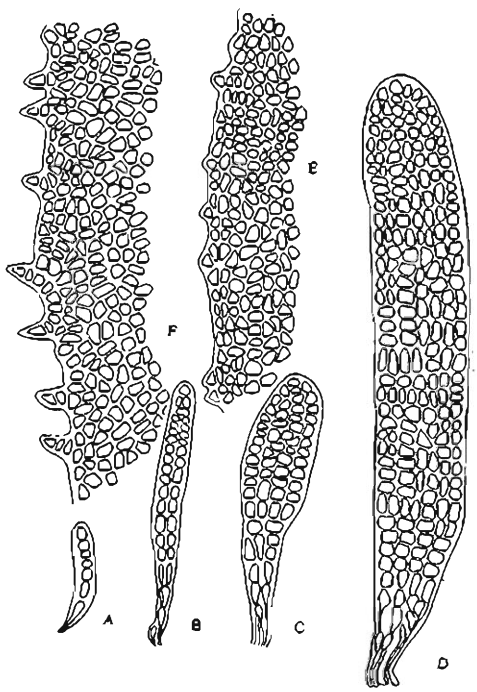



Fig. 14. *Porphyra Okamuraí* UEDA.
A-D: Various stages of young plants. × 190.
E-F: Marginal portions of the fronds. × 190.

The present species grows on rocks in the upper littoral zones. It is an annual, only to be seen in the early winter months. The plant is, as already

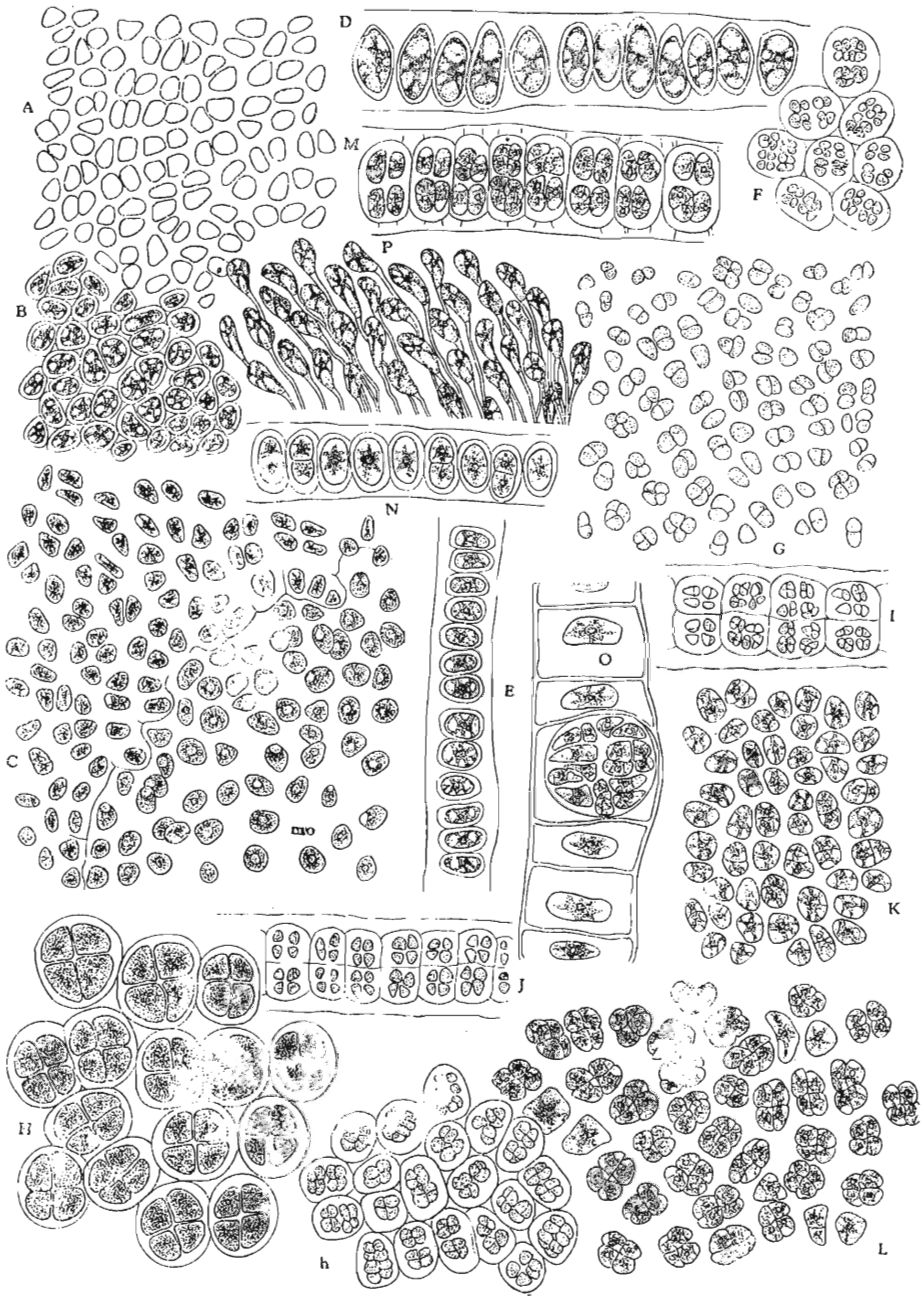



Fig. 15. *Porphyra Okamurai* UEDA. A-B: Surface view of vegetative frond. ×320. C: Marginal portion of the frond bearing monopores. mo: monospores, ×220. D-E: Section of vegetative frond. ×320. F-H and h: Surface view of antheridial portion. E. G. H: ×320. H: ×460. I-J: Section of anthridial portion. ×320. K-L: Surface view of cystocarpic portion. ×320. M-N: Section of cystocarpic portion. ×320. O: Section of the mature cystocarpic portion (abnormal division). ×460. P: Lower most cells of the frond, with rhizoidal filaments ×200.

mentioned and figured by UEDA, fairly constant in shape, varying from ovate in the young plants to oblong-ovate in the older ones. It is but seldom linear-lanceolate, and the margin is slightly undulate. The microscopic spinulate processes on the marginal parts of the fronds are numerous and well developed. The base is decidedly stipitate. The frond is always monostoromatic. No indications of the distromatic nature have even found. Each cell contains a stellate chromatophore with short laminate arms radiating in all directions, and a central pyrenoid within it.

The asexual plant is very small and usually lanceolate in shape. It attains about 1 cm in height and is characterized by the constancy of their minute size. In the late autumn, the monosporangia formed by a gradual transformation of the vegetative cells at the marginal portion of the frond. The monospores are in fully developed states nearly globular, about 18 $\mu$ in diameter: they have a more or less granular contents than vegetative cells and often show a little parietal chromatophores. The frond is monoecious. At first antheridia are only found being limited at the tip and the marginal portion. Inside this margin, the sporocarps and antheridia are intermixed, the antheridia usually forming irregularly elongated, yellowish patches among the dark red sporocarps.

Each sporocarp contains sixteen carpospores. These mature carpospores are divided cruciately in surface view of the frond, dividing each then into four parts by the divisions parallel to the surface.

The antheridium mother cells are at first divided by cruciate division perpendicular to the surface of the frond, followed continuously three times by the parallel and the second perpndicular divisions. An antheridium contains 128 antherozoids, arranged in four tiers of four each in surface view.

The specimens at hand, accord very well with the description of the present species in the essential characters. *P. Okamurai* UEDA is most nearly allied to *P. suborbiculata* KJELLMAN, but it differs from the latter by the shape of the frond and the formula of the divisions of carpospores and antheridia. Concerning to distribution, it appears to be limited to the Japan Sea, occuring from Iwami Prov. to southern Hokkaido.

## *Porphyra suborbiculata* KJELLMAN

PL. III, 2–4. and Fig. 16.

Japan. Art. af Slägt. Porphyra (1897) p. 10, t. 1, figs. 1–3, t. 2, fig. 5–9, t. 7, figs. 4–7: DE TONI, Syll. Alg., IV (1897) p. 15; OKAMURA, Nippon Sorui Meii (in Japanese, 1916) p. 6, On the Alg. from Island Hatidyō (1930) p. 93, Nippon Kaisosi (in Japanese, 1936) p. 382, fig. 185; UEDA, l. c., p. 15, p. 1, figs. 11–12, pl. II, figs. 4–11, pl. XII, figs. 3–4; TSENG, Econ. Seaw. Amoy (1936) p. 34; SEGAWA, On Mar. Susaki, Prov. Izu and its Vicinity (1935) p. 71.

*P. leucosticta* (non THURET) YENOO, Notes on Alg. New to Japan, IV (1916) p. 52.

*P. areolata* KJELLMAN, Japan. Art. af Slägt. Porphyra (1897) p. 8, t. 2, figs. 1–4, t. 5, figs. 1–3.

Japanese name. *Maruba-amanori*,

Hab. Ryûkyû; Kyûsyû; Hatidyô Islands; Corea; Widely distributed on the Pacific coast of Honshû.

Distrib. Japan; China.

Frond membranaceous, ovate or reniform, 3–10 cm high, 3–7 cm broad, monostoromatic, with a little or not undulate margin, base cordate or umbilicate, stipitate; microscopic spinulate processes at the marginal portion abundunt; colour light pink or purplish red; vegetative parts of the frond 30–48 $\mu$ thick, surface jelly more or less thick; vegetative cells, in surface view angular with

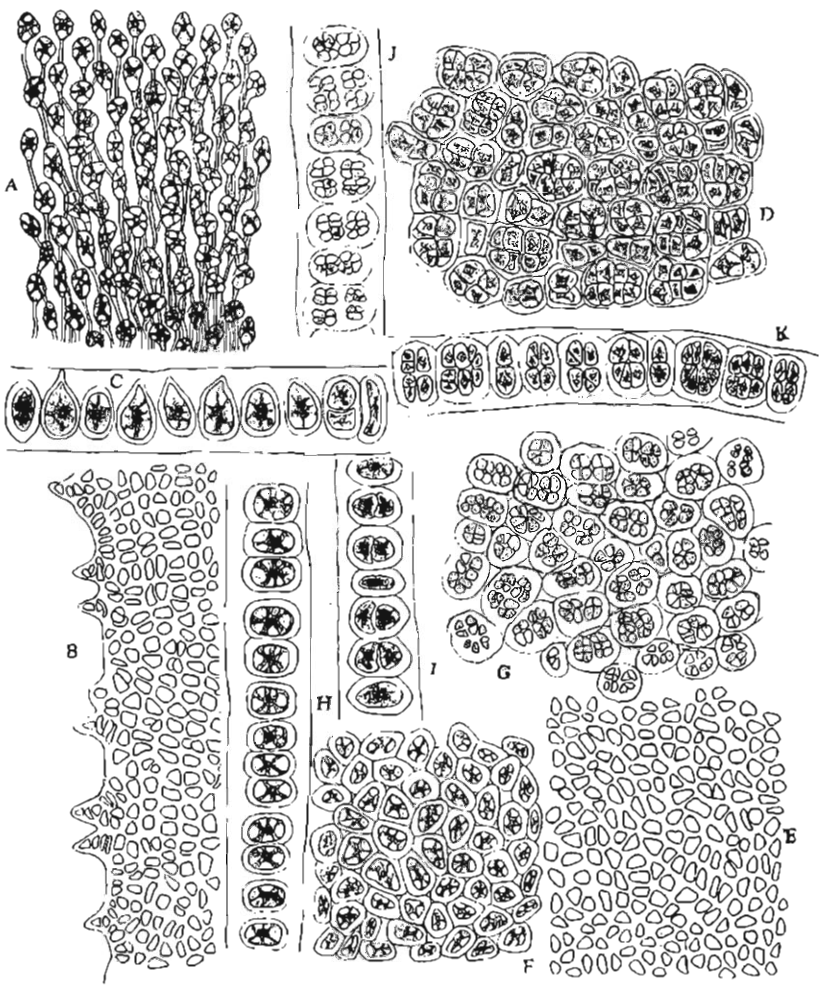



Fig. 16. *Porphyra suborbiculata* KJELLMAN A: Lower most cells of the frond with rhizoidal filaments. × 190. B: Marginal portion of the frond, showing microscopic spinulate processes. × 190. C. I. and K: Section of cystocarpic portion. × 320. D: Surface view of cystocarpic portion. × 320. E-F: Surface view of vegetative frond. E: × 320. F: × 320. G: Surface view of antheridial portion. × 320. H: Section of vegetative frond. × 320. J: Section of antheridial portion. × 320.

rounded corners, somewhat regularly arranged, in cross section quadrate with rounded angles, usually slightly higher than broad; each cell containing a star-shaped chromatophore with a few short arms radiating in all directions, and with a central pyrenoid; monoecious; sporocarps and antheridia in irregular splashed patches, arranged at the marginal region of the frond; sporocarpic parts of the frond 40-50 $\mu$ thick, 32 carpospores in each cystcarp according to the formula, $32\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$; antheridial part of the frond about 45 $\mu$ thick, 64 antherozoids in each antheridium, according to the formula, $64\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{4}\right)$.

The present species grows on rocks and other substratum in the upper littoral belt on the open coast. The plant is found in the month of October to May. The shape of the frond of *P. suborbiculata* KJELLAN is, as a rule, ovate, with a slightly undulate margin and a cordate base. But frequently more or less expanded broadly laciniate fronds are met with, which possess an umbilicate base. Between these two extreme forms which the frond may assume, numerous transition are found.

The plant is attached at the base by rhizines, which grows downwards from the lower cells in the common outer-wall. The thickness of the fronds varies from 30 $\mu$ to 47 $\mu$ being often due to a great amount of jelly than to a difference in the height of the cells. The microscopic spinulate processes are very well developed at the marginal part of the frond. The cells in the lower most part of the frond are usually angulate-capitate. The present species is always monoecious.

YENDO (l.c.) described that the localization of the antheridial cells in the streak-form patches within the carpogonal area is a constant and reliable character for specific distribution of *Porphyra*. The patches of sporocarps and antheridia occur here marginally side by side and usually alternating.

The cystocarpic area can be readily recognized by their deep red colour, and is sharply outlined against the yellowish coloured antheridia. The carpogonia gradually grow in size, and when they are ready for fertilization they send out distinct trichogyne. Two divisions take place first at the same time or consectively on the sporocarps. They happen cruciately with each other and perpendicularly to the surface. Subsuequent the other divisions parallel to the surface, take place two times on these segments. Each sporocarp contains 32 carpospores, arranged in two tiers of four each in cross section, and in four tiers of two each in surface view.

The antheridium mother cell, by a cruciate division perpendicular to the surface of the frond, gives rise to four antheridia. Each antheridium now undergoes a division parallel to the surface of the frond followed by another parallel division in all segments. The antheridium is now divided into sixteen parts, each of which by a cruciate division, gives rise to four antherozoids; so that the whole antheridium now consists of sixty-four antherozoids, arranged in four tiers of sixteen each.

The type specimen of *Porphyra suborbiculata* KJELLMAN is preserved in the herbarium of Botanical Museum of Upsala, Sweden. These specimens are collected by J. PETERSEN and deliniated and described by F. K. KJELLMAN in 1897.

Through the kindness of Prof. Y. YAMADA the writer has been able to examine some co-type specimen of *P. suborbiculata* KJELLMAN from Gotô Islands, Japan; these specimens are all very small in size, but matured antheridia and sporocarps are often observed.

## *forma latifolia* f. nov.

PL. III, 3.

Fronde membranacea, majore et latiore, monostoromatica, non raro in 2–5 lobata laciniata, marginibus plus minus undulatis, ad basin cordata vel umbilicata, 5–10 cm longa, 3–8 cm lata, ca. 35–48 $\mu$ crassa.

Japanese name. *Hiroha-maruba-amanori.*

Hab. Taira, Simabaru and Kazusa, Hizen Prov.; Moppo, Corea.

Distrib. Endemic.

Frond membranaceous, large and broad, monostoromatic, often laciniate into two to five lobes, with undulate margins, cordate or umbilicate at the base, 5–10 cm high, 3–8 cm broad, and 35–45 $\mu$ thick.

The present new forma is often laciniate into few lobes with very undulate margins. The largest specimens that the present writer has often observed, attained to 15 cm in length and 8 cm in breadth at its broadest part. They are rounded at the base when young, becoming later cordate or even umbilicate. In outer appearance, present forma can be distinguished at first sight from the typical form of *Porphyra suborbiculata* KJELLMAN.

## *Porphyra crispata* KJELLMAN

PL. IV, 2-3 and Fig. 17.

Jap. Arter. af Slägt. *Porphyra* (1897) p. 15, t. 1, figs. 4–5, t. 3, figs. 5–7, t. 5, fig. 15; DE TONI, Syll. Alg., IV (1897) p. 16; OKAMURA, Nippon Sorui Meii (in Japanese, 1936) p. 16, Mar. Alg. Kotoshô (1931) p. 108, Nippon Kaisosi (in Japanese, 1936) p. 382; UEDA, l.c., p. 18, pl. 1. figs. 7, 10, 13, pl. II., figs. 12–16, pl. III, figs. 1–5, pl. XIII, figs. 1–2.

Japanese name. *Tukusi-amanori.*

Hab. Formosa; Ryûkyû; Bonin Islands; Widely distributed in the southern part of Kyûsyû.

Distrib. Japan; China.

Frond ovate or reniform, caespitose, membranaceous or somewhat submembranaceous, minute, 2-5 cm high, 2--4 cm broad, light yellowish red or light russet, often lanciniate with slightly crenate margins, stipitate; base cuneate; microscopic spinulate processes always present; lower most cells projecting rhizoidal filaments strongly oblong-capitate; chromatophore stellate with a central pyrenoid within it; vegetative cells, in surface view oblong-elliptical, 15–20 $\mu$ in diameter, more or less irregularly arranged, in cross section elliptical, 55 – 60 × 20 – 27 $\mu$, about one half times as high as broad; surface jelly rather thick, about 12 $\mu$ thick; monoecious; antheridia and sporocarps formed on the marginal portion of the frond, not intermixed, sporocarps and antheridial regions separating from each other and not forming splashed patches; antheridia formed within yellowish marginal zone of the frond and not intermixed with

cystcarps, containing 128 antherozoids after having divided according to the formula, 128 $\left(\frac{a}{4}\frac{b}{4}\frac{c}{8}\right)$; sporocarps formed with purplish red region of the marginal frond, containing 32 carpospores after having divided according to the formula 32 $\left(\frac{a}{2}\frac{b}{4}\frac{c}{4}\right)$.

The present species grows on rocks in the upper part of the littoral zone. It is widely distributed in the warm sea of southern Japan. In outer appearance, it is characteristic on account of small size, somewhat roughly submembranaceous and caespitose thallus. The shape of the frond of *P. crispata*

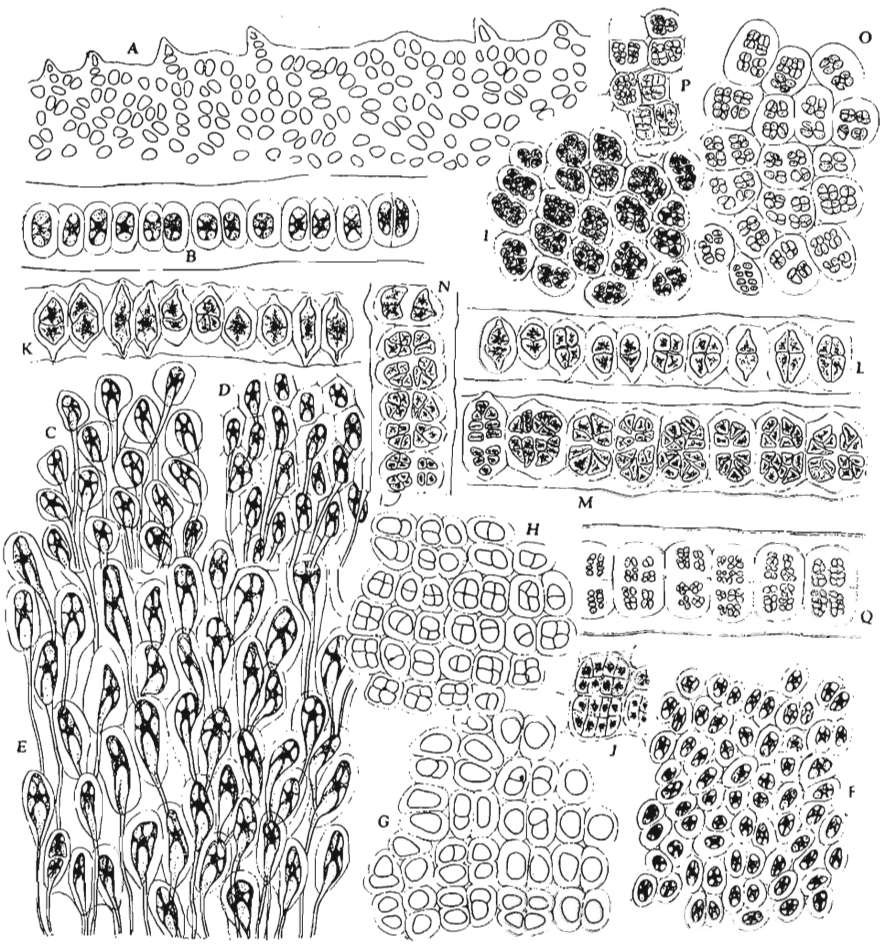



Fig. 17. *Porphyra crispata* KJELLMAN A: Marginal portion of frond. ×125. B: Section of vegetative frond. ×220. C-E: Lower most cells of frond, with rhizoidal filaments. ×170. F: Surface view of vegetative frond. ×125. G-J: Surface view of cystocarpic portion. ×125. K-N: Section of cystocarpic portion. ×220. O-P: Surface view of antheridial portion. ×220. Q: Section of antheridial portion. ×220.

KJELLMAN, as already described and figured by KJELLMAN and UEDA, is as a rule irregularly elliptical or reniform, with an undulate margin. But frequently more or less expanded, broadly laciniate fronds are often met with, possessing a very short cordate base. The plant attains a length of about 4 cm. The thickness of the frond varies from 45–68 $\mu$. The majority of the species, however, were measured about 46 $\mu$. The lower most cells of the frond which projecting rhizoidal filaments towards the basal disc, are charactaristically elongated capitate in shape. Each cell contains a stellate chromatophore with several short arms radiating in all directions. The central pyrenoids are always distinctly observed. The plant is as a rule monoecious. The sporocarpic and antheridial patches are found on the marginal region of the frond. These patches are separated from each other and not intermixed. Among the abundant materials from Bokotô, Formosa, some dioecious plants are observed.

The antheridial patches are yellowish, and the sporocarpic ones as a rule brownish red. The antheridium mother cells are at first divided by a cruciate division perpendicular to the surface of the frond. Subsequent divisions parallel to the surface take place thrice, followed twice by other perpendicular ones. After completion of the divisions, antherozoids, in cross section of the frond, are arranged in four tiers of eight each, and in surface view, in four tiers of four each.

The development of the carpospores in various stages of this plant was observed with much interest. Each sporocarp contain 32 carpospores. They are formed the vegetative cells by a wall parallel to the surface, followed by a cruciate divisions of the frond. These division give rise to two tiers of four carpospores each. There are often observed such irregular divisions, as a part of segments is divided perpendicularly, and others parallel or even oblique to the surface, or may be changed in the order of the divisions. Subsequently the next division take place parallel or often oblique to the surface.

According to UEDA (l.c.), the sporocarps of *P. crispata* KJELLMAN are divided into 24 or 26 carpospores, according to the formula, $24\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{6}\right)$ or $26\left(2\left(\frac{a}{1}\ \frac{b}{1}\ \frac{c}{1}\right) \times 24\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{6}\right)\right)$, but those of the writer's specimens are as far as writer's observation show, divided according to the formula, $32\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$.

Materials at hand accord very well with a detailed description of *P. crispata* KJELLMAN, given by KJELLMAN except only the presence of microscopic spinulate processes. Among the genus *Porphyra* the present species is easily distinguished from the other ones by several charactaristic prominent features.

## *Porphyra dentata* KJELLMAN

PL. IV, 1. and Fig. 18.

Jap. Arter. af. slägt. *Porphyra* (1897) p. 13, t. 1, figs. 7–8, t. 3, figs. 1–4, t. 5, figs. 8–13.; DE TONI, Syll. Alg., IV (1897) p. 16; OKAMURA, Nippon Sorui Meii (in Japanese, 1916) p. 6, On Alg. from Is. Hatidyō (1930) p. 93, Nippon Kai-so si (in Japanese, 1931) p. 382; UEDA, l.c. p. 19, pl. 1, figs. 9–10, pl. III, figs. 6

13, pl. XIII, figs. 3–4, pl. XIV, fig. 1; SEGAWA, On Mar. Alg. Susaki, Izu Prov. and its Vicinity, II (1936) p. 181.

Japanese name. *Oni-amanori.*

Hab. Kyûsyû; Misaki, Enosima and Zusi, Sagami Prov.; Kominato, Awa Prov.; Moppo, Corea; Widely distributed in the middle and southern parts of the Pacific coast of Honshū.

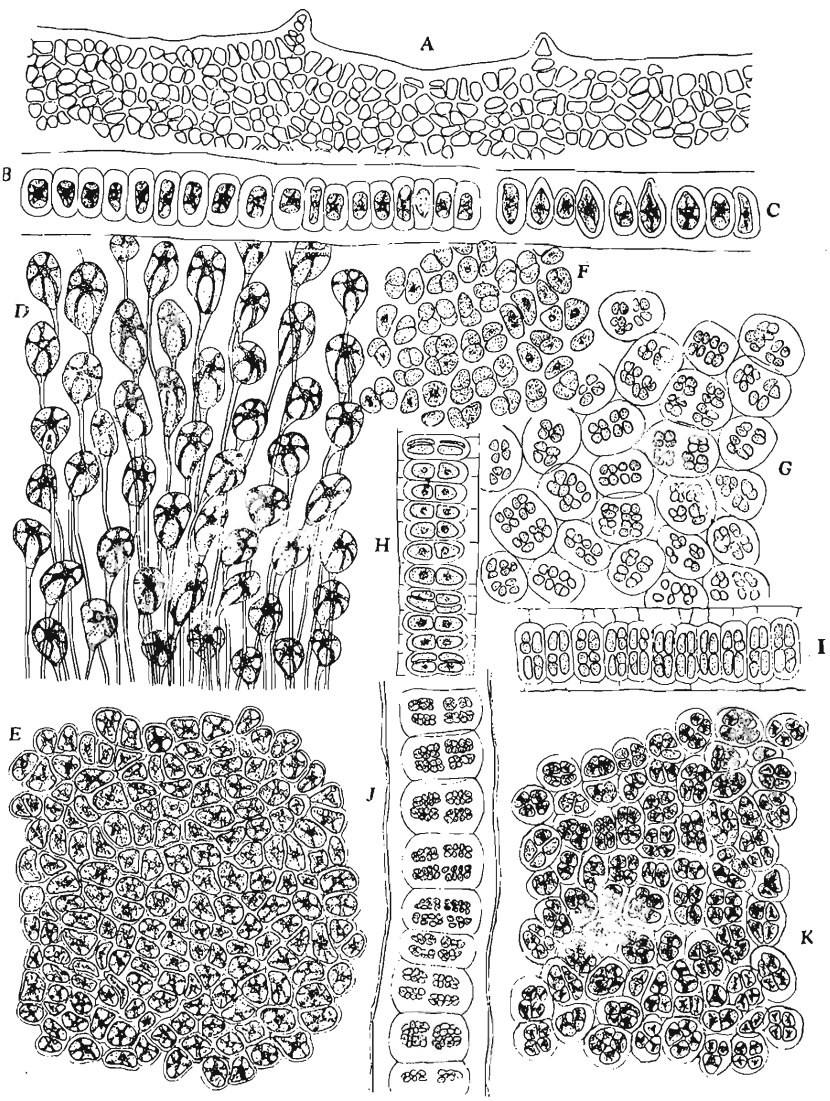



Fig. 18. *Porphyra dentata* KJELLMAN. A: Marginal portion of frond showiog microscopic spinulate processes. × 190. B: Section of vegetative frond. × 320. C. H, and I: Section of cystocarpic portion. × 225. D: Lower most cells of frond. × 320. E. Surface view of vegetative frond. × 190. F: and K. Surface view of cystocarpic portion. × 320. G: Surface view of antheridial portion. × 320. J: Section of antheridial portion. × 320.

Distrib. Endemic.

Frond linear-lanceolate or oblong-ovate, membranaceous, monostoromatic, light purplish red or pale brownish red, 10 cm long, 2 – 4 cm broad, 30 – 58 $\mu$ thick, somewhat undulate margin, base usually cordate, attached to the substratum by means of a small disc; lower most cells projecting rhizoidal filaments angulate-capitate; chromatophore star-shaped and a central pyrenoid within it; vegetative cells, in surface view angular with rounded angles, more or less irregularly arranged, in cross section quadrate with rounded angles or slightly longer than broad; surface jelly rather thin; dioecious; antheridia and cystocarps growing on the marginal region of the frond; sporocarps containing 16 carpospores after having divided according to the formula, $16\left(\frac{a}{2}\cdot\frac{b}{2}\cdot\frac{c}{4}\right)$; each antheridium containing 128 antherizoids, after having divided according to the formula, $128\left(\frac{a}{4}\cdot\frac{b}{4}\cdot\frac{c}{8}\right)$.

The present species grows on rocks not congested in upper littoral belt on the open coasts. The plant is linear-lanceolate to linear, and often possesses a crenulate margin which gives the frond a very charactaristic appearance. The fronds are always monostoromatic, rarely perforate, and more or less with an undulate margins. They are rounded at the base when young, becoming cordate. They measure mostly 10–17 cm in length and 2–4 cm in width and 30–58 $\mu$ in thickness. The largest specimens that the writer has observed, attained up to 33 cm in length. The surface jelly of the frond is about $\frac{1}{4}$ times in thickness as that of the frond. Each cell contains stellate chromatophore with a central pyrenoid quite in accordance with that found in *P. suborbiculata* KJELLMAN.

The present species is dioecious. The antheridia and sporocarps are both found respectively within distinct, narrow, marginal zones of the different thalli.

The antheridium mother cells are at first divided into four parts by a cruciate division, perpendicular to the surface of the frond, followed continuously three times by the parallel and the second perpendicular divisions. Then each antheridium now contains 128 antherozoids. The first division of the sporocarps is cruciate and perpendicular to the surface of the frond. This is followed by a division parallel to the surface of the frond. Subsequent the other division parallel to the surface, takes place two times on these segments. In this case, the carpospores count 16 in number. On the completion, the carpospores are observed arranged in two tiers of four each in cross section, and in surface view, in four tiers of four each.

The present species often grows together with *P. suborbiculata* KJELLMAN and is distributed very widely in the warmer part of the Pacific coast of Honshû. In this case, it seems to the writer that *P. dentata* KJELLMAN. is always grows on the higher place than *P. suborbiculata* KJELLMAN. In general appearance, *P. dentata* KJELLM. much resembles *P. pseudolinearis* UEDA and *P. umbilicalis* (L.) J. AG. *f. linearis* (GREV.) HARV., it differs, however, in its spinulate processes and the formula of division of sexual cells. It has been observed in the month of September-April and was in fruit in that time.

## *Porphyra yezoensis* UEDA

PL. V, VII, 3. and Fig. 19.

l. c., p. 23, pl. 1, figs. 9, 14, pl. IV, figs. 11–17, pl. XVI, figs. 3–4; INAGAKI, Mar. red Alg. Oshoro Bay, Hokkaidō and its Adjacent Waters (in Japanese, 1933) p. 15; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 385; TAKAMATSU, Mar .Alg. Tsugaru strait, Northeastern Honshû, Japan (1938) p. 31, Mar. Alg. Sanriku Coast, Northeastern Honshû, Japan (1938) p. 104, pl. XIII, fig. 1.

Japanese name. *Susabi-nori.*

Hab. Found along the northeastern Pacific coast of Japan and western coast of Hokkaidô; Corea.

Distrib. Japan.

Frond usually ovate to oblong-ovate, membranaceous, monostoromatic, stipitate, with rounded or cordate base, 5–23 cm long, 2–16 cm broad. about 30–52 $\mu$ thick; vegetative cells, in surface view angular with rounded corners, about 18 $\mu$ in diameter, more or less irregularly arranged, in cross section rectangular with round angles, usually twice as long as broad; surface jelly rather thin; lower most cells projecting rhizoidal filaments usually oblong-capitate; chromatophore stellate and peculiar yellowish blue-colour; asexual monosporangial thalius smaller than sexual ones, about 0.5–2 cm long, monospore formed by a gradual transformation of vegetative cells of the marginal frond, monospores usually spherical, about 10–16 $\mu$ in diameter, containing darkish red chromatophore; monoecious; antheridia forming small, elongated colourless patches among the dark coloured sporocarps; sporocarp contains 16 carpospores, each after having divided according to the formula, $16\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$; antheridia containing 64 antherozoids each after having divided according to the formula, $64\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{8}\right)$; colour of the frond peculiarly purplish red or blueish dark-red.

The present species grows on rocks or other algae, and twigs in the upper sublittoral zone. It is usually found inland sea or somewhat open sea. *Porphyra yezoensis* UEDA is fairly constant in shape, varying from oval laciniate and the margin is somewhat undulate. The base of the frond decidely stipitate. The thallus is constantly monostoromatic in the vegetative part. Each cell contains a stellate chromatophore with more or less regular, slender arms radiating in all directions, and a central pyrenoid. The colour of the chromatophore is yellowish red. The lower most cells which project rhizoidal filaments are usually elongate. The monospore is formed by a gradual transformation of the vegetative cells, and they arranged themselves in the single layer in contradistinction to the sexual cells; the colour of the chromatophre is darker than that of the vegetative cells.

The frond is monoecious. At first the fruit is found only at the tip and along the margins. In a ripe frond, the writer found a colourless margin, consisting of antheridia. Inside this margin, the sporocarps and antheridia are intermixed, the antheridia usually forming irregularly streak-form patches with the cerise sporocarps. The sporocarps are at first divided by a cruciate division, being perpendicular to the surface of the frond and they are to be

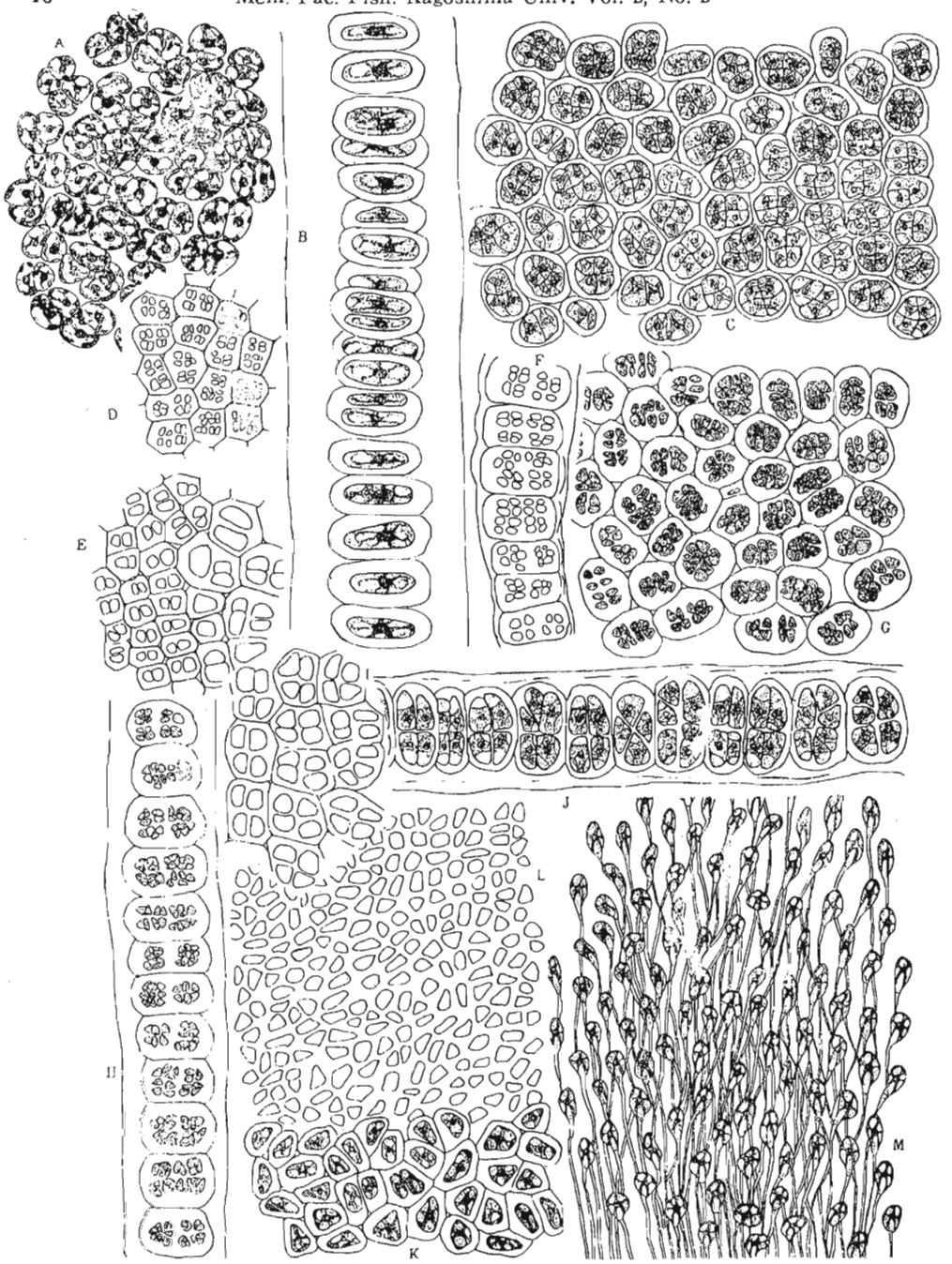



Fig. 19. *Porphyra yezoensis* UEDA. A, C, I: Surface view of cystocarpic portion. A, C: ×320, I: ×225. B: Section of vegetative portion. ×320. D, G: Surface view of antheridial portion. D: ×200. G. ×320. E: Surface view of antheridial and cystocarpic portion. ×200. F. H: Section of antheridial portion. ×320. J: Section of cystocrapic portion. ×320. K-L: Surface view of vegetative portion. K: ×320. L: ×200. M: Lower most cells with rhizoidal filaments. ×200.

changed into four carpospores. Subsequent division parallel, or somewhat oblique, to the surface take place twice. Each sporocarps contain 16 carpospores.

The antheridium mother cells are divided into four parts by a cruciate division perpendicular to the surface of the frond, followed continuously three times by the parallel and the once perpendicular divisions. An antheridium contains 64 antherozoids, arranged in four tiers of two each in surfac view.

*Porphyra yezoensis* UEDA *f. coreana* UEDA is established by UEDA with the specimens of Corea and Northern Hokkaidō. But Corean plants of this forma seen to the writer, not to be sufficiently different to justify their separations. In outer and anatomical characters, the present species is most nearly allied to *P. leucosticta* THURET and *P. tenera* KJELLMAN, but it differs from the latter by the formula of divisions of cystcarps and antheridia.

## *f. Kinositai* YAMADA et TANAKA forma nov.

PL. V, 1. and Fig. 20.

Fronde membranacea, monostoromatica, caespitosa, oblonga-lanceolata vel lineali-lanceolata, ad basin stipitata, rotunda vel cordata, crebre et profunde undulato-plicata, 15 – 30 cm longa, 3 – 8 cm lata, 32 – 48 $\mu$ crassa.

Japanese name. *Utasutu-nori* (*n.n.*).

Hab. Utasutu, Hokkaidō.

Distrib. Endemic.

Frond membranaceous, monostoromatic, caespitose, oblong-lanceolate to linear-lanceolate, stipitate; base cordate or ovale, with undulate margin, 15 – 30 cm long, 3 – 8 cm broad, 32 - 48 $\mu$ thick.

Among the genus *Porphyra*, the vegetation of this new forma is very charactaristic and observed with interest. The present forma abundantly grows on rocky bottom in a depth of about 3 - 7 fathoms. The writer has never seen any species of *Porphyra* growing in such a deep water. The thallus is decidedly oblong and ribbon-shaped, and strongly undulate on the margins, but not laciniate. The largest specimen that the present writer has obtained, attained to 60 cm in length. The colour of the frond is peculior light purplish red. The frond of this forma is more or less thinner than that of *P. yezoensis* UEDA. The plant is monoecious. Each sporocarp contain usually eight or rarely sixteen carpospores. They are formed from the vegetative cells by a cruciate division which is to be followed by a division parallel to the surface of the frond, taking place once or twice. The formula of antheridial division is similar to that of *P. yezoensis* UEDA.

## *Porphyra seriata* KJELLMAN

PL. VII, 1. and Fig. 21.

Jap. Arter. af Slägt. *Porphyra* (1897) p. 17, t. 3, figs. 8 – 10, t. 4, fig. 1, t. 5, figs. 16 - 21; DE TONI, Syll. Alg., IV (1897) p. 16,; OKAMURA, Sorui Meii (in Japanese, 1916) p. 7, Nippon Kaisosi (in Japanese, 1936) p. 386; UEDA, l. c., p. 24, pl. 1, figs. 9 – 10, pl. V, figs. 6 – 14, pl. XVII, fig. 2.

Japanese name. *Itimatu-nori*.

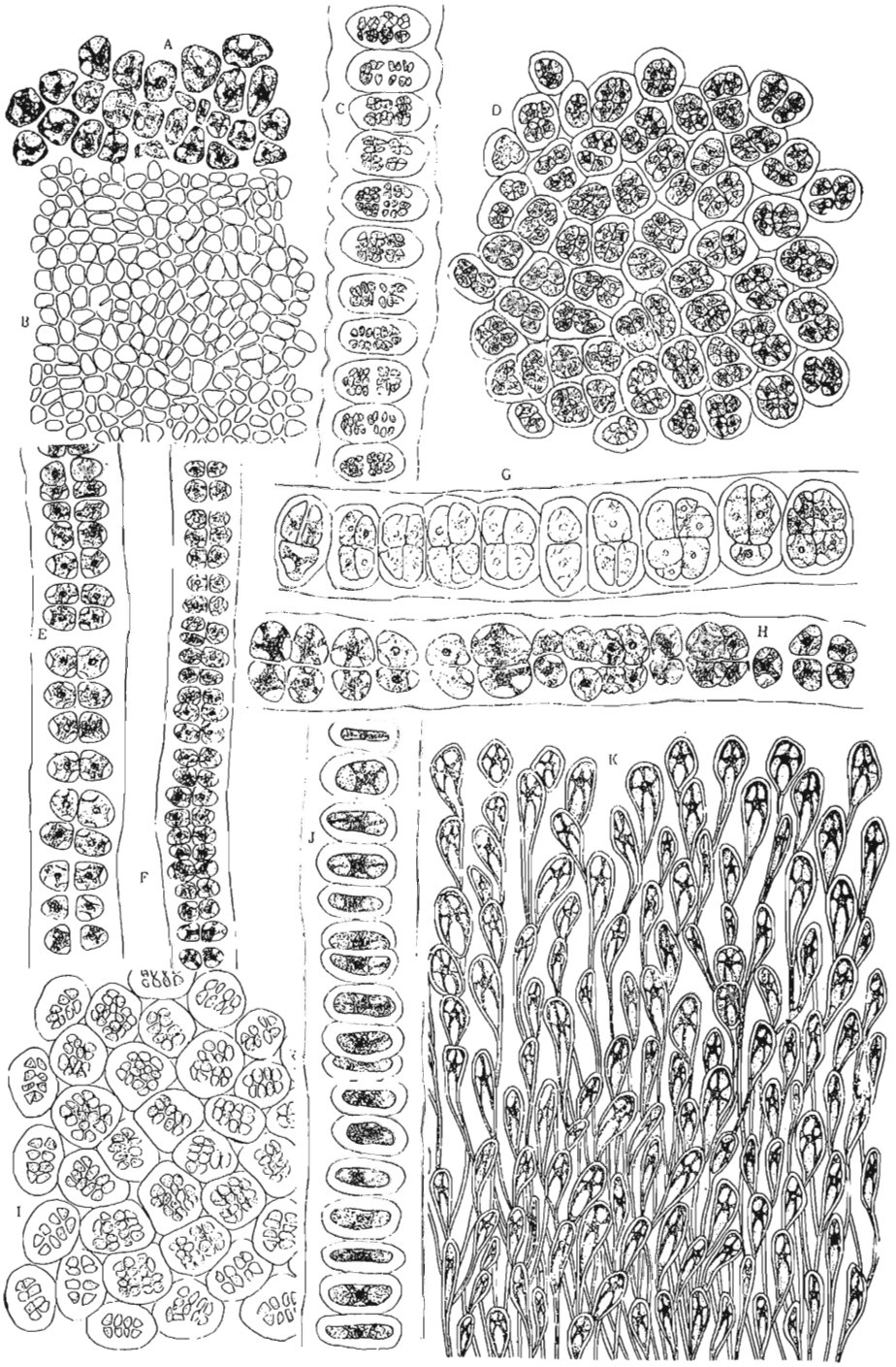



Fig. 20. *Porphyra yezoensis* UEDA f. *Kinositai* YAMADA et TANAKA. A-B: Surface view of vegetative frond. A: × 220, B: × 140. C: Section of antheridial portion. × 220. D: Surface view of cystocarpic portion. × 220. E-H: Section of cystocarpic portion. × 220. I: Surface view of antheridial portion. × 220. J: Section of vegetative portion. × 220. K: Lower most cells with rhizoidal filaments. × 140.

Hab. Taisen, Moppo and Fusan, Southwestern part of Corea.

Distrib. Japan; China.

Frond submembranaceous, monostoromatic, orbicular to reniform with slightly undulate margin, shortly stipitate, with cordate or umbilicate base, 5 – 12 cm long, 38 – 74 $\mu$ thick; vegetative cells usually elliptical in surface view, more or less irregularly arranged, in cross section rectangular with rounded corner or about two times as long as broad; surface jelly rather thin; lower most cells projecting rhizoidal filaments ovate or capitate; each cell containing stellate chromatophore and a central pyrenoid within it; colour of the frond purplish red or pale violet; monoecious; cystocarps and antheridia formed from the marginal portion of the frond; each cystocarp containing 16 carpospores, each after having divided according to the formula, $16\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$;

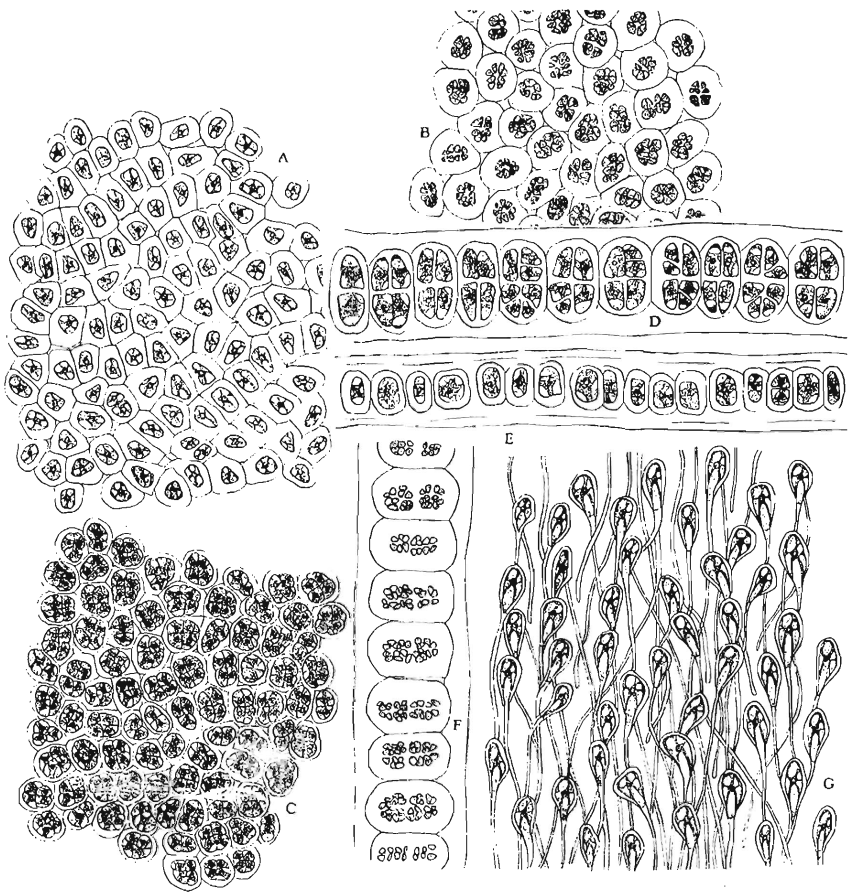



Fig. 21. *Porphyra seriata* KJELLMAN. A: Surface view of vegetative portion. × 275. B: Surface view of antheridial portion. × 275. C: Surface view of cystocarpic portion. × 275. D: Section of cystocarpic portion. × 275. E: Section of vegetative portion. × 275. F: Section of antheridial portion. × 275. G: Lower most cells with rhizoidal filaments. × 205.

antheridium dividing into 128 antherozoids according to the formula, $128\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$.

The present species grows on rocks in the littoral zone. The frond is usually rounded reniform or funnel shape with somewhat undulate margin. The frond is reddish purple, sometimes also becoming partly pale brownish red when old. The present species is always monoecious. The sporocarps and antheridia are both found at the tip or along the marginal portion of the same frond. The antheridia are found within the yellowish regular chequered feature of *P. seriata* KJELLMAN. The antheridium mother cells are at first divided by cruciate divisions perpendicular to the surface of the frond, followed continuously thrice by the parallel and the second perpendicular division. An antheridium contains 128 antherozoids, arranged in four tiers of four each in surface view.

The sporocarpic patches are formed on the marginal region of the frond. Each sporocarp divided cruciately, giving rise to four cells. Each of these now undergoes twice parallel division.

The specimens at hand, accord well in the essential characters with the present species, given by KJELLMAN and by UEDA respectively. The first record of the present species is that by KJELLMAN in his "Japanska Arter af Slägtet *Porphyra*". He described it from the specimens which were collected by Russian Botanist CHR. GOBI from Japan. Concerning the type-locality of this species, it is very uncertain. In outer appearance, the present species resembles *P. crassa* UEDA. The present alga is usually found in the months of Feburaly – April.

## *Porphyra ochotensis* NAGAI

PL. VI, and Fig. 22.

Mar. Alg. Kurile Islands, II (1941) p. 144, pl. IV, figs, 3 – 8, pl. VI, figs. 1 – 2.

*Porphyra perforata* (non J. AGARDH) UEDA, l. c., p. 26, pl. V, figs. 15 – 17, pl. XVII, figs. 3 – 4; YAMADA, Mar. N. Kurile (1934) p. 347, Mar. Alg. Urup (1935) p. 21; OKAMURA, Nippon Kaisosi (in Japanese, 1932) p. 386; KAWABATA, List Mar. Alg. Isl. Shikotan (1936) p. 207.

*Porphyra linearis* (non GREVILLE) TOKIDA, Mar. Alg. Robben Island (1932) p. 11, fig. 3.

Japanese name. *Ana-amanori*.

Hab. Simushu Island; Paramusiro Island, North Kurile Islands; Harumukotan Island, Matuwa Island, Usisiru Island, Ketoi Island, Simusiru Island, Uruppu Island, Middle Kurile Islands; Etorofu Island, South Kurile Islands; Sikotan Island.

Distrib. Saghalien and Kurile Islands.

Frond membranaceous, monostoromatic, linear or ovate-lanceolate often laciniate into two five lobes, perforate, shortly stipitate, with undulate margin, 20 – 70 cm long, 10 – 40 cm broad, 60 100 $\mu$ thick; vegetative cells quadrate with round angles or elliptic, irregularly arranged in surface view, quadrate with round coners or often twice as high as broad; surface jelly rather thin;

lower most cells projecting rhizoidal filaments usually capitate; each cell containing stellate chromatophore and a central pyrenoid within it; dioecious; sporocarpic and antheridial patches found on the marginal region of the different thalli; each antheridium containing 128 antherozoids, arranged in four

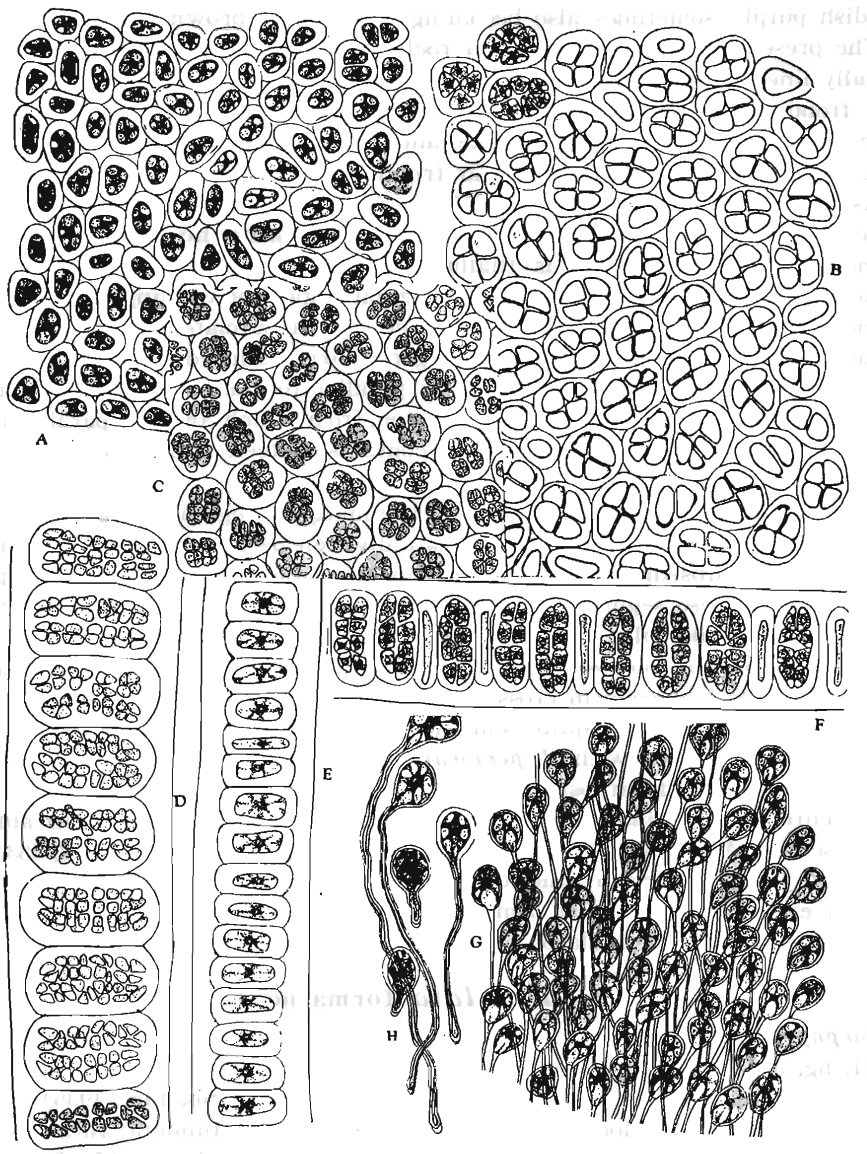



Fig. 22. *Porphyra ochotensis* NAGAI. A: Surface view of vegetative portion. × 250. B: Surface view of cystocarpic portion. × 250. C: Surface view of antheridial portion. × 250. D: Section of antheridial portion. × 290. E: Section of vegetative portion. × 180. F: Section of cystocarpic portion. × 165. G-E; Lower most cells with rhizoidal filaments. G: × 140. H. × 235.

tiers of four each in surface view, according to the formula of division, corresponding to $128\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$; sporocarp containing 32 carpospores each after having divided according to the formula, $32\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$; colour of the frond reddish purple, sometimes also becoming partly olive brown when old.

The present species was found on rocks in the littoral zones. The plant is usually linear-lanceolate to ovate-lanceolate in shape. The shape and size of the frond are very variable. The materials examined contain two forms. The one is usually ovate-lanceolate and often laciniate into two-five lobes. The other has usually narrow linear frond.

As already UEDA, YAMADA and NAGAI described respectively, the present species is, as a rule, dioecious. According to TOKIDA, however, it is rarely monoecious. In the dioecious thallus, the antheridia are found within the yellowish irregular patches on the marginal region of the upper part of the frond. The antheridium mother cell undergoes a curciate division perpendicular to the surface of the frond, giving rise four antheridia. The first reproductive division of the antheridium is parallel to the surface of the frond. This is often followed by a cruciate division, from which another parallel takes place; so that each antheridium now contains sixteen segments arranged in four tiers of four each.

The sporocarpic patches are found on the marginal region of the frond. The sporocarps are at first divided by cruciate division perpendicular to the surface of the frond. Subsequent the other divisions parallel to the surface, take place two times on these segments. Finally two divisions more, which are parallel to each other, take place in the direction perpendicular to the surface. On the completion, the carpospores now consist of sixty-two carpospores arranged in two tiers of four each in cross section, and in four tiers in surface view.

The present species is quite similar to *P. perforata* J. AG. It has many characters in common with *P. perforata*, but differs from it, the difference of the division mode of carpospores, and the dioecious frond insted of monoecious one. Through the kindness of Prof. Y. YAMADA, the writer has been able to study several American specimens of *P. perforata* J. AG.; Number 682, 683, 684, of the Phycotheca Boreali Americana under the name of *P. perforata*. After-careful examination of these American specimens, the writer ascertained the correctness of HUS's formula of the division mode of carpospore and antheridia.

## *f. lanceolata* forma nov.

*Porphyra linearis* (non GREVILLE) TOKIDA, Mar. Alg. Robben Island (1932) p. 11, fig. 3.

*P. perforata* (non J. AGARDH) KAWABATA, Mar. Alg. Sikotan (1936) p. 207.

Fronde lineali-vel oblongo-lanceolata, ad basin late rotundata, rara cuneata vel cordata, perforata, crebre undulato-plicata, 10 – 25 cm longa, 2.5 - 8 cm lata, 60 – 80 $\mu$ crassa.

Japanese name. *Nagaba-ana-amanori*.

Hab. Sikotan Island; Saghalien.

Distrib. Endemic.

Frond linear- or oblong-lanceolate, with undulate margin, perforate, with round or cordate base, 10 – 25 cm long, 2.5 – 8 cm broad, 60 – 80 $\mu$ thick.

The present forma can be distinguished at first sight from the species by its narrow linear frond. Also it may be distinguished from *P. ochotensis* by the light red-purple colour of the frond, and also more or less thinner frond.

## *Porphyra angusta* OKAMURA et UEDA

PL. XII, 2. and Fig. 23.

UEDA, l. c., p. 28, pl. 1, figs. 4, 10, pl. VI, figs. 8 – 16, pl. XVIII.

*Porphyra* sp. OKAM. sp nov.?, in OKAMURA's Nippon Sorui Meii (1916) p. 7.

Japanese name. *Kosuzi-nori.*

Hab. Izu Prov.; Sagami Prov.; Hitati Prov.

Distrib. Endemic.

Frond membranaceous, usually oblong-lanceolate to linear, caespitose, simple, monostoromatic, shortly stipitate, with slightly undulate margin; base usually cuneate; 6 – 12 cm long, 1 – 3 cm broad, 24 – 36 $\mu$ thick; vegetative cells, in surface view, angulate with round angles; surface jelly rather thin; lower most cells projecting rhizoidal filaments oblong; each cell containing chromatophore and a central pyrenoid within it; colour of the frond light purplish red or pale violet; dioecious; cystocarps and antheridia formed on the marginal region of the different thalli; each antheridium containing 128 antherozoids, after having divided according to the formula, $128\left(\frac{a}{4}\cdot\frac{b}{4}\cdot\frac{c}{8}\right)$; each sporocarps containing eight carpospores, after having divided according to the formula, $8\left(\frac{a}{2}\cdot\frac{b}{2}\cdot\frac{c}{2}\right)$.

The present species grows on rocks or twigs often associated with *Porphyra tenera* KJELLMAN. It is found in somewhat open places in rather high salinity. The frond is very narrow, elongate-lanceolate in shape.

Each vegetative cell contain a stellate chromatophore from which several slender arms radiating in all directions. Among the materials at hand, the largest specimen is up to 20 cm, in height and 4 cm in breadth at its broadest part. The plant is dioecious. Each sporocarp contain eight carpospores, which arise from the vegetative cells by a cruciate division, followed by a parallel division, thus giving rise to eight carpospores in two tiers of four each.

The antheridium mother cells are, at first, divided into four parts by a cruciate division perpendicular to the surface of the frond. Subsequently division to the surface take place thrice, followed twice by other perpendicular ones. After completion of the division, antherozoids, in cross section of the frond, and arranged in four tiers of eight each, and in surface view, in four tiers of four each.

The species at hand, accord well in the essential characters with the description of the present species, given by UEDA. In general appearance, *P. angusta* OKAMURA et UEDA closely resembles *P. tenera* KJELLMAN., but differs from it, by the dioecious and the division mode of antheridia.

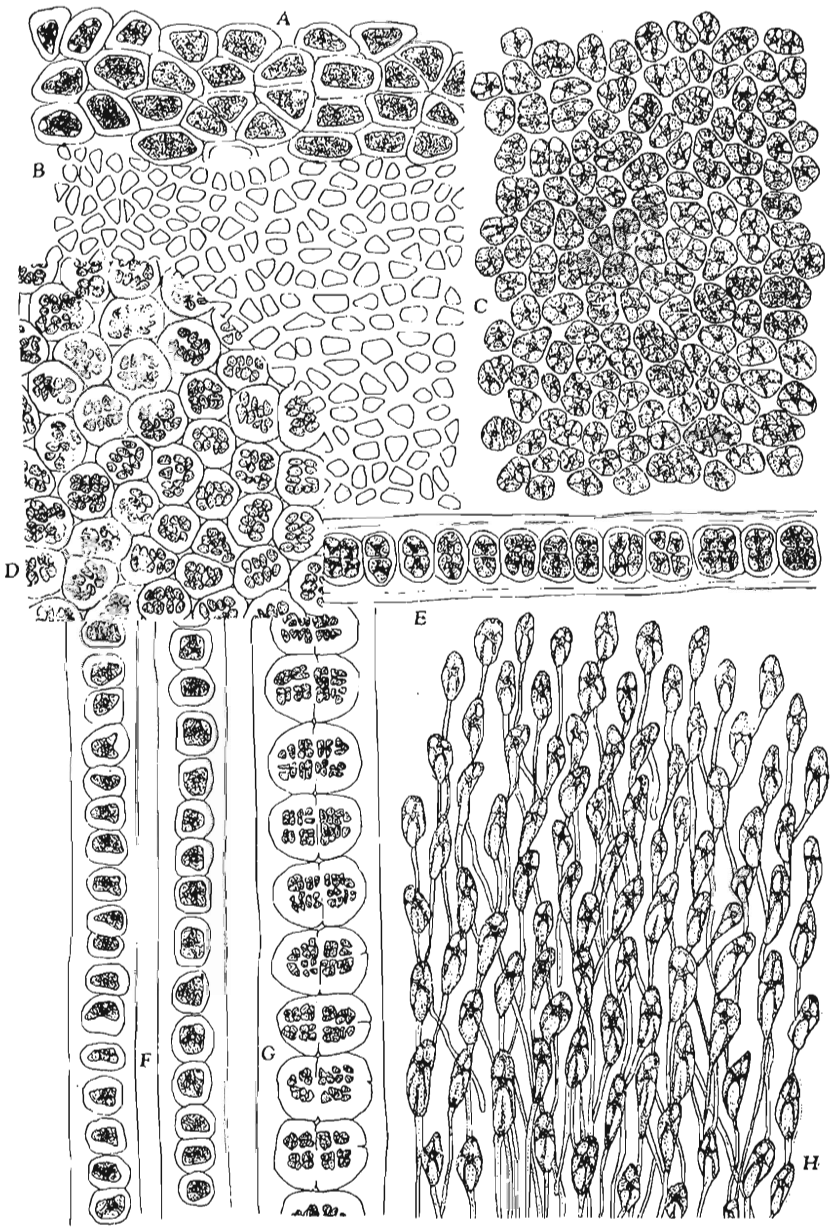



Fig. 23. *Porphyra angusta* OKAMURA et UEDA A-B: Surface view of vegetative portion. A: × 440, B: × 270. C: Surface view of cystocarpic portion. × 440. D: Surface view of antheridial portion. × 440. E: Section of cystocarpic portion. × 290. F: Section of vegetative portion. × 450. G: Section of antheridial portion. × 440. H: Lower most cells with rhizoidal filaments. × 270.

## *Porphyra pseudolinearis* UEDA

PL. VIII–IX, and Fig. 24.

l. c., p. 29, pl. 1, fig. 6, pl. VI, figs. 17–18, pl. VII, figs. 1–5, Pl. XIX; INAGAKI, Mar. Red Alg. Osyoro Bay, Hokkaidō and its Adjacent Waters (in Japanese, 1933) p. 15; YAMADA, Mar. Alg. Urup (in Japanese, 1934) p. 31, fig. 13, Mar. Alg. Urup (1935) p. 20; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 387; KAWABATA, List Mar. Alg. Isl. Shikotan (1936) p. 207; TAKAMATU, Mar. Alg. Kinkwasan Isl. (1936) p. 56, Mar. Alg. Tsugaru Strait (1936) p. 31, Mar. Alg. Sanriku Coast (1939) p. 102, Mar. Alg. Japan Sea (1939) p. 48; NAGAI, Mar. Alg. Kurile Islands, II (1941) p. 144.

*Porphyra linearis* (non GREVILLE) YENDO, Notes on Alg. New to Japan, III (1915) p. 106.

Japanese name. *Uppurui-nori.*

Hab. Urupu Island, Middle Kurile Islands; Etorofu Island, South Kurile Islands; Shikotan Island; Eastern coast of Corea; Commonly distributed in Japan Sea, but found only along the nothern coast in the Pacific; Hokkaidō.

Distrib. Endemic.

Frond membranaceous, monostoromatic, lustrous, linear to oblong-lanceolate, shortly stipitate, slightly or not undulate on the margin, often crenata and lobed, with round or cordate base, rarely umbilicate, 10–30 cm long, 2–4.5 cm broad, 30–56 $\mu$ thick; vegetative cells, in surface view somewhat irregular pentagonal and more or less irregularly arranged, in cross section quadrate with round angles or slightly higher than broad; surface jelly rather thick; lower most cells projecting rhizoidal filaments rather large and angulate-capitate; each cell containing stellate chromatophore and a central pyrenoid within it; dioecious; antheridia forming within yellowish narrow marginal zone of the upper part of the frond, containing 128 antherozoids after having divided according to the formula, $128\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$; Sporocarps formed on the marginal zone of the upper and middle part of the frond, containing 32 carpospores each after having divided according to the formula, $32\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$; colour of the frond purplish red or hydrangea red, becoming violet at the base.

The present species is found upon rocks in the lower and upper littloral zones. The plant is very long and narrow linear in shape. It is round at the base when young, becoming later cordate or even umbilicate. They measure mostly 32–56$\mu$ thick, 10–30 cm long and 2–4.5 cm wide. The largest specimens that the writer has obtaind, attained to 50 cm in length and 18 cm in breadth at its broadest part. The frond is reddish purple, sometimes becoming hydrandea red in age, especially dull blue violet at the base. The vegetative cells of the frond are irregularly pentagonal and disposed in an irregular manner in surface view. They show a most charactaristic pavement form. The plant is, in the vegetative portion of the frond, constantly monostoromatic. No indication of a distromatic nature has ever been found.

The present species is always dioecious. The antheridia are formed within the yellowish irregular patches on the marginal region of the upper part of

the frond. Antheridium mother cells are at first divided by cruciate division perpendicular to the surface of the frond, followed continuously three times by the parallel and the second perpendicular division. An antheridium contains 128 antherozoids, arranged in four tiers of four each in surface view.

The sporocarpic patches are found on the marginal region of the different thallus. Vegetative cells are often intermixed among the sporocarps. And so

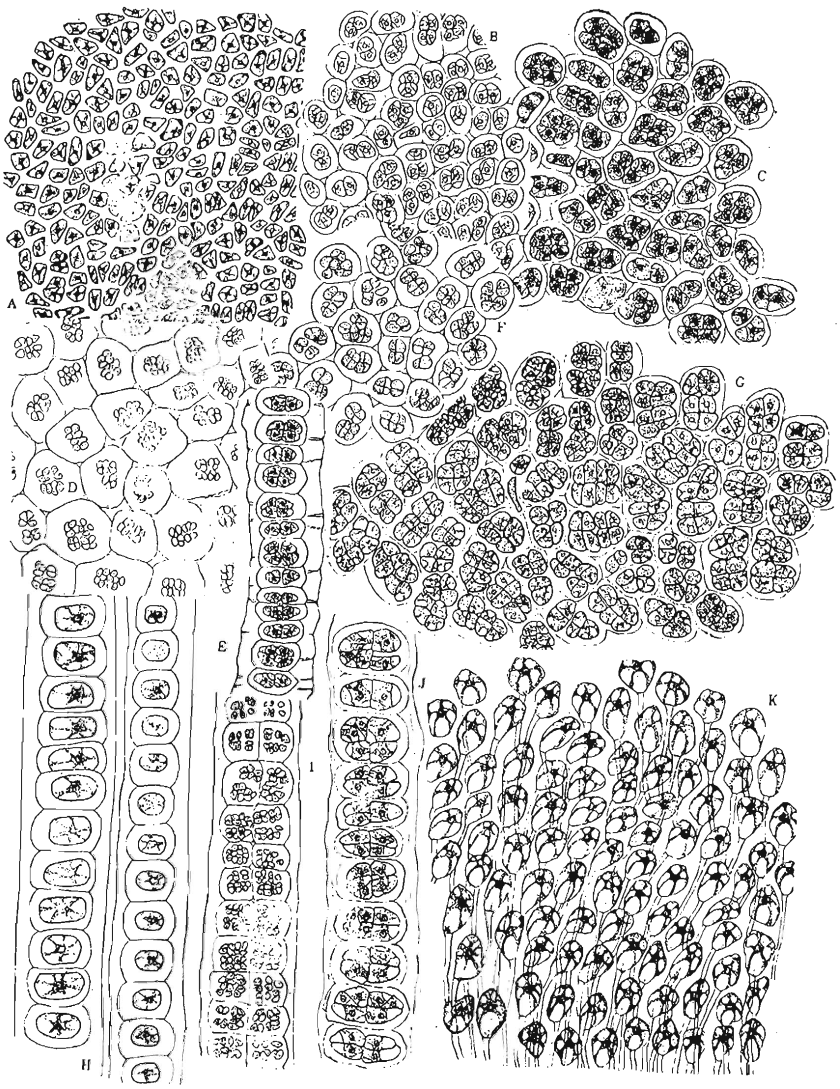



Fig. 24. *Porphyra pseudolinearis* UEDA. A: Surface view of vegetative portion. × 150. B, D, F: Surface view of antheridial portion. × 220. C, G: Surface view of cystocarpic portion. × 220. E, J: Section of cystocarpic portion. × 220. H: Section of vegetative portion. × 170. I: Section of antheridial portion. × 220. K: Lower most cells with rhizoidel filaments. × 150,

at the matured female region the linear sword-cut like streaks are often observed. Each sporocarp contain 32 carpospores, arranged in peculiar tortoise shell-like form. The first division of the sporocarps is cruciate to the surface of the frond. This is followed by a division perpendicular to the surface of the frond, this giving rise to eight segments in two tiers of four each, even one of which undergoes an irregular perpendicular or somewhat oblique divisions, giving rise to 32 carpospores in two tiers of sixteen each.

The first record of the present species is that by UEDA in his "*Porphyra* of Japan, 1932" by the specimens from Takasima, near Otaru, Hokkaidô. The size and shape of the frond is very variable. In fact, the frond of the materials from Uppurui, Izumo Prov., is very small and remarkably linear in shape. They measure mostly 2–4 cm in length and 0.5–0.8 cm in breadth at its broadest part. The largest specimens from Muroran, Hokkaido that the present writer has obtained, attained to 30 cm in length and 12 cm in breadth at its broadest part. Between these two extreme forms which the frond may assume, numerous transition forms are obserbed.

In general appearance, the present species closely resembles *P. linearis* GREVILLE, but the shape and arrangement of the vegetative cells are apparently from that of *P. linearis*. Furthermore, *P. pseudolinearis* differs from *P. linearis* in division mode of carpoapores. YENDO in his "Notes on Algae new to Japan, II", referred the present plant to *P. linearis* GREVILLE. Unfortunately the present writer has not been able to compare it with any authentic specimens of *Porphyra linearis* GREV. However, the writer, followed by UEDA, has come to the conclusion that the present Japanese algae should be treated as an independent species *P. pseudolinearis* which is closely related to *P. linearis* GREVILLE.

The plant has been found usually in the month of September to March in Japan Sea, but it has been usually found from June in Kurile Islands.

## *Porphyra tenera* KJELLMAN

PL. X–XI, and Fig. 25.

Jap. Arter. af Slägt. *Porphyra* (1897) p. 35, t. 1, fig. 6, t. 4, figs. 2–5, t. 5, figs. 22–26; DE TONI, Syll. Alg., IV (1897) p. 18; OKAMURA, Nippon Soruí Meii (in Japanese, 1916) p. 7, Nippon Kaisosi (in Japanese, 1936) p. 383; UEDA, l. c., p. 20, pl. I, figs. 4, 12, pl. III, fig. 14, IV, figs. 1–10, pl. XIV, figs. 2–3, pl. XV, figs. 1–3, pl. XVI, figs. 1–2; KUNIEDA, On the life history of *Porphyra tenera* KJELLMAN (1939) p. 397.

*P. leucosticta* (non THURET) YENDO, Notes Alg. New to Japan, IV (1916) p. 52.

Japanese name. *Asakusa-nori*.

Hab. Widely distributed both on the Pacific (common) and Japan Sea coast (rare) of Honshû; Kyûshû; Corea.

Distrib. Japan; Corea; China.

Frond membranaceous, monostoromatic, obovate to linear-lanceolate, stipitate, 3–8 cm long, 2–14 cm broad, 14–26 $\mu$ thick, with an undulate margin; base usually cuneate or cordate; vegetative cells, in surface view, angular with round corners, about 17 $\mu$ in diameter, more or less regularly arranged, in cross

section quadrate with round angles or slightly higher or shorter than broad; surface jelly thin; lower cells projecting rhizoidal filaments angular-capitate or oblong-capitate; chromatophore star-shaped, bright brownish red and a central pyrenoid within it; andro-dioecious or monoecious; antheridia and cystocarps formed on marginal region of the frond and gradually spreading over the whole frond, not intermixed with vegetative cells, antheridia forming small, elongated, colourless patches among the dark coloured sporocarps; each antheridium containing 64 antherozoids, according to the formula, $64\left(\frac{a}{4}\cdot\frac{b}{4}\cdot\frac{c}{4}\right)$; each sporocarp containing 8 carpospores, after having divided according to the formula, $8\left(\frac{a}{2}\cdot\frac{b}{2}\cdot\frac{c}{2}\right)$; asexual monosporic thallus minute, about 0.5 – 3 cm in height; monosporangia formed by a gradual transformation of the vegetative cells at the marginal frond, monospores usually spherical, about 12 $\mu$ in diameter, containing dense darker chromatophore than the vegetative cells; colour of the frond usually purplish red, but often changed in colour by the outer condition.

The first mention of this species of *Porphyra* was made by KJELLMAN in 1897. The materials on which KJELLMAN established *P. tenera* KJELLMAN are dried commercial products and he reported that it was dioecious. Lately UEDA (1932) established two forms of this species, *f. typica* and *f. Kjellmanii*. According to UEDA, the differrence between these two forma lie in the shape of the vegetative cells in cross section of the frond. Through the kindness of Prof. YAMADA, the writer examined one of the co-type specimens of *P. tenera* KJELLM. from Japan, which was collected by J. PETERSEN. It is an article prepared for food. In these materials, the frond is, according to the writer's observation, somewhat lanceolate in shape and is monoecious. As far as the present writer's observation show, the difference between above two forma have not been able to be found in the cotype materials.

The shape and size of the frond are exceedingly variable. The largest specimens that the writer obtained, attained to one meter in length and 20 centimeter in breadth at its broadest part. A large collection of *Porphyra tenera* KJELLMAN from various localities of Japan upon which the present writer based examination, contains two forms of the present species. As already noted by KUNJEDA, these two forms may be considered as round-type and long-type frond. The frond of round-type is, as far as the writer awares usually thicher than those of long-ones.

The plant is constantly monostoromatic. The thikness of the frond varies 14 - 26 $\mu$. But among the abundant materials from various localities, a great difference in thickness of the frond have been observed; they are as follows;

| | |
|---|---|
| Tokyo Bay. | 14 – 26 $\mu$ thickness ( long-type ) |
| Tokyo Bay. | 17 – 26 $\mu$ thickness (round-type) |
| Hiroshima Bay. | 15 – 22 $\mu$ thickness ( long-type ) |
| Hiroshima Bay. | 17 - 26 $\mu$ thickness (round-type) |
| Irakozaki. | 18 - 24 $\mu$ thickness (round-type) |
| Osaka Bay. | 15 – 22 $\mu$ thickness ( long-type ) |

| | |
|---|---|
| Hakata Bay. | 17 – 25 $\mu$ thickness (round-type) |
| Hakata Bay. | 14 – 22 $\mu$ thickness ( long-type ) |
| Simoda, Izu Prov. | 18 – 23 $\mu$ thickness (round-type) |

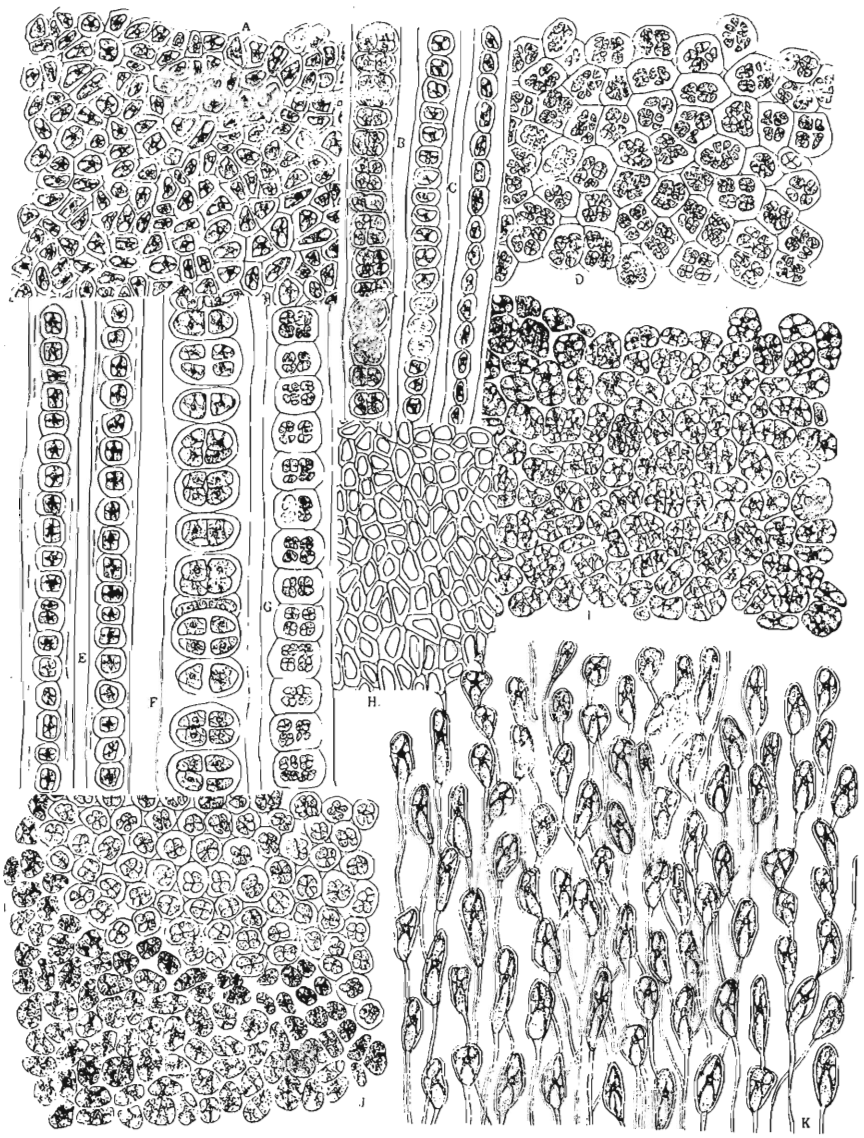



Fig. 25. *Porphyra tenera* KJELLMAN. A: Surface view of vegetative portion. × 170. B: Section of cystocarpic portion (co-type specimen). × 180. C: Section of vegetative portion (co-type specimen). × 180. D: Surface view of antheridial portion. × 240. E: Section of vegetative portion. × 180. F: Section of cystocarpic portion. × 190. G: Section of antheridial portion. × 180. H: Surface view of vegetative portion (co-type). × 170. I: Surface view of cystocarpic portion. × 190. J: Surface view of antheridial and cystocarpic portion. × 180. K: Lower most cells with rhizoidal filamants. × 170.

| | |
|---|---|
| Ariake Bay. | 22 - 26 $\mu$ thickness (round-type) |
| Onahama, Iwaki Prov. | 20 – 26 $\mu$ thickness (round-type) |
| Onagawa, Rikuzen Prov. | 16 – 21 $\mu$ thickness ( long-type ) |
| Kominato, Awa prov. | 16 – 21 $\mu$ thickness ( long-type ) |
| Moppo, Corea. | 14 – 22 $\mu$ thickness ( long-type ) |
| Moppo, Corea. | 21 - 26 $\mu$ thickness (round-type) |

The present species is as a rule monoecious, but often andro-dioecious; antheridia forming irregular, elongated patches among the darkish cervise sporocarps. But frequently on male frond antheridia are formed and on female frond the carpogonia are formed together with some antheridia. Each sporocarps contain eight carpospores. It is formed from the vegetative cells by a cruciate division, followed by a division parallel to the surface of the frond. These divisions produce two tiers of four carpospores each.

According to KUNIEDA, the matured sporocarps are often divided into more than eight carpospores in some specimens.

The antheridium mother cells, by a cruciate division perpendicular to the surface of the frond, give rise to four antheridia. Each antheridium now undergoes a division parallel to the surface of the frond, being followed by another parallel into sixteen parts, each of which, by a cruciate division, gives rise to four antherozoids, so that whole antheridium now consists of sixty-four antherozoids arranged in four tiers of sixteen each.

Concerning the species problem of *Porphra tenera* KJELLMAN, KUNIEDA described it; "A more complete account of the species problem of *P. tenera* will be published in the future, that at this occasion, several points which are useful for the understanding of the life-history will be commented upon. Althrough no definite statement can be made as to the modes of development and the methods of reproduction of the majority of the species of *Porphyra* are known, so far as the author can except, it will probably be possible to classify two types, the long-type and the round-type, as a basis of classification."

The colour of the frond seems to have the likeness depending upon the age of the plant; the young specimens are generally light purplish red, but the colour seems to fade out older specimens, which are often a faint brownish red. The chromatophore are stellate and of bright brown-red colour. The present species is usually found in the month October – March, growing on the twigs of Bamboo or trees, and other algae.

Recentry BOERGESEN (1937) reported the occurance of *P. tenera* KJELLM. from India, but he did not touch at the essential characters, and the formula of division of sexual organs.

## *Porphyra crassa* UEDA

PL. XII, 1, and Fig. 26.

l. c., p. 27, pl. 1, figs. 9 – 10, pl. 6, figs. 1 – 7, pl. 18, fig. 1; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 387; YAMADA and TANAKA, Mar. Alg. in the Viciuity of Akkesi Mar. Biolog. Station (19 -44) p. 67.

Japanese name. *Atuba-amanori.*

Hab. Moppo and Fusan, Corea; Sakata, Uzen Prov.; Hukaura, Mutu Prov.; Suttu, Esasi, Akkesi, Siretoko Penninsula, Risiri Island, Teuri Island and Yagisiri Island, Hokkaidō; Ōdomari, Saghalien.

Distrib. Endemic.

Frond usually orbiculate or reniform, monostoromatic, slightly lustrous, somewhat submembranaceous or coriaceous, with cordate base, not undulate margin, stipitate, 8-16 cm long, 8-12 cm broad, 42-78 $\mu$ thick; vegetative cells in surface view quadrate with round corners, more or less regularly arranged, in cross section rectangular with round angles, twice as high as broad; surface jelly very thick; lower most cells projecting rhizoidal filaments usually capitate; each cell containing stellate chromatophore with central pyrenoid; colour of the frond light purplish red or russet; dioecious or andro-dioecious; antheridia and sporocarps both formed respectively within distinct, narrow, marginal zones of the same or different thalli; each sporocarp containing 16 or 32 carpospores, after having divided according to the formula, $16\left(\frac{a}{2}\cdot\frac{b}{4}\cdot\frac{c}{4}\right)$ or $32\left(\frac{a}{2}\cdot\frac{b}{4}\cdot\frac{c}{4}\right)$; each antheridium containing 128 antherozoids, after having divided according to the formula, $128\left(\frac{a}{4}\cdot\frac{b}{4}\cdot\frac{c}{8}\right)$.

The present species grows abundantly on rocks in the upper littoral zone. The frond is as a rule orbiculate or reniform, not undulate at the margin, and provided with a very short stipe. The largest specimens of the materials at hand attains up 20 cm in length. The frond is reddish purple, sometimes also becomes partly russet or olive brown when old. The surface jelly of the frond is 1/3-1/4 as thick as the thickness of the frond. The cells contain star-shaped chromatophore which several slender arms radiating in all directions.

The present species is, as a rule, dioecious or often andro-dioecious. According to UEDA, however, it is simple dioecious. In the dioecious thallus, the antheridia are found within the yellowish, irregular patches on the marginal region of the upper part of the frond. In the andro-dioecious thallus, that is, on "female fronds" only carpogonia are found on "male fronds" the antheridia are formed together with the carpogonia.

The antheridium mother cells are at first divided by cruciate division perpendicular to the surface of the frond, followed continuously three times by the parallel and the second perpendicular divisions. An antheridium contains 128 antherozoids, arranged in four tiers of four each in surface view.

The sporocarpic patches are found on the marginal region of the frond. The patches are also irregular in outline as in the antheridial thallus, as usual, longer than in the latter case. The sporocarp is at first divided cruciately in surface view of the frond, dividing each then into four parts by divisions parallel to the surface. Thus there are observed sixteen carpospores, but frequently this mode of division undergoes changes. As far as the writer's observation show, the matured cystocarps often containing 32 carpospores. The formula of these division corresponds to $32\left(\frac{a}{2}\cdot\frac{b}{4}\cdot\frac{c}{4}\right)$.

The present materials agree quite well with the description and figures by UEDA in the essential characters except being andro-dioecious. *P. crassa* UEDA is very similar to *P. seriata* KJELLMAN. It has many chracters in comman with *P. seriata*, but differs from it in thicker thallus, and in being dioecious or andro-dioecious insted being monoecious.

The present algae is usually observed in winter month and grows somewhat exposed places.

## *Porphyra umbilicalis* (LINNAEUS) J. AGARDH.

PL. XIII – XIV, and Fig. 27.

Till. Alg. Systematik, VI (1883) p. 66, Tab. II, fig. 61; BOERGESEN, Mar. Alg.

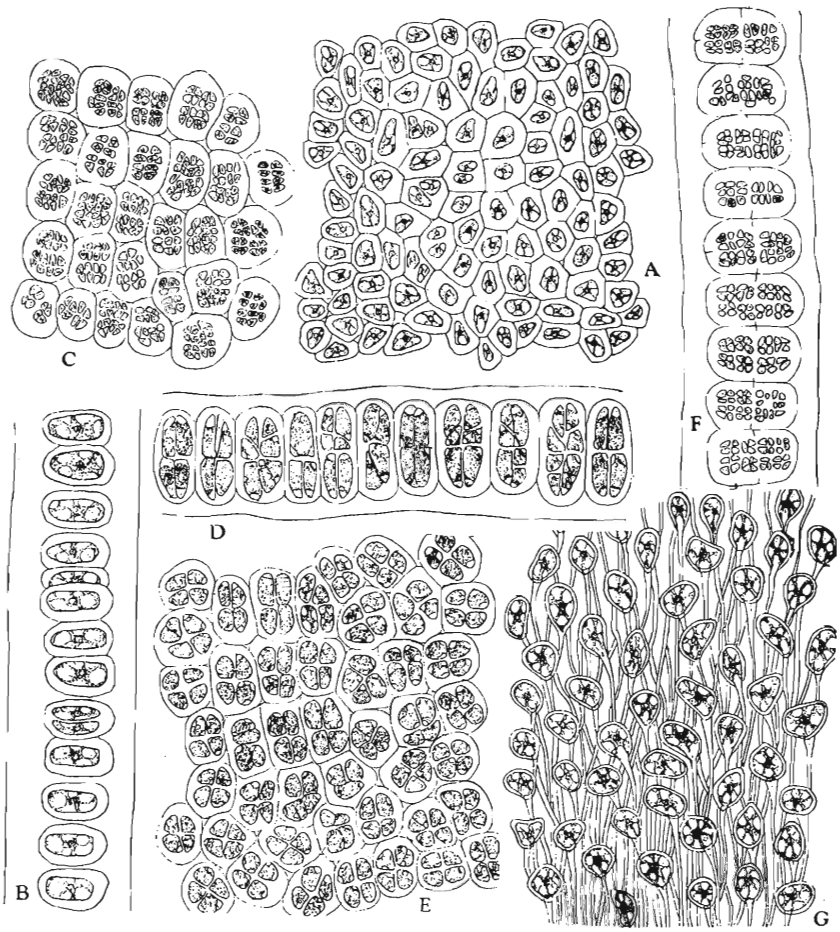



Fig.26. *Porphyra crassa* UEDA. A: Surface view of vegetative portion. × 210. B: Section of vegetative portion. ×210. C: Surface view of antheridial portion. ×210. D: Section of cystocarpic portion. × 210. E: Surface view of cystocarpic portion. × 210. F: Section of antheridial portion. × 210. G: Lower most cells with rhizoidal filaments. × 160.

Faeröes (1902) p. 348; ROSENVINGE, Mar. Alg. Denmark, I (1901) p. 60, pl. I et II, figs. 1–3; RAKOWITZ, Die Algenflora der gesamt, Ostsee (1929) p. 299, fig. 406–408; NEWTON, Handbook British Seaweeds (1931) p. 240, fig. 146; UEDA, l. c., p. 31, pl. 1, figs. 10, 11, 15, pl. VII, figs. 6–16, pl. VIII, fig. 1, pl. XX, figs. 1–3, pl. XXXI, figs. 1–2; NAGAI, Meeresalg. a. Kamtchatka (1933) p. 17; TOKIDA, Mar. Alg. Robben Isl. (suppl. rep.) (1934) p. 18, pl. II; YAMADA, Mar. Alg. Urup (1935) p. 21, pl. VII; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 388; KAWABATA, List Mar. Alg. Isl. Shikotan (1936) p. 207; TAKAMATU, Mar. Alg. Kinkwasan Island (1936) p. 58; Mar. Alg. Sanriku Coast (1938) p. 103, pl. XIII, fig. 2, Mar. Alg. Tsugaru Strait, Northeastern Honshû, Japan (1938) p. 31; NAGAI, Mar. Alg. Kurile Islands, II (1941) p. 141; YAMADA and TANAKA, Mar. Alg. in the Vicinity of the Akkesi Mar. Biolog. Station (1944) p. 67.

*Ulva umbilicalis* LINNAEUS, Sp. Plant., er 2 (1753) p. 1633.

*Porphyra laciniata var. umbilicalis* AGARDH, Icon. Europ. (1828–'35) tab. XXVI.

*Porphyra laciniata* THURET, in Le Jolis, Liste Alg. Mar. Cherbourg (1863) p. 99.

*Wildemania umbilicalis* DE TONI, Syll. Alg., IV (1397) p. 20.

*Porphyra laciniata* HUS, West coast *Porphyras* (1900) p. 62, Account *Porphyra* Pacific N. America (1902) p. 196.

Japanese name. *Tisima-kuronori.*

Hab. Kurile Islands; Northeastern part of Hokkaido; Northern part of Honshû.

Distrib. North Atlantic Occean; Arctic Sea; Alaska; Kamtschatka and Japan; North America.

Frond membranaceous, monostoromatic, but rarely distoromatic, round to oblong-lanceolate, often linear, slightly or sometimes strongly crenate on the margin, with cordate or umbilicate base, shortly stipitate 8–30 cm long, 4–10 cm broad, 34–58 $\mu$ thick; vegetative cells, in surface view round, more or less irregularly arranged, in cross section rectangular with round angles or two times as high as broad; surface jelly rather thick; lower most cells projecting rhizoidal filaments usually ovate-capitate; each cell containing stellate chromatophore with several short arms radiating in all directions; dioecious or monoecious; sporocarps and antheridia formed respectively within narrow zones on the marginal of the upper part of the different thalli; frond dividing by a longitudinal limiting line into a male and female portion in monoecious plant; cystocarp dividing into 32 carpospores according to the formula, $32\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$; each antheridium containing 128 antherozoids according to the formula, $128\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$; colour of the frond light purplish red or hydrangea red, sometimes dull blue violet when old.

The present species has been found on rocks gregariously in the highest part of the sublittoral zone facing to the surf. The shape and size of the frond are very variable. According to UEDA, the present species is almost monostoromatic, but rarely distoromatic. The plant is dioecious or monoecious. In the dioecious plant, the antheridial and sporocarpic patches are found on

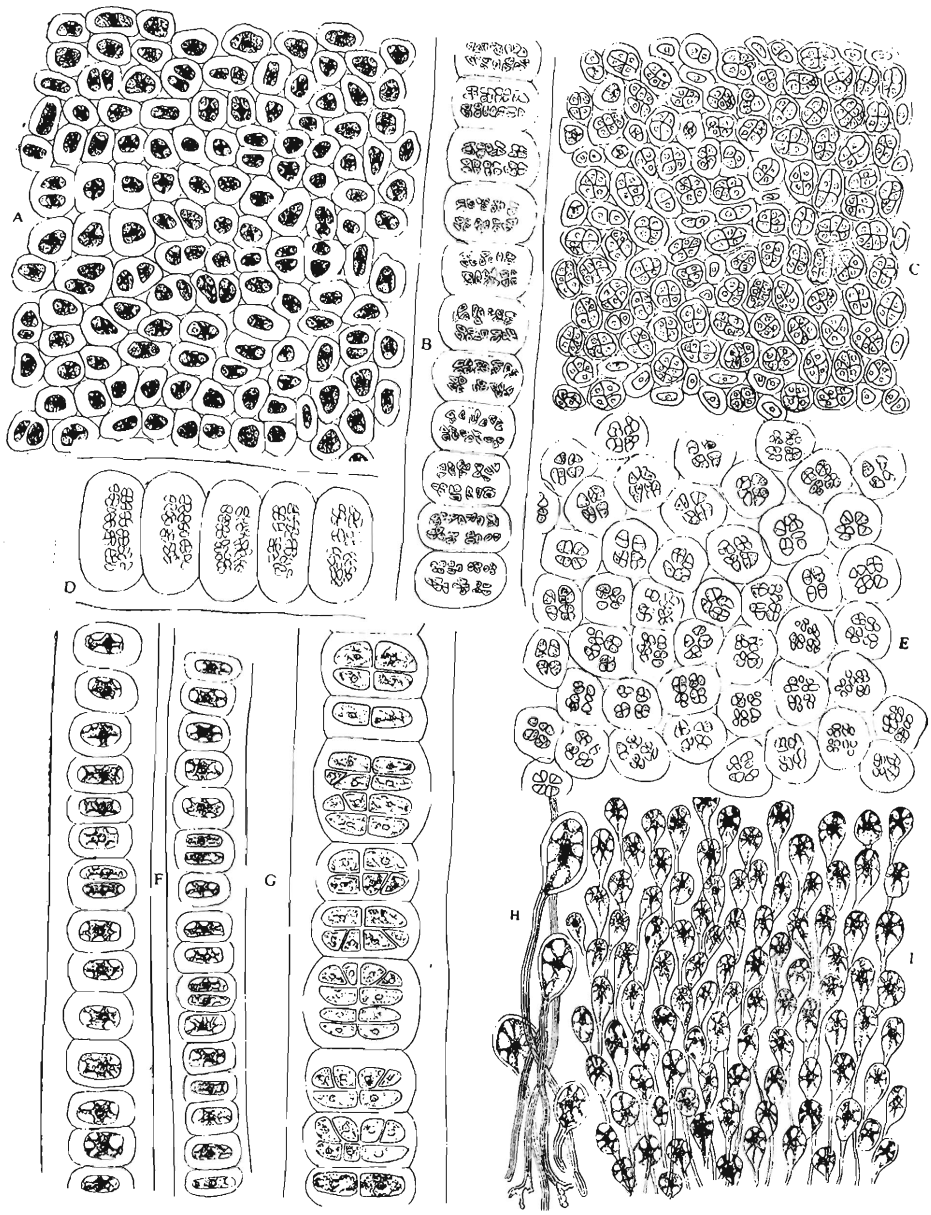



Fig. 27. *Porphyra umbilicalis* (L.) J.AGARDH. A: Surface view of vegetative portion. × 220. B: Section of antheridial portion. × 220. C: Surface view of cystocarpic portion. × 640. D: Section of antheridial portion. × 220. E: Surface yiew of antheridial portion. × 220. F: Section of vegetative portion. × 220. G: Section of cystocarpic portion. ×220. H-I: Lower most cells with rhizoidal filaments. H: ×220, I: × 140.

the marginal zone of the different thalli. The antheridia are divided into 128 antherozoids, according to the formula, 128 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$, as ascertained respectively by HUS and UEDA. As to the antherozoids, UEDA described them as 128 or 256 in number, according to the formula, 128 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$ or 256 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{16}\right)$.

In our specimens, however, only 128 antherozoids are count in an antheridium.

The sporocarps are divided into 32 carpospores according to the formula, 32 $\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$, as already ascertained by UEDA. In monoecious plant, the frond is generally divided by a longitudinal limiting line into a male and female portion, distinguished thereby that margin of the first is yellowish white, and that of the second is purple. The limiting line is most often straight; it is very distinct towards margin, while downwards it becomes indistinct and finally vanishes on reaching the sterile portion of the frond. But often it attains to the basal part. In some specimens the male and female parts of the frond are divided equally, while in the other ones the female part is often broader than the male ones. As to the structure of male and female organs of the frond, ROSENVINGE describes it, "According to HUS (1902, p. 197), the sporocarps and antheridia in *Porphyra laciniata* (*umbilicalis*) when they are developed in the same frond, "occure in patches very much as in *P. perforata*". If that is really normal to the species of the Pacific coast, it must be supposed that it is a different species from the European *P. umbilicalis*".

The first record of the present species is that by LINNAEUS in his "Species Plantarum" under the name of *Ulva umbilicalis*. The Japanese species accords well with the description and figures of *P. umbilicalis* given by J. AGARDH and by ROSENVINGE respectively. And it also accords well to the description given by HUS, in the essential characters, except the difference of the division mode of carpoapores. According to HUS, the sporocarps of *P. umbilicalis* are divided into 16 $\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$, but those of the writer's specimens are divided according to the formula, 32 $\left(\frac{a}{2}\ \frac{b}{4}\ \frac{c}{4}\right)$ each difference in the formula of division has already been pointed out by UEDA. The writer has been able to compare his specimens with several European and American ones in YAMADA's Herbarium.

### *f. linearis* (GREVILLE) HARVEY

PL. XIV, 2.

Phyc. Brit., II (1849) pl. CCXI, fig. 2–3; THURET, in LE JOLIS, Liste Alg. Mar. Cherbourg (1863) p. 99; ROSENVINGE, l. c., p. 60, pl. II, fig. 1–3; UEDA, l. c., p. 33, pl. XXI, figs. 1–2; NAGAI, Mar. Alg. Vicinity Akkesi Mar. Biolog. Station (1944) p. 68.

*Porphyra linearis* GREVILLE, Alg. Brit. (1830) p. 170, Tab. XVIII; KUETZING, Tab, Phyc., Tab. 70, figs. g–i,

*Wildemania linearis* DE TONI, l. c. (1897) p. 22.

Japanese name. *Hosaba-tisimakuronori.*

Hab. Usisiru Island, Simusiru Island and Uruppu Island, Middle Kurile Islands; Etorofu Island and Kunasiri Island, Souht Kurile Islands; Akkesi, Hokkaido; Robben Island, Saghalien.

Distrib. Atlantic Ocean and Japan.

Frond usually linear or linear-lanceolate, shortly stipitate, with cuneate or cordate base, 8 – 25 cm long, 1.5 – 6 cm broad, 35 – 75 $\mu$ thick, with a slightly or not undulate margin.

The plant which the writer refers to the present forma is usually linear in shape, always provided with a very distinct but short and slightly or not undulate at margin. The present forma has a very close resemblance to *P. pseudolinearis* UEDA, which is, however, different from it by the shape of the vegetative cells and the structure of the reproductive organs. In fact, the material collected from Akkesi, Hokkaido is as a rule dioecious, but that from Kurile Ialands is often monoecious. The colour of the frond is peculiar dull blue violet. The plant is often found in the month of late July to September in Kurile Islands.

## *f. vulgaris* (AGARDH) THURET

PL. XIV, 1.

In LE JOLIS, Liste Alg. Mar. Cherbourg (1863) p. 99; ROSENVINGE, l. c., p. 60; NAGAI, l. c., p. 141.

*Porphyra vulgaris* AGARDH, Icon. Alg. Europ. (1828 – '35) Tab. XXVIII; GREVILLE, l. c., p. 169; HARVEY, l. c., pl. CCXI, fig. 1; KUETZING, l. c., XIV, Tab. 82, Figs. a – b.

Japanese name. *Nagaba-tisimakuronori.*

Hab. Paramusiru Island, North Kurile Islands; Usisiru Island and Uruppu Island, Middle Kurile Islands; Etorofu Island and Kunasiri Island, South Kurile Islands; Sikotan Island; Kinkwazan, Rikuzen Prov.; Iwaya, Mutu Prov.

Distrib. Atlantic Ocean and Japan.

Frond lanceolate, oblong-lanceolate or oblong, with slightly undulate margin, shortly stipitate, 15 – 38 cm long, 15 – 17 cm broad, 28 – 42 $\mu$ thick, cuneate or cordate at the base.

Most of the specimens referable to the present forma, are often sterile, but some bear antheridia only. In the latter specimens, the antheridia are formed within yellowish zones on the margin of the upper and middle part of the frond. The colour of the frond is light purplish red or peculiar greenish purple.

## *f. laciniata* (LIGHTFOOT) THURET

PL. XIII.

In LE JOLIS, Liste Alg. Mar. Cherbourg (1863) p. 99; BORNET et THURET, Etudes Phycologique (1876) p. 58, pl. 31; ROSENVINGE, l. c., p. 61, pl. 1, fig. 2; UEDA, l. c., p. 33, pl. XX, figs. 1 – 3.

*Ulva laciniata* LIGHTFOOT, in Flora Scotia (1777) p. 974, Tab. XXXIII.

*Porphyra laciniata* AGARDH, Syst. Alg. (1824) p. 190 Icon. Alg. Europ., Tab.

XXVII; GREVILLE, l. c., p. 168; HARVEY, l. c., pl. XCII; KUETZING l. c., Tab. 82, figs. c–e; GRUNOW, Algae von Novara (1868) p. 58; HAUCK, Meeresalg. Deutch. und Oesterreich (1885) p. 26, fig. 2; HUS, Preliminary notes West coast *Porphyra* (1900) p. 62, Account *Porphyra* Pacif. coast North America (1902) p. 196; SETCHELL and GARDNER, Alg. Northeastern Amer. (1903) p. 289; YENDO, Notes Alg. New Japan (1909) p. 127; OKAMURA, Nippon Sorui Meii (1902) p. 8; SINOVA, Alg. Kamtschatka (1932) p. 29, Les Alg. de la Mer. du Japon (1940) p. 46, Alg. of the Commander Island (1941) p. 204.

*Wildemania laciniata* DE TONI, l. c., (1897) p. 20.

*Porphyra laciniata f. typica* KJELLMAN, Alg. Arctic Sea (1883) p. 190.

Japanese name. *Maruba-tisimakuronori.*

Hab. Araido Island and Paramusiru Island, North Kurile Islands; Onnekotan Island; Ketoi Island, Simusiru Island and Uruppu Island, Middle Kurile Islands; Etorofu Island and Kunasiri Island, South Kurile Islands; Shikotan Island; Rausu, Hokkaidō; Kinkwazan, Rikuzen Prov.; Onahama, Iwaki Prov.

Distrib. Atlantic Ocean; Arctic Ocean; Alaska; Kamtschatka; Japan.

Frond round or oblong-vate when young, becoming expanded broadly above and much lobed into laciniate at maturity, shortly stipitate, with cordate base, 6–18 cm long, 7–14 cm broad, 30–47 $\mu$ thick.

The specimens at hand referable to this forma, and round ovate sometimes oblong-obovate in shape, being not laciniate when young. When matured, they expand broadly above, often becoming asymmetrical, in the monoecious plant, as the antheridial area becomes to be broken away as soon as the sporocarp begins division. The present forma becomes much undulate and folded on the surface of irregular development and sometimes the frond is divided into several laciniae above. The material collected from Rausu, Hokkaido has comparatively small size. It attains about 4 cm in length and 2.5 cm in broadth at its broadest part, and about 28 $\mu$ in thickness. The colour of the frond is light purplish red or peculiar dull violet.

## *Porphyra Onoi* UEDA

PL. XVI. and Fig. 28.

l. c., p. 34, pl. 1, figs. 4. 12, pl. VIII, figs. 2–10, pl. XXI, figs. 3–4; INAGAKI, Mar. Red Alg. Oshoro Bay (in Japanese, 1933) p. 16; TOKIDA, Phycolog. Observation, II; On the structure of *P. Onoi* UEDA (1935); OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 389; TAKAMATU, Mar. Alg. Tsugaru Strait (1938) p. 30, pl. VII, fig. 4.

*Porphyra abyssicola* (non KJELLMAN) UEDA, l. c., p. 39, pl. 1, figs.5, 10, pl. X, figs. 4–5, pl. XXIX, fig. 2; YAMADA and TANAKA, Mar. Alg. Vicinity Akkesi Mar. Biolog. Station (1944) p. 67.

Japanese name. *Ōno-nori.*

Hab. Found in colder waters, ranging from Mutu Prov. to Northeastern coast of Hokkaido.

Distrib. Endemic.

Frond membranaceous, monostoromatic or distromatic, ovate or oblong-ovate with very undulate margin, shortly stipitate, lustrous, 5–15 cm. long, 3–8 cm

broad, 28–45 $\mu$ thick, cordate at the base, vegetative cells in surface view usually round or elliptic, ca. 10–28 $\mu$ in diameter, more or less irregularly arranged, in cross section rectangular with round angles, two times as high as broad; surface jelly rather thin; vegetative cell containing one of two irregular, stellate chromatophore and a central pyrenoid; monoecious; antheridia and cystocarps both formed respectively within distinct marginal zones in the same thallus; cystocarps containing 8 carpospores each after having divided according to the formula, $8\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{2}\right)$; antheridium containing 64 antherozoids each after having divided according to the formula, $64\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{4}\right)$; colour of the frond purplish red or cerise.

The present species is always epiphytic on other algae, e.g. *Iridophycus cornucopiae* (POST. et RUPR.) SETCH. et GARDN., *Rhodglossum pulchrum* (KG.) SETCH. et GARDN., *Chondrus pinnulatus* (HARV.) OKAM., etc. The plant is usually ovate to oblong-ovate in shape. While the young frond is liable to be more or less round and with slightly undulate margin, older specimens, however, are liable to be much undulate on the margin. The frond is for the most part composed of one layer of cells, and in portions, it is often distromatic. The frond is light reddish purple or cerise. The vegetative cell of the red-algae belonging to Protoflorideae, is well known to have usually a single stellate chromatophore with one pyrenoid in the center.

As the structure of the cell content, TOKIDA (l.c.) noted that the vegetative cells of *P. Onoi* UEDA, in the monostromatic part of the frond, contained two eccentric chromatophores, in the distromatic part of the frond, however, they contained only one parietal chromatophore, but not the center one. The chromatophore of the present species has quite peculiar character among the species of *Porphyra*. Therefore TOKIDA (l.c.) established a new subgenus *Diploderma* in 1935.

The present species is monoecious. The sporocarps and antheridia are both formed within narrow, margin zones of the same thallus.

The antheridial patches are yellowish and sporocarpic ones, as a rule, slightly darkish purple. The antheridium mother cells are at first divided into fonr parts by a cruciate division perpendicular to the surface of the frond. Subsequent divisions parallel to the surface take place twice; followed twice, by other perpendicular ones. Each antheridium containes 64 antherozoids.

The sporocarps are divided by a cruciate divisions, perpendicular to the surface of the frond. into four carpoapores, being followed a divisions parallel to the surface of the frond. These divisions give rise to two tiers of four carpoapores each. Each cystocarp contains 8 carpospores.

The abundant materials at hand, accord well with the description of the present species given by UEDA. In general appearance, *P. Onoi* UEDA is quite simiar to *P. abyssicola* KJELLMAN, but differs from it in the division-modes of cystocarpa and antheridia. According to HUS, the formation of the divisions modes of cystocarps and that of antheridia of *P. abyssicola* are as followed; cystocarp, $4\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{1}\right)$ and antheridium, $8\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{2}\right)$.

UEDA reported *Porphyra abyssicola* KJELLMAN, in his "*Porphyra* of Japan" from the northeastern coast of Hokkaido. According to UEDA's description, *P. abyssicola* KJELLMAN differs from *P. Onoi* UEDA, by the distromatic frond and

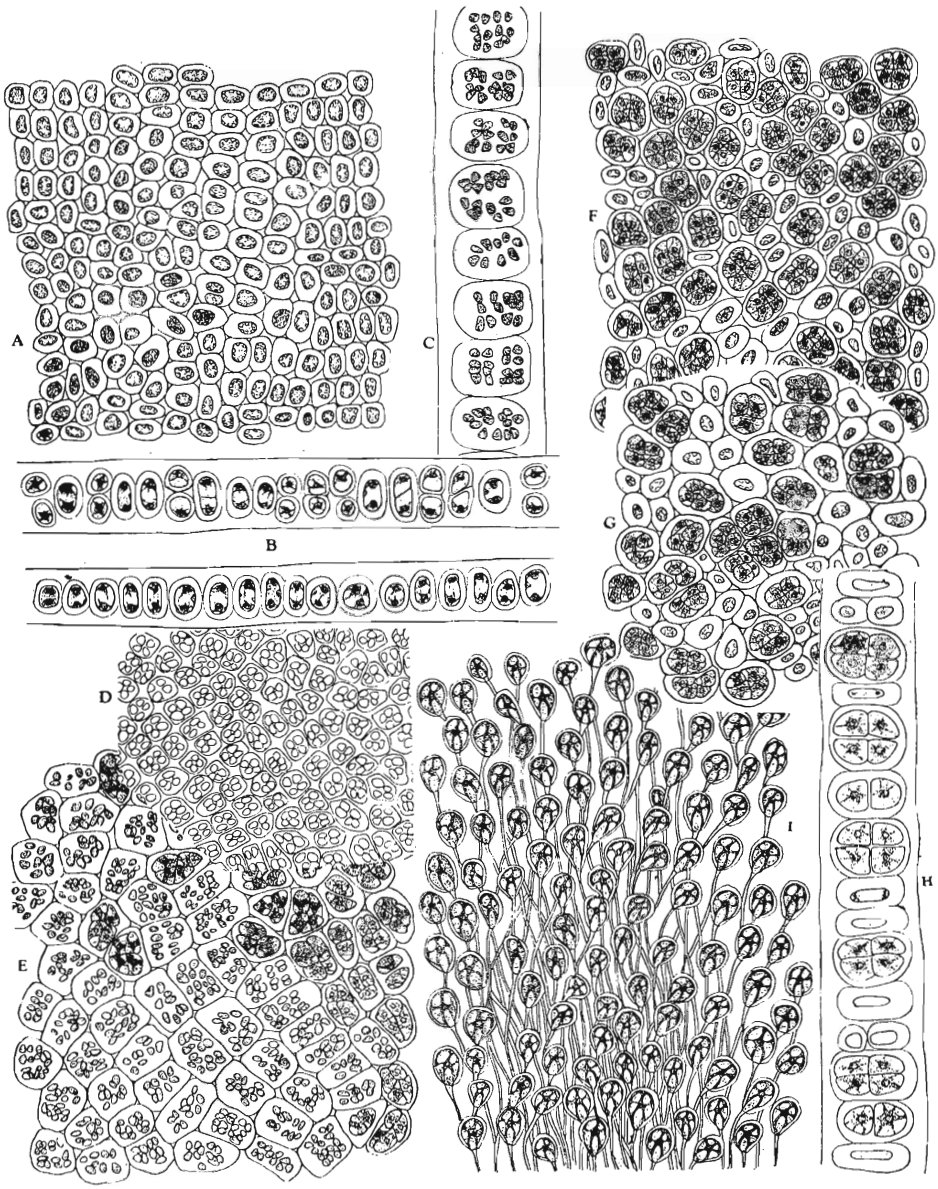



Fig. 28. *Porphyra Onoi* UEDA. A: Surface view of vegetative portion. × 130. B: Section of vegetative portion. × 150. C: Section of antheridiial portion. × 150. D - E: Surface view of antheridial and cystocarpic portion. ×150, F - G: Surface view of cystocarpic portion. × 150. H: Section of cystocarpic portion. × 150. I; Lower most cells with rhizines. × 130.

the division modes of sexual cells. After careful examination of abundant materials from northeatern coast of Hokkaido (Kusiro, Akkesi, Kiritappu and Nemuro etc.), the present writer has come to the conclusion that the *P. abyssicola* (non KJELLMAN) UEDA is the same as *P. Onoi* UEDA.

## *Porphyra Tasa* (YENDO) UEDA

PL. XVII, 2. and Fig. 29.

l. c., p. 35, pl. 1, figs. 10, 16, pl. VIII, fig. 11, pl. IX, fig. 1 – 6, pl. XXII; YAMADA, Mar. Alg. Northern Kuriles (in Japanese, 1934) p. 347, Mar. Alg. Urup (in Japanese, 1934) p. 37, fig. 16, Mar. Alg. Urup (1935) p. 21; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 394; NAGAI, Alg. Kurile Islands, II (1941) p. 152, pl. IV, figs. 13 – 20.

*Wildemania Tasa* YENDO, Nov. Alg. Jap. (1920) p. 3.

Japanese name. *Tasa* or *Tasanori*.

Hab. Araido Island, Simusiru Island and Paramusiru Island, North Kurile Islands; Onnekotan Island, Rasyuwa Island, Usisiru Island, Simusiru Island and Uruppu Island, Middle Kurile Islands; Etorofu Island, South Kurile Islands; Sikotan Island.

Distrib. Endemic.

Frond coriaceo-pergameous, distromatic, seesile usually simple with undulate base, commonly longer than broad, slightly irregular in outline when young, becoming later expanded rather vigorously toward both lateral side rather than upwards, often dividing deeply into irregular lobes, perforate in the lower portion, 18 – 36 cm long, 14 – 36 cm broad, 110 – 180 $\mu$ thick; vegetative cells, in surface view, quadrate with round corners, about 25 $\mu$ in diameter, more or less irregularly arranged, in cross section rectangular with round angles, about twice as long as broad; surface jelly rather thin, 10 – 16 $\mu$ in thickness; lower most cell projecting rhizoidal filaments almost spherical, irregularly arranged; each cell containing steliate chromatophore and a central pyrenoid; monoecious or andro-dioecious; antheridia and cystocarps formed respectively within distinct, narrow marginal zones of the frond; each antheridium containing 128 antherozoids, after having divided according to the formula, $128\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{8}\right)$; each cystocarp containing 4 carpospores, after having divided according to the formula, $4\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{1}\right]$; colour of the frond grayish purple or peculiar reddish hazel.

The present species grows abundantly on rocks in the upper littoral belt. As already mentioned by YENDO and UEDA, the present species is as a rule monoecious. According to NAGAI, however, it is dioecious. As far as the present writer's observation show, this species is often andro-dioecious. that is, on the male frond only antheridia are formed and on the female frond there are produced small antheridial patches among the sporocarpic area. The antheridium patches are yellowish white, and the sporocarpic ones are as a rule brownish red or dark purple, but rarely taking yellow hue added here

and there with pink. The antheridium mother cells are at first divided by cruciate division perpendicular to the surface of the frond, followed continuously three times by the parallel and second perpendicular divisions. An antheridium contains 128 antherozoids, arranged in four tiers of four each in surface views.

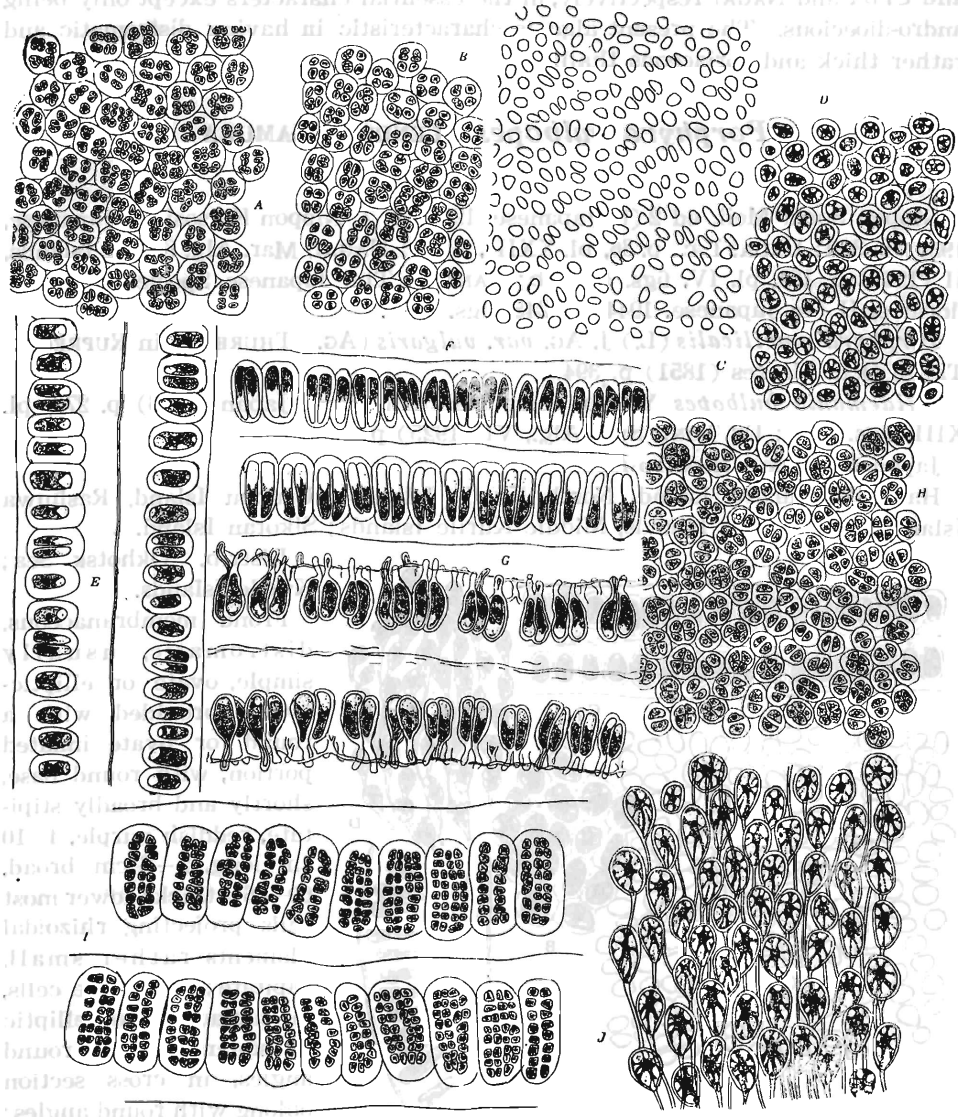



Fig. 29. *Porphyra Tasa* (YENDO) UEDA. A - B: Surface view of antheridial portion. ×200. C - D: Surface view of vegetative portion. C: ×120, D, ×200. E. Section of vegetative portion. ×200. F - G: Section of cystocarpic portion. ×200. H: Surface view of cystocarpic portion. ×200. I: Section of antheridial portion. ×200. J: Lower most cells with rhizoidal filaments, ×125,

The sporocarps are divided only by a cruciate division, perpendicular to the surface of the frond into four carpospores. The mature carpospores, in cross section, are oblong in shape and arranged in pairs.

The specimens at hand gathered from various localities in Kurile Islands, accord well with the description of *P. Tasa* (YENDO) UEDA, given by YENDO and UEDA and NAGAI respectively, in the essential characters except only being andro-dioecious. The present alga is characteristic in having distromatic and rather thick and coriaceous thallus.

## *Porphyra bulbopes* (YENDO) OKAMURA

PL. XVIII - XX. and Figs. 30 - 31.

Nippon Sorui Meii, ed 2 (in Japanese, 1916) p. 7, Nippon Kaisosi (in Japanese, 1936) p. 390; UEDA, l. c., p. 36, pl. XXIII, fig. 1; NAGAI, Mar. Alg. Kurile Islands, II (1941) p. 154, pl. IV, figs. 4, a - b; TANAKA, The Japanese Species of Protofloridae, II (in Japanese, 1944) p. 248, figs. 1 - 7.

*Porphyra umbilicalis* (L.) J. AG. *var. vulgaris* (AG.) THURET a. in RUPRECHT, Tange Och. Meeres (1851) p. 394.

*Wildemania bulbopes* YENDO, Some New Alg. from Japan (1913) p. 276, pl. XIII, figs. 1 - 9; DE TONI, Syll. Alg., VI (1925) p. 13.

Japanese name. *Hukuro-tasa.*

Hab. Paramusiru Island, North Kurile Islands; Uruppu Island, Rashuwa Island and Simusiru Islands, Middle Kurile Islands; Sikotan Island.

Distrib. Okhotsk Sea; Kurile Islands.

Frond membranaceous, distromatic, usually simple, ovate or elliptic-ovate, provided with a round or ovate inflated portion, with round base, shortly and broadly stipitate, reddish purple, 4 - 10 cm long, 2 - 6 cm broad, 60 - 86 $\mu$ thick; lower most cells projecting rhizoidal filaments rather small, capitate; vegetative cells, in surface view, elliptic or squarish with round angles, in cross section oblong with round angles; surface jelly rather thin; each cell containing stellate chromatophore and a central pyrenoid within it; monoecious; anther-

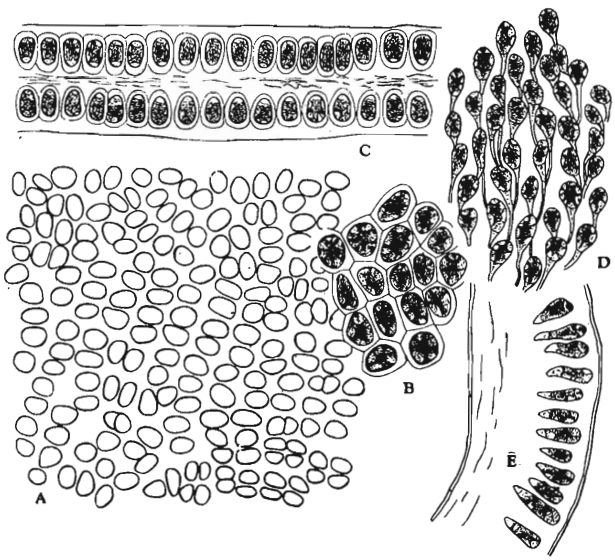



Fig. 30. *Porphyra bulbopes* (YENDO) OKAMURA. A: Surface view of vegetative portion. ×300. B: Surface view of frond. ×460. C: Section of vegetative portion. ×300. D: Lower most cells with rhizines. ×300. E: Section of inflated portion. ×300.

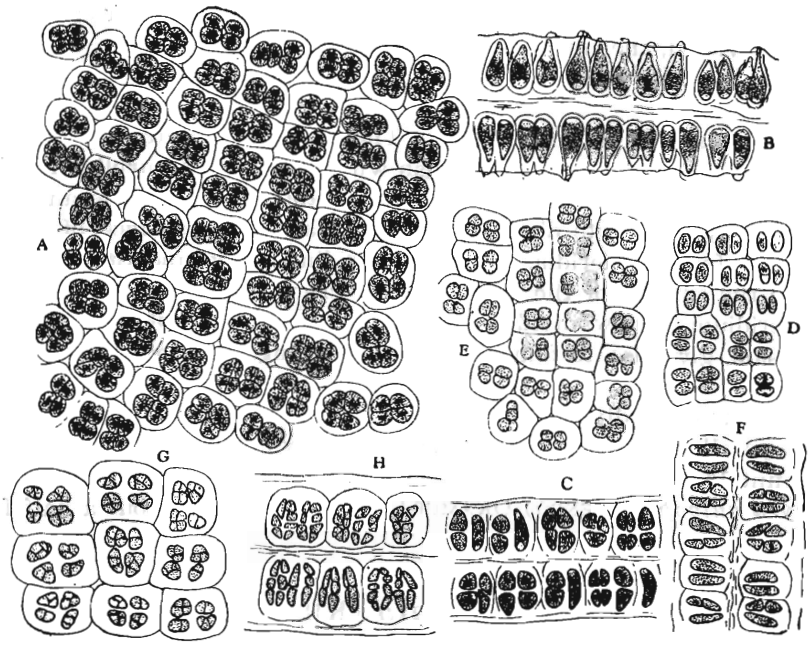



Fig. 31. *Porphyra bulbopes* (YENDO) OKAMURA. A: Surface view of cystocarpic frond. ×200. B-C: Section of cystocarpic portion. ca. ×200. D-E: Surface view of antheridial portion. ×195. G: Surface view of mature antheridial portion. ×195. F, H: Section of antheridial portion. ca. ×195.

idial and sporocarpic regions divided by a longitudinal limiting line into two parts; antheridia containing 64 antherozoids, after having divided according to the formula, 64 $\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{4}\right)$; cystcarp containing 16 carpospores, after having divided according to the formula, 16 $\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$.

The present species grows on rocks in the upper sublittoral zone. The first record of the present species was made by YENDO in his "Some New Algae from Japan" under the name of *Wildemania bulbopes* YENDO, and it was latter revised by OKAMURA as *Porphyra bulbopes*. YENDO noted in his description of this species, as follows; In the herbarium of the Academy Science in St. Petersburg, I found similar specimens collected at Behring Island, Kamtschtka, in 1847. They were determind by RUPRECHT as "*Porphyra umbilicalis vulgaris* AG. a". They form is metioned in his Tange des Ochotischen Meeres, p. 394, but with only a short description. He seems not to have noticed the characteristic inflation at the base, or at least to have attached little importance to it; but the peculiarity is so remarkable, that when we put the fresh specimens in water for mounting, all the fronds have, in the water with the inflated base, floating on the surface."

Because of the presence of the peculiar inflation of the frond, *Porphyra bulbopes* (YENDO) OKAMURA is easily identifiable. The inflated part is observed

not only in the base, but also in the marginal portion of the frond. In some extreme individual, the inflated part extends all over the frond. The stipe is short, and is rather wide and thick for the size of the frond, and cushion-shaped at the base.

The present species is monoecious. The frond is generally divided by a longitudinal limiting line into a yellowish white male and a purplish red female portion. The limiting line is most often remarkably straight. The antheridium mother cells by a cruciate division perpendicular to the surface of the frond, give rise to fonr antheridia. Each antheridium now undergoes a division parallel to the surface of the frond, then a cruciate division in all segments. The antheridium is now divided into sixteen parts, each of which, by a cruciate division, give rise to four antherozoids arranged in four tiers of sixteen each.

The cystocarp first divides cruciately, giving rise to four cells. Subsequently divisions parallel to the surface takes place, twice; in this case, the carpospores count 16 in number.

*Porphyra bulbopes* (YENDO) OKAMURA is found usually about a half fathom deep in open places.

## *Porphyra variegata* (KJELLMAN) HUS

PL. XXI. and Fig. 32.

Prelim. notes west coast *Porphyras* (1900) p. 69, Accont *Porphyra* Pacific Coast N. America (1903) p. 225, pl. XXI, fig. 18; SETCHELL and GARDNER, Alg. Northeastern America (1903) p. 291; UEDA, l. c., p. 38, pl. 1, fig. 9, pl. IX, fig. 7, pl. X, figs. 1–3, pl. XIV, figs. 1; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 391; KAWABATA, Liste Mar. Alg. Isl. Shikotan (1936) p. 207; TAKAMATU, Mar. Alg. Sanriku Coast Northeastern Honshû, Japan (1938) p. 103, pl. XIII, fig. 3; NAGAI, Mar. Alg. Kurile Ialsnds, II (1941) p. 148; YAMADA and TANAKA, Mar. Alg. Vicinity Akkesi Mar. Biolog. Station (1944) p. 67.

*Diploderma variegata* KJELLMAN, Beringhafv. Algenf. (1889) p. 33, pl. II, figs. 1–4.

*Wildenmania variegata* DE TONI, Syll. Alg., IV (1897) p. 23, VI (1924) p. 13.

*Porphyra miniata f. amplissima* (non ROSENVINGE) YENDO, Notes on Alg. New to Japan, I (1909) p. 126.

Japanese name. *Huiri-tasa.*

Hab. Found in the northern Pacific of Japan; Okuziri Island, Suttu. Oshoro. Japan Sea side of Hokkaidō; Northern part of Honshû, ranging from Kurile Islands to Sanriku coast; Sikotan Island; Kunasiri Island, Kurile Islands; Saghalien.

Distrib. Bering Sea; Pacific coast of America; Japan.

Frond membranaceous, distromatic, sessile, areolate, variegata, oblong-ovate to broad-lanceolate, but usually unilaterlly recurved with slightly undulate margin, with rounded or cordate base, 10–36 cm long, 8–18 cm broad, 80–185 $\mu$ thick; vegetative cells, in surface view, angulate with round corners, 28–42 $\mu$ in diameter, more or less regularly arranged in cross section quadrate with round angles or little higher than broad, 46–58 × 28–36 $\mu$; surface jelly very

thick; lower most cells projecting rhizoidal filaments usually round; each cell containing a stellate chromatophore which sends several slender arms radiating in all directions, and with a central pyrenoid; monoecious; young frond generally divided by a longitudinal limiting line into a yellowish white male and a purplish red female portion; antheridium containing 64 antherozoids, arranged in four tiers of four each in surface view, according to the formula,

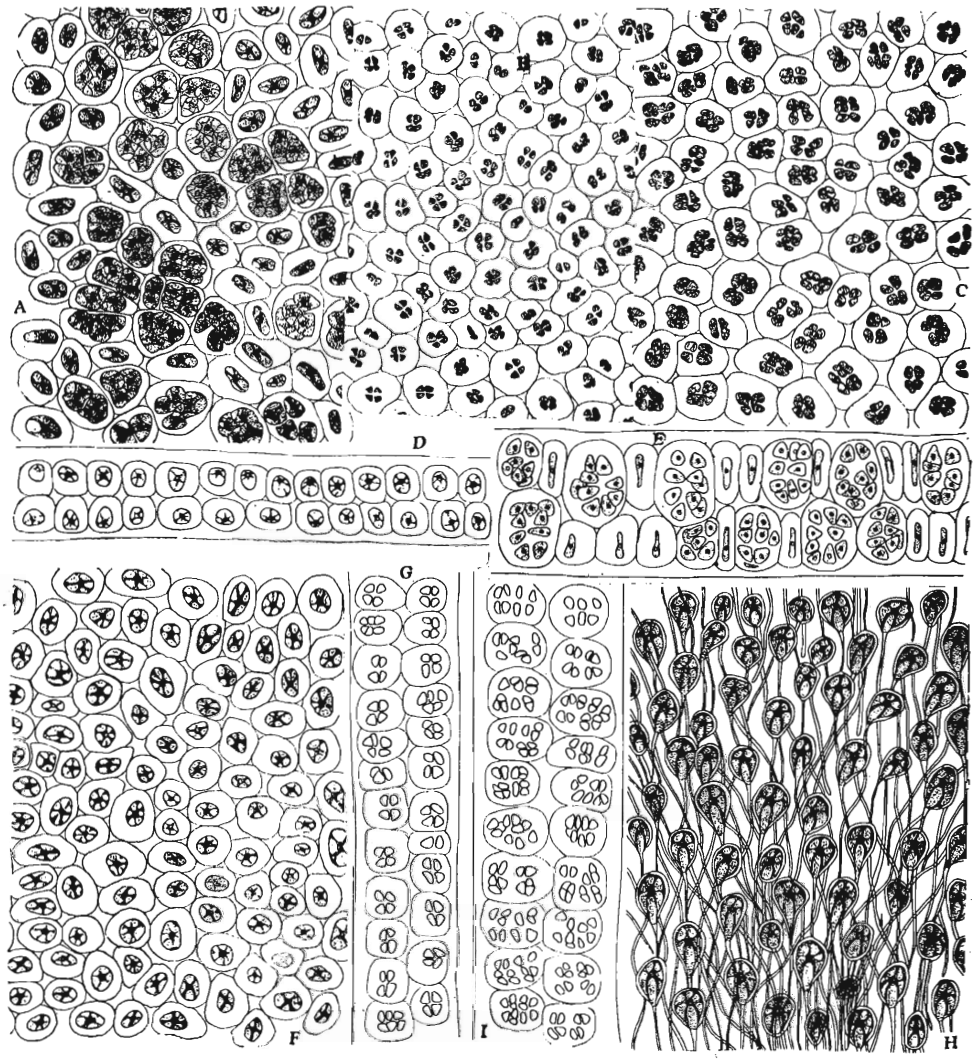



Fig. 32. *Porphyra variegata* (KJELLMAN) HUS. A; Surface view of cystocarpic frond. ×185. B-C: Surface view of antheridial portion. ×185. D: Section of vegetative portion. ×185. E: Section of cystocarpic portion. ×185. F: Surface view of vegetative portion. ×185. G.-I: Section of antheridial portion. ×185. H: Lower most cells with rhizoidal filaments. ×185.

$64\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{4}\right)$; sporocarp scattering over the whole frond, containing 16 carpospores each after having divides according to the formula, $16\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$; colour of the frond light purplish red but gloomy red when old.

The present species is always epiphitic upon the thallus of other plants, e.g., *Phyllospadix* sp., *Tichocarpus crinitus*, *Odonthalia corymbifera*, *Ptilota pectinata*, *Chondrus pinnulatus*, *Cystophyllum hakodatense* etc. The abundant matarials examined contain two forms. The one agrees quite well with the description of the present species, given by KJELLMAN, HUS, UEDA and NAGAI, etc. respectively. The other is usually round or ovate in shape, and not unilaterally recurved. At first sight, these two forms give impression as if they were two different species. However, it has become clear that the one form is nothing but the younger stage of the other, and the various intermediate forms between these two forms have been found by further observation. The younger frond is usually oblong-ovate or broad-lanceolate in shape. It is often divided by a longitudinal limiting line into a male and a female portions, as already Dr. NAKAMURA observed, distinguishable thereby, that the margin of the first is yellowish white, but that of the second is purplish red. The limiting line is mostly straight or slightly recurved; it is very distinct from the marginal portion to the base. In the young frond, the antheridia are already matured and completed their division, however, at this time fertilized cystocarps can hardly be found. After male portion of the frond decayed away and disappeared, the female portion is gradually becomes larger and developed, especially into the outer marginal region of the frond. The older frond is unilaterally recurved to take a large comma-shaped, with round base. The cystocarps are at first cruciately divided in surface view of the frond, then into four parts followed by the division parallel to the surface. The mature sporocarp is divided into sixteen carpospores. The maturation of the sporocarp does not proceed from a certain side evenly toward the opposite or inward, but occurs in every portion at random over the whole frond. Thus the sporocarps are formed intermixed among the vegetative cells. Such specimens take a characteristic variegata appearance.

The antheridium mother cells, by a cruciate division perpendicular to the surface of the frond, give rise to four antheridia. Each antheridium now undergoes a division parallel to the surface of frond, then a cruciate division perpendicular to the surface of the frond, followed by another parallel division in all segments. The antheridium is now divided into sixteen parts, each of which, by a cruciate division, gives rise to four antherozoids; so that the whole antheridium now consists of sixty-four antherozoids in four tiers of sixteen each.

This alga is usually found in the month of April – July in the comparatively lower part of the littoral zones.

In 1909, YENDO reported *P. miniata f. amplissima* ROSENVINGE from the specimens from Hakodate and Otaru, Hokkaido. It seems to the writer, however, very probable that it represents the younger stage of the frond of *Porphyra variegata* KJELLMAN.

## *Porphyra amplissima* (KJELLMAN) SETCHELL et HUS

PL. XVII, 1. XXII. XXIII. and Figs. 33–34.

In Hus. Prelim. notes West Coast *Porphyras* (1900) p. 67, account *Porphyras* Pacific Coast N. America (1902) p. 215, pl. XX, fig. 13, a–b; UEDA, l. c., p. 40, pl. 1, figs. 4–9, pl. X, figs. 6–7, pl. XI, figs. 1–5, pl. XXIV, fig. 3; YAMADA, Mar. Alg. N. Kurile (1934) p. 347; TOKIDA, Mar. Alg. Robben Isl. (1934) p. 19; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 392; KAWABATA, Liste Mar. Alg. Isl. Shikotan (1936) p. 204; NAGAI, Mar. Alg. Kurile Islands, II (1941) p. 147.

*Diploderma amplissima* KJELLMAN, Alg. Arct. Sea (1883) p. 188, pl. XVII, figs. 1–3, pl. XVIII, fig. 1–8.

*Diploderma amplissima f. typica* FOSLIE, Contrib. Mar. Alg. Norway (1890) p. 56.

*Wildemania amplissima* FOSLIE, Contrib. Mar. Alg. Norway, II (1890) p. 14; DE TONI, Syll. Alg., IV (1897) p. 24, VI (1924) p. 13.

*Porphyra miniata f. amplissima* ROSENVINGE, Grøend. Havalg. (1893) p. 827, Mar. Alg. Faeröes (1902) p. 347.

*Porphyra occidentalis* SETCHELL et HUS (non HUS) KAWABATA, List Mar. Alg. Isl. Shikotan (1936) p. 207; NAGAI, Mar. Alg Kurile Islands, II (1941) p. 147, pl. IV, figs. 9–12, 1. fiig. 3.

Japanese namae. *Beni-tasa.*

Hab. Araido Island, Simusyu Island and Paramusiru Island, North Kurile Islands; Onnekotan Island, Harumukotan Island, Matuwa Island and Uruppu Island, Middle Kurile Islands; Etorofu Island and Kunasiri Island, South Kurile Islands; Sikotan Island.

Distrib. Arctic Sea; Alaska; Washington; Japan.

Frond membranaceous, distromatic, elliptic to ovate or oblong-lanceolate, with broad-cuneate to round or cordate base, shortly stipitate, 15–58 cm long, 10–20 cm broad, 70–120 $\mu$ thick; vegetative cells, in surface view, angular with round corners, in cross section squarish with round angles or slightly higher than broad; lower most cells projecting rhizoidal filaments usually capitate; surface jelly rather thick; chromatophore star-shaped and a central pyrenoid within it; dioecious; sporocarps and antheridia are formed within distinct, marginal zones of the different thalli; sporocarp containing 8 carpospores each after divided according to the formula, $8\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{2}\right)$; antheridia containing 16 or 64 antherozoids each after divided according to the formula, $16\left(\frac{a}{2}\ \frac{b}{2}\ \frac{c}{4}\right)$ or $64\left(\frac{a}{4}\ \frac{b}{4}\ \frac{c}{4}\right)$; colour of the frond light purplish red or crimsonlake.

The present species grows gregariously on rocks in lower littoral zone or is found floating on the surface of the water. The shape of the frond is to a certain entent variable. The extreme forms are usually elliptical and lanceolate. Between these two forms, *f. elliptica* and *f. lanceolata*, a large number of intermediate forms may be observed. The diversity of form is perhaps due to a great extent to mechanical influence. The largest specimens attain up to

1 meter in length and 30 cm in its broadest part. The thickness of the frond is mostly 70 - 120 $\mu$, but rarely attains only 55 $\mu$. The thickness form, *f. crassa* KAWABATA, in Shikotan Island measures 145 – 165 $\mu$ in thickness.

According to KJELLMAN and HUS, the present species is as a rule monoecious. In our Japanese specimens, however, it is always dioecious. The present writer failed to obtained any monoecious plant. In the dioecious frond, the antheridia are found within the yellowish irregular patches on the marginal region of the upper part of the frond.

The antheridium mother cells are at first divided by cruciate division perpendicular to the surface of the frond, followed continuously two times by the

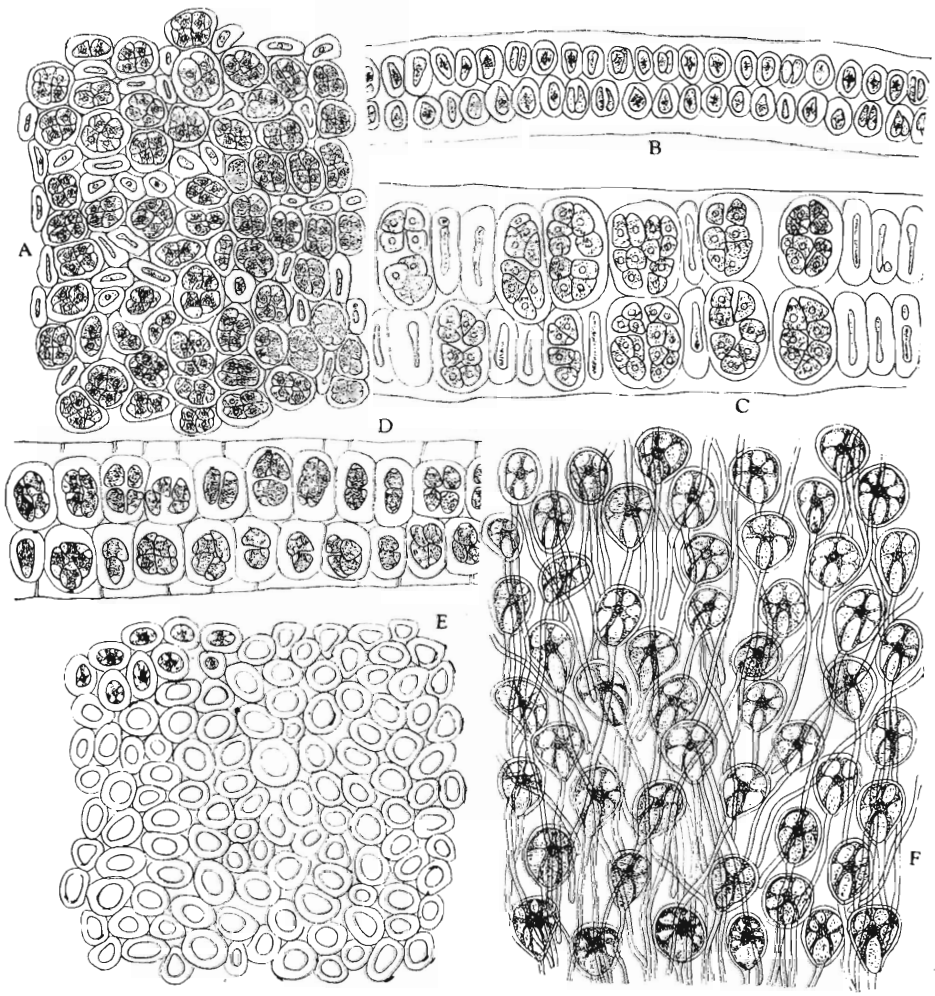



Fig. 33. *Porphyra amplissima* (KJELLMAN) SETCHELL et HUS. (Female plant.). A : Surface view of cystocarpic frond. ×220. B : Section of vegetative portion. ×175. C - D : Section of cystocarpic portion. C : ×280, D : ×220. E : Surface view of vegetative portion. ×175. F : Lower most cells with rhizoidal filaments. ×175.

parallel divisions. An antheridium contains 16 antherozoids, arranged in four tiers of four each.

As already Hus described the number of the divisions of the antheridium

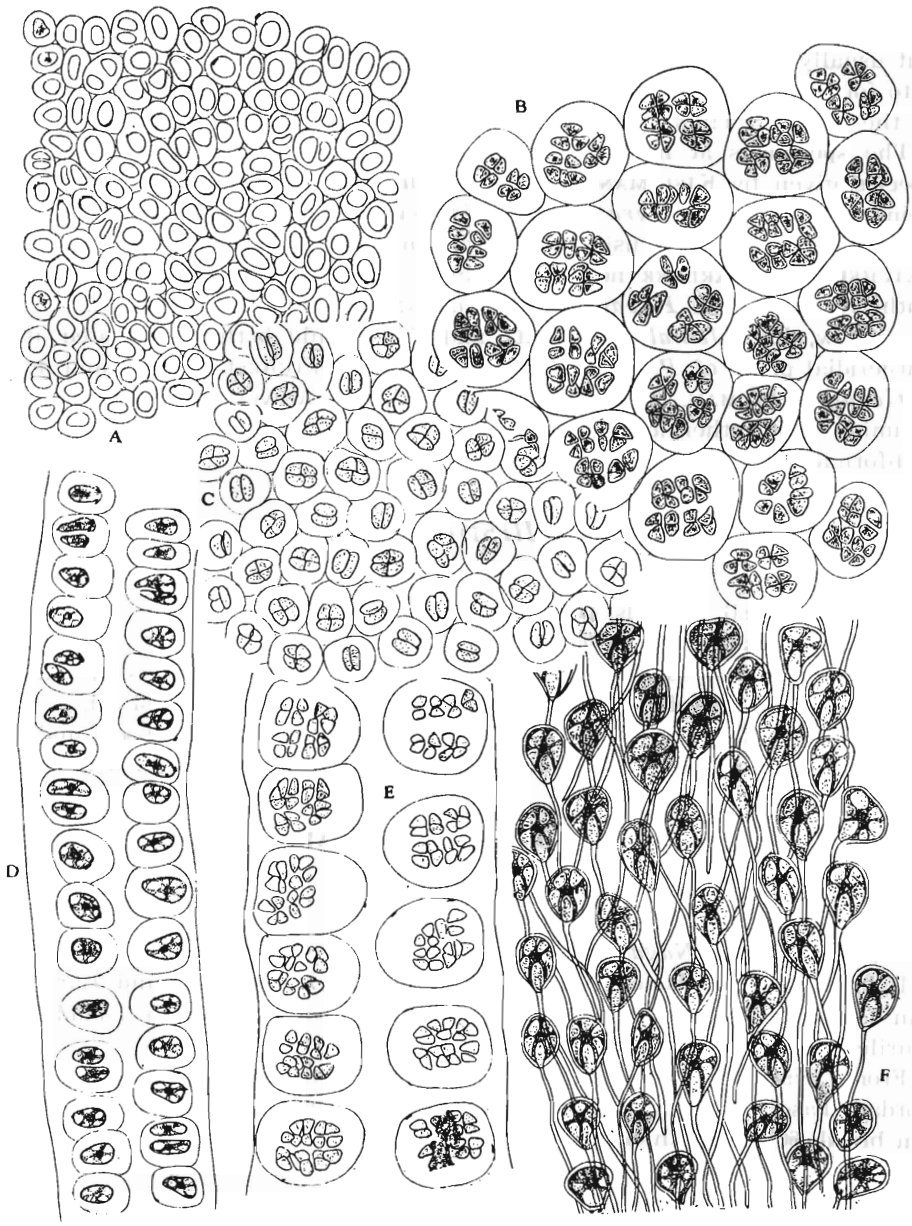



Fig. 34. *Porphyra amplissima* (Kjellman) Setchell et Hus. (Male plant.). A: Surface view of vegetative portion. × 175. B-C: Surface view of antheridial portion. × 270. D: Section of vegetative portion. × 190. E: Section of antheridial portion. × 270. F: Lower most cells with rhizoidal filaments. × 190.

may, however, vary, and from two causes. Frequently the additional divisions in the antheridium take place, so that each antheridium possesses sixty-four antherozoids.

The sporocarpic patches are found on the marginal region of the different thalli. The patches are also irregular in outline as in the antheridial thallus, but usually larger than those in the latter case. The sporocarp at first divides into four parts by a cruciate division, followed by the outer division parallel to the surface. Thus number of carpospores in each cystocarp is almost eight.

The specimens at hand, accord well with the description of the present species, given bv KJELLMAN and HUS in the essential characters except only being dioecious. *Porphyra occidentalis* SETCHELL et HUS is, at first, described by SETCHELL and HUS using the specimens from California in 1900. Lately SETCHELL and GARDNER noticed, however, that *P. occidcntalis* might be the antheridial plant of *P. varieagta* KJELLMAN. As far as the writer's observation show, *P.occidentalis* STECHELL and Hus should better be treated as the antheridial plant of *P. amplissima* (KJELLMAN) SETCHELL et HUS and not *P. variegata* KJELLMAN. Unfortunately the writer, however, has not been able to examine any authentic specimens of *P. occidentalis* from the type locality, California.

### *f. elliptica* NAGAI

PL. XVII, 1.

Mar. Alg. Kurile Islands, II (1941) p. 150.

Japanese name. *Maruba-benitasa.*

Hab. Onnekotan Island, Harumukotan Island and Uruppu Island, Middle Kurile Islands; Etorofu Island, South Kurile Islands; Shikotan Island.

Frond elliptic, ovate with cordate or round base, more or less densely undulate-plicate to the middle part, 31 – 35 cm long, 25 – 33 cm broad, 60 – 120 $\mu$ thick.

### *f. lanceolata* NAGAI

PL. XXII, 2.

Mar. Alg. Kurile Islands, II (1941) p. 150.

Japanese name. *Nagaba-benitasa.*

Hab. Paramusiru Island, North Kurile Islands; Onnekotan Island, Harumukotan Island and Uruppu Island, Middle Kurile Islands; Etorofu Island, South Kurile Islands; Shikotan Island.

Frond ovate-lanceolate or oblong-lanceolate, with cuneate, rarely round or cordate base, densely undulate-plicate to middle part, 45 - 115 cm long, 15 – 26 cm broad, 60 – 120 $\mu$ thick.

### *f. crassa* KAWABATA

PL. XXII, 1.

List Mar. Alg. Shikotan (1936) p. 207; NAGAI, Mar. Alg. Kurile Islands, II (1941) p. 150.

Japanese name. *Atuba-benitasa.*

Hab. Shikotan Island; Floating on the surface of the waters.

Frond ovate to oblong-ovate, with cordate base, deep reddish violet, often densely undulate-plicate, 35 – 55 cm long, 20 – 30 cm broad, 140 – 165 $\mu$ thick.

## Family 2. *Erythropeltidaceae*

### *Erythrocladia* ROSENVINGE, 1909

Frond filamentous, microscopic, horizontally expanded, consisting of creeping ramified filaments, more or less confluent to a monostromatic disc; cells usually cylindrical or oblong, variable in shape; chromatophore parietal laminate without a central pyrenoid; reproduction by monospores produced by the vegetative cells of the thallus; monospore cut off in the ordinally cells by a more or less oblique curved wall; colour of the frond purplish red.

#### Key to the species

A.) Terminal portion of the frond forming a continuous margin and not a free end ..... *E. subintegra* ROSENVINGE.

B.) Terminal portion of the frond forming not a continuous margin and a free end ..... *E. irregularis* ROSENVINGE.

### *Erythrocladia subintegra* ROSENVINGE

Figs. 35 – 36.

Mar. Alg. Denmark, I (1909) p. 73, figs. 13 – 14; COLLINS and HERREY, Algae of Bermuda (1917) p. 95; BOERGESEN, Mar. Alg. Danish West Indies (1915) p. 7, figs. 3 – 4, Mar. Alg. Easter Island (1924) p. 268, Some Indian *Rhodophyc.* espesialy Bombay, I (1931) p. 2, Some Mar. Alg. from Ceylon (1936) p. 79, Contrib. to a South Indian Mar. Alg. Flora, (1937) p. 319, Mar. Alg. Iranian Gulf (1937) p. 102; WEBER VAN BOSSE, Liste des Algues du Siboga, II, *Rhodophyc.* (1921) p. 188; KYLIN, Mar. Red Alg. in the Vicinity of Friday Harbor, Wash. (1925) p. 9, fig. 3, c – g, Anatomie der *Rhodophyc.* (1937) p. 42, fig. 17, D, Californische *Rhodophyc.* (1941) p. 3; TAYLOR, Mar. Alg. Florida (1926) p. 132, pl. 20, fig. 3; TSENG, Mar. Alg. from Amoy (1936) p. 32, pl. IV, 16; INAGAKI, Mar. Alg. of Oshoro Bay, Hokkaido and to Adjacent waters (in Japanese, 1933) p. 9, fig. 1 – 2, Some mar. Alg. recent discover in Japan and new to Science (1935) p. 41; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 371, fig. 177; YAMADA and TANAKA, Mar. Alg. Island Yonakuni (1938) p. 68.

Japanese name. *Isohanabi.*

Hab. Yonakuni Island, Ryûkyû; Onagawa, Rikuzen Prov.; Oshoro, Suttu and Otaru, Hokkaidō.

Distrib. Denmark; Indian Ocean; Atlantic Ocean; Pacific Ocean.

Frond microscopic, roundish or elliptical in surface view, ca. 100 – 300 $\mu$ in diameter, horizontally expansive, forming a small suborbicular and monostromatic disc, with continuous margin, showing a marginal growth and not a free end; cells dividing dichotomously toward the marginal portion and oblong

in the middle portion, 3 – 10 $\mu$ broad and 5 – 20 $\mu$ long; chromatophore parietal mantle-shaped and without a central pyrenoid; monosporangia roundish or elliptical in surface view, 4 – 10 $\mu$ in diameter, cut off in the end of the ordinally cells through a faintly curved cell, sometimes at the proximal, often at the distal end of the cell, containing a parietal, cup-shaped chromatophore. Colour of the frond purplish red.

The present species was found epiphytic upon *Polysiphonia*, *Chondria crassicaulis* HARV., *Cladophora*, *Microdictyon* and many others. The young specimens have a nearly circular or somewhat undulate continuous margin, in older specimens it is more irregular and the extremities of the filaments

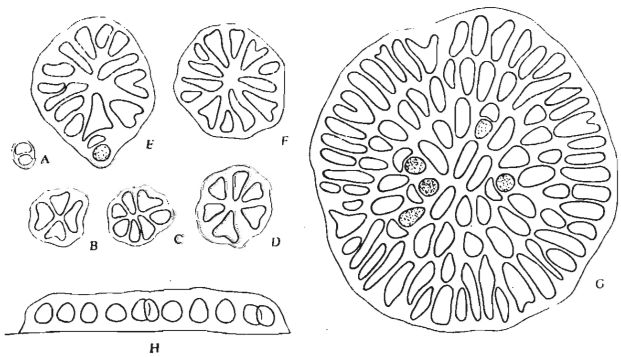



Fig. 35. *Erythrocladia subintegra* ROSENVINGE.
A - G : Various stages of the plants. ×350. H : Transverse section of the frond. ×350.

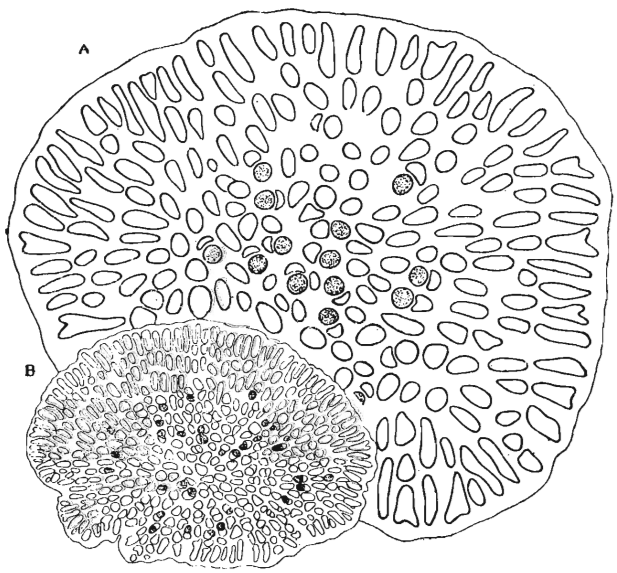



Fig. 36. *Erythrocladia subintegra* ROSENVINGE.
A - B : Two plants with monosporangia. A : ×340, B : ×150.

become more or less free. As already pointed out by ROSENVINGE, the cells are usually dichotomously divided but the bifurcation is most often not quite equal, the one being longer than the other. The arrangement of the cell as well as the size and the location of monospores of *Erythrocladia subintegra* shows a great similarity to those of basal disc of *Erythrotrichia japonica* TOKIDA, but in *Erythrocladia subintegra* is always monostromatic, whereas in those of *Erythrotrichia japonica* is polystromatic.

According to ROSENVINGE (l.c.), the thallus of the genus *Erythrocladia* consists of mutually separate filaments which only at the outer portion, are partly confluent. This character seems to be observed commonly in *Erythrocladia irregularis* ROSENVINGE, but not seen in younger stages of the present species. But later BOERGESEN (l.c.) has pointed out that the present alga has a completely continuous margin in the younger stage and is not grow with free ends. In 1896, FR. SCHMITZ, established a genus *Erythropeltis*, which in its reproduction agree with the genus *Erythrocladia* but differs from it by the marginal growth. According to the opinion of BOERGESEN and HOWE, this genus *Erythropeltis* is very problematic and imperfect. The writer has reffered Japanese specimens to the present species with some doubt as BOERGESEN, HOWE and INAGAKI (l.c.).

## *Erythrocladia irregularis* ROSENVINGE

Fig. 37.

Mar. Alg. Denmark, I (1909) p. 72, figs. 11–12; DE TONI, Syll. Alg., V I(1924) p. 17; KYLIN, Mar. Red Alg. in the Vicinity Friday Harbor, Wash. (1925) p. 9, fig. 3, a-b; TANAKA, The Japanese Species of Protoflorideae (1944) p. 93, text-fig. 14.

Japanese name. *Toge-isohanabi*.

Hab. Yonakuni Island, Ryûkyû; Makurazaki, Kusi and Bônotu, Satuma Prov.

Distrib. Denmark; Atlantic Ocean; Pacific Ocean.

Frond epiphytic, microscopic, horizontally expansive, forming an irregular monostromatic spot of diameter up to 50–100 $\mu$, showing a free end at the marginal portion; cells usually cylindrical or oblong, about 4–7 $\mu$ broad, 8–11 $\mu$ long, usually $1\frac{1}{2}$-2 times as long as broad; bifurcating cells always absent; chromatophore parietal laminate, containing an obscure central pyrenoid, monosporangia nearly globular or somewhat elliptical, about 4–6 $\mu$ in diameter, in a similar manner as in the genus *Erythrotrichia*, cut off on the ordinally intercalary vegetative cells through a faintly curved wall; colour of the frond purplish red.

This species has been found upon the branches of *Asparagopsis Sanfordiana* HARVEY associated with *Colaconema furcata* TANAKA and *Rhodochorton* sp. It forms an irregular spot of diameter up to 100 $\mu$ and shows a free end at the margin. The daughter cells of spores of the present species usually grow out in two opposite directions. The primary filaments give off branchlets at both sides. These branches show apical growth and give off further, and in the more developed frond the filaments are therefore radiating in all directions in the horizontal plane, and the filaments are then more or less fused together in

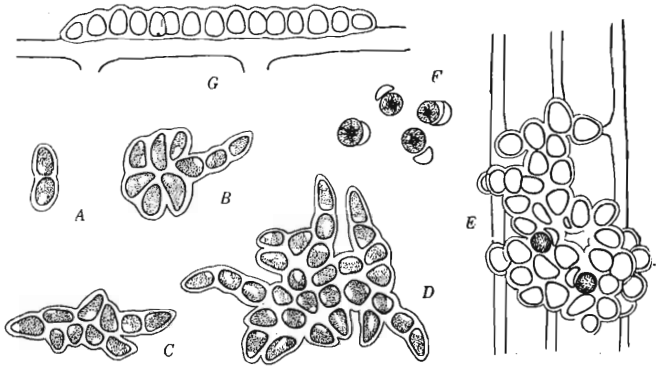



Fig. 37. *Erythrocladia irregularis* ROSENVINGE.
A - D : Young plants. × 400. E : Mature plant with monosporangia, growing epiphytic on *Asparagopsis Sanfordiana*. × 400. F : Monosporangia. × 400. G : Transverse section of the frond. × 400.

the central part of the frond. The branches usually arise in the subterminal cells, sometimes also in cells nearer the center of the frond. The ramification in thus monopodial. The outer appearance of the plant is always more or less irregular, some filaments growing longer than others.

The monospores have more granular contents than the vegetative cells and often show a star-like parietal chromatophore.

The material at hand agrees well with *Erythrocladia irregularis* ROSENVINGE, in the description and figures given by ROSENVINGE, and also agrees well with the description and figure of this species, given by KYLIN.

## *Porphyropsis* ROSENVINGE 1909

Frond at first parenchmatous, later erect vesiculose, minute, epiphytic, gregarious, monostromatic; cells spherical or ovate; spore mother cell crescent shaped; chromatophore parietal laminate, without central pyrenoid; monospore formed by segregation of part of the vegetative cells, cut off by an oblique walls.

## *Porphyropsis coccinea* (J. AGARDH) ROSENVINGE

Fig. 38.

Mar. Alg. Denmark, 1. (1909) p. 69, figs. 9 – 10; DE TONI, Syll. Alg., VI (1924) p. 17; HAMEL, Floridèes de France, Bangales (1924) p. 430; KYLIN, Mar. Red Alg. Vicinity Biolog. Station at Friday Harbor, Wash. (1925) p. 9; NEWTON, Handbook British Seaweeds (1931) p. 244, fig. 148; INAGAKI, Mar. Red Alg. Oshoro Bay, Hokkaido and its adjacent waters (in Japanese, 1933) p. 13, fig. 6, Some mar. alg. recent discover. in Japan new to Science (1935) p. 42; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 373, fig. 179 - 180; LEVRING, Zur Kenntnis der Algenflora der Norwegischen westküste (1937) p. 79; TAYLOR, Mar. Alg. Northeastern Coast North America (1937) p. 219; KYLIN, Anatomie der *Rhodophyc.* (1937) p. 45, fig. 19, D – K.

*Porphyra coccinea* J. AGARDH, Nov. Fl. Suec. (1836) p. 6 (without description), Till Alg. Systematik (1882) p. 56, tab. II, figs. 41–43; ARESCHOUG, Phyceae Scandinaviae Marinae (1846–'50) p. 181, t. L, D; KUCKUCK, Demark. Meeresalg. von Helgoland, II (1897) p. 390, figs. 13–14; DE TONI, Syll. Alg., VI (1897) p. 13; JÓNSSON, The mar. alg. Iceland (1903) p. 131; KYLIN, Stud. Algenflora schwedischen Westküste (1907) p. 109.

Japanese name. *Hinanori.*

Hab. Suttu, Sioya and Otaru, Hokkaidō.

Distrib. Denmark; Atlantic Ocean; Japan Sea.

Frond minute, monostromatic, purplish red, epiphytic, irregularly elliptical with a remarkably undulate margin, ca. 1.5 cm high, 18–30 $\mu$ thick; cells in the basal portion of the frond arranged in two or more layers, forming filamentous rhizines; cells rounded or oval, 4–12 $\mu$ in diameter; chromatophore much divided, parietal, laminate; monospore rounded or oval, 4–8 $\mu$ in diameter, cut off in the ordinally vegetative cells by a somewhat curved wall, in the similar manner as in the genus *Erythrotrichia.*

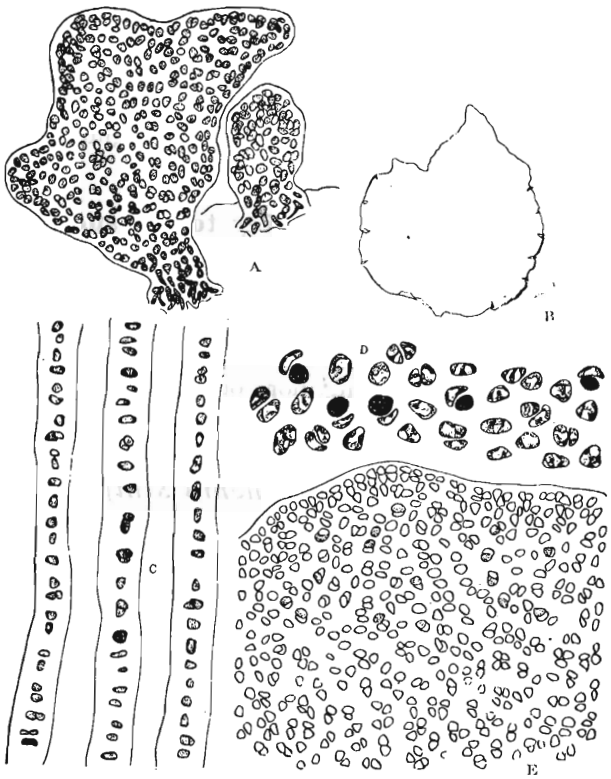



Fig. 38. *Porphyropsis coccinea* (J. AGARDH) ROSENVINGE.
A: Young plants. ×200. B: Habit of a plant. ×200. C: Transverse section of vegetative portion. ×220. D-E: Morginal portion of the frond showing monosporangia. D. ×300, E. ×200.

The present species has been found upon *Sargassum, Gelidium, Cladophore* etc. in the lower tide mark. The frond is attached to the substratum by means of the cushion-shaped basal disc. This plant is very similar to some younger plants of *Porphyra,* but it differs from the latter by its thinner frond and its smaller cells. Furthermore, the method of formation of monospores and the shape of chromatophores of *Porphyropsis coccinea* (J. AGARDH) ROSENVINGE shows, fairly difference to those corresponding characters of *Porphyra.* As already ROSENVINGE (l.c.) described, these above mentioned difference have been taken as sufficient reason for describing this species as a independent genus distinguished from *Porphyra.*

The sporangia are as detailed by ROSENVINGE (1909), cut off in the end of

the vegetative cells through a somewhat curved wall. The spore mother cells are crescent shaped. The chromatophores are parietal-laminate insted of being stellate and without a central pyrenoid. It has been collected in the month of May – July and was in fruit in that time.

## *Colaconema* BATTERS, 1896

Frond microscopic, epiphytic, purplish red, filamentous, irregularly much branched, anastomosing so as to form a network among the cortical layer of the host plant; cells variable in shape, simple or furcate, cruciate or irregular, here and there often swollen; chromatophore parietal laminate with central pyrenoid; monospores lateral or terminal on the lateral branches, formed from part of the contents of the monosporangium, the reminder persisting as a thickened cuplike base below the spore.

### Key to the species

A.) Cells of the filaments long and usually simple
.....*C. simplex* INAGAKI.

B.) Cells of the filaments short and often furcate
1) Frond forming an irregular network .....*C. furcata* TANAKA.
2) Frond forming more or less a regular network
.....*C. reticulatum* BATTERS

## *Colaconema simplex* INAGAKI

Fig. 39.

Some mar. alg. recently discov. in Japan and new to Science (1935) p. 44, fig. 2; OKAMURA, Nippon Kaisosi (in Japanese, 1936) p. 372, fig. 178.

Japanese name . *Beni-mayudama.*

Hab. Himi, Ettu Prov.; Sioya, Suttu and Otaru, Hokkaidō.

Distrib. Endemic.

Frond microscopic, purplish red or reddish green, filamentous, consisting of a single row of cells, much and irregularly branched, anastomosing so as to form an irregular network among the cortical layer of the host plant; cells variable in shape, generally oblong simple and rarely furcate or irregular, 3–12 $\mu$ in diameter, 2 – 18 times as long as broad; hair-like prolongation often issuing from main filaments and branches, composed of several colourless elongated cells, 2 – 4 $\mu$ broad and 3 – 10$\mu$ long; chromatophore parietal lobed with a inconspicuous pyrenoid; monosporangia almost solitary or sometimes 2 – 4 aggregate, terminal or lateral, sessile or pedicellate, subglobose, 6 – 12 $\mu$ in diameter.

The present species has been found growing on *Asparagopsis hamifera* (HARIOT) OKAMURA. Materials at hand agree well with a detailed description of *C. simplex* INAGAKI given by INAGAKI, except only for the presence of hair-like prolongation.

*Colaconema simplex* is very similar to *C. Bonnemisoniae* BATTERS and *C. americama* JAO. It has many characters in common with these two above mentioned species but differs from them in the fact that the monosporangia are almost solitary insted of being aggregate,

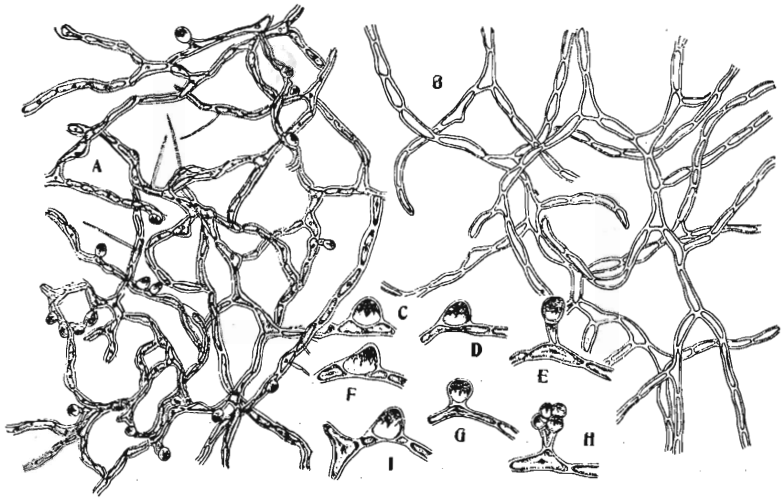



Fig. 39. *Colaconema simplex* INAGAKI. A: Filaments with monosporangia. ×250. B: Parts of Young filaments. ×250. C-I: Fragments of the filaments with monosporangia. ×250.

## *Colaconema furcata* TANAKA

Fig. 40.

The Japanese Species of Protoflorideae (1944) p. 95, text-fig. 15.

Japanese name. *Yonakuni-mayudama.*

Hab. Yonakuni Island, Ryûkyû; Makurazaki, Satuma Prov.

Distrib. Endemic.

Frond endophytic, filamentous, forming more or less an irregular network between the cortical cells of the host plant; filaments consisting of a single row of cells, much and irregulaly branched; side branches arising from the main filaments or branches nearly at right angles, alternate or opposite; hair-like erect filaments arising from the endophytic filaments, 2 to mostly 3 cells in length, cyrindrical, tapering toward the end, about 3 $\mu$ in diameter, about 10 $\mu$ long, almost colourless; cells variable in shape, generally oblong and slender, often furcate, more or less angular, about 4 $\mu$ in diameter, 3–8 times as long as broad; chromatophore parietal laminate with an obscure central pyrenoid; monosporangia globose, or subglobose, sessile, often soitary, about 6–8 $\mu$ in diameter, lateral or terminal on the cells of the filaments; colour of the frond purplish red.

The present species has been found among the cortical cells of *Asparagopsis Sanfordiana* HARVEY. The frond is much and irregularly branched, consisting of a single row of cells, anastomosing so as to form an irregular net-work. The cells of the frond are often forked and some-what angular, The monosporangia are almost solitary and not aggregated, lateral or terminal on the short branches. The characteristic cup-like base of monosporangia of the genus *Colaconema* is not so distinct. The specimens which the writer collected in the month of April are almost fertile.

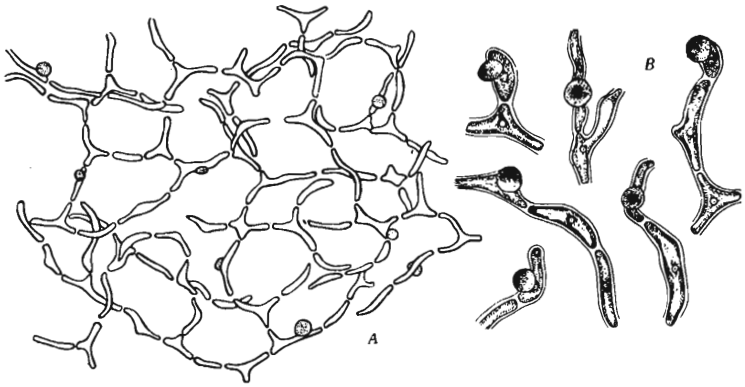



Fig. 40. *Colaconema furcata* TANAKA. A. Filaments with monosporangia. × 320. B: Parts of the filaments with monoporangia. × 650.

*Colaconema furcata* TANAKA is most nearly related to *C. simplex* INAGAKI, but it differs from the latter by the size and shape of the cells. The cells of the filaments of *C. furcata* are somewhat smaller and thinner composed with those of *C. simplex*.

Genus *Colaconema* was established by BATTERS in 1896 (Journ. of Botany, vol. 34.). It was later placed by BATTERS near to the genus *Acrochaetium* and one species of *Colaconema* was removed to *Acrochaetium*. In spite of the likeness of this genus to *Acrochaetium* in habit, it seems correct not to refer it to Namalionales but to regard it as the representative of Bangiales, characterized in perticular by the mode of formation of the monosporangia.

## *Colaconema reticulatum* BATTERS

Some new British Mar. Alg. (1896) p. 7, A catalog, British Mar. Alg. (1902) supple., p. 57; DE TONI, Syll. Alg., VI (1924) p. 250; NEWTON, Handbook British Seaweeds (1931) p. 250; TANAKA, The Japanese Species of Protoflorideae (1944) p. 96, text-fig. 16.

Japanese name. *Ami-mayudama.*

Hab. Onagawa, Rikuzen Prov.

Distrib. England; Japan.

Frond microscopic, filamentous, greenish red, much and irregularly branched, anastomosing so as to form more or less regular network among the cells of the host-plant; cells variable in shape, short and angular, about as long as broad or a little longer; chromatophores parietal laminate with a central pyrenoid; monosporangia globose or subglobose, almost sessile, terminal or lateral, 6 – 8 $\mu$ long, 4 – 7 $\mu$ broad.

The present species has been found in the membrane of the cortical cells of *Lomentaria hakodatensis* YENDO. The filaments are much and irregularly branched, anastomosing so as to form more or less a regular net-work among the cortical cells of the host plant. The cells are variable in shape, short and angular, about as long as broad or a little longer, 5 – 10 $\mu$ wide and 8 – 11 $\mu$

long, often somewhat curved at the middle part. The endophytic filaments often bearing hyaline hairs, which are free from the cortical layer of the host plant. The hairs reach a length of about 7 $\mu$ and are about 2 $\mu$ in breadth, one or mostly two cells in length. The monosporangia are subglobose or hemispherical in shape, 6 – 8 $\mu$ long and 4 – 7 $\mu$ broad, lateral or terminal of the filaments. The cup-like base of the monosporangia is not so distinct. The specimens with monosporangia found in July.

The material at hand agrees well with *Colaconema reticulatum* BATTERS in the description given by BATTERS in 1896 (l.c.), although it shows small difference. According to BATTERS, the side branches often run by closely to the primary filaments, it seems as if the thallus consists of double series of cells. But such a habit is scarcely to be seen in our plant. In our plant the shape and size of the cells are quite similar to those of *C. reticulatum* BATTERS in the description which was given by BATTERS.

## Order 4 *Compsopogonales*

### Family *Compsopogonaceae*

### *Compsopogon* MONTAGNE, 1846

Frond erect, filiform, caespitose, laterally much branched, consisting cortical and central layers, attached to the substratum by means of basal-disc which consists of several layers of cells; chromatophore band-shaped without central pyrenoid; reproduction by monosporangia, monospore formed directly from a cortical cells.

### *Compsopogon Oishii* OKAMURA

PL. I. and Fig. 41.

Icon. Japan. Alg., vol. III, no. 7 (1915) p. 128, pl. 132, Nippon Kaisosi (in Japanese, 1936) p. 375, pl. 182.

Japanese name. *Ôishisô.*

Hab. Mito, Hitati Prov.; Yanokuti, Sumida River, Inokasira, Musasi Prov.; Hizikuro River, Hizen Prov.; Hisikari and Kagoshima, Satuma Prov.

Distrib. Endemic.

Frond erect, caespitose, filiform, rather harsh to touch and fragile, usually crooked and somewhat entangled, dark greenish blue-violet, 10 – 30 cm high, 1 – 1.5 mm thick, attached to the substratum by means of basal disc which is consisted of several layers of cells, branched in an alternate manner, young branches consisting of a single longitudinal row of disc-shaped cells, but soon longitudinal partitions forming near margins, giving rise to the central and cortical cells; central cells in mature frond attaining a thickness of about 400 $\mu$, showing a tendency to be destroied and leaving the interior of the frond hollow, cortical layer consisting of two layers of cells, of which the inner are larger and roundish, while the outer smaller and anticlinally a little elongated; lower most cells of the frond issuing rhizoidal filaments which are articulated and run in both intra- and extra-cortical ways and by coalescing together from a somewhat conical holdfast; chromatophores roundish angular in shape;

monosporangis either directly from a cortical cell or from a cell produced by horizontal oblique partitions, monospore containing very deeply coloured contents and a nucleus.

The present freshwater alga has been found on the leaf and stem of *Valisneria spiralis*, gravels, woods etc, in a running river. This plant was first collected by Mr. OISHI at the river of Tama, Musasi Prov. in 1900 and Dr. *K.* OKAMURA described and delineated minutely in his Icones of Japanese Algae, vol. III, no. VII, 1915.

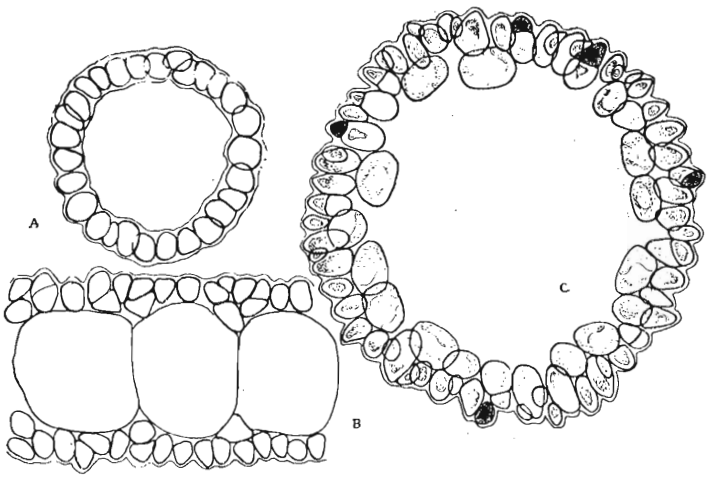



Fig. 41. *Compsopogon Oishii* OKAMURA. A : Transverse section of the young frond. × 190. B : Longitudinal section of the young frond. × 190. C : Transverse section of the filament, bearing spores. × 190.

## IV. LITERATURE CITED

1. AGARDH, C. A. (1820) Species algarum rite congnitae cumsynonymus, differentiis specificis et descriptionibus succinctis. Vol. 1, pl. 1.
2. ..... (1924) Systema algarum. Lund.
3. ..... (1828–'35) Icones Algarum Europearum. pl. I–XL.
4. AGARDH, J. G. (1882) Till. Algernes Systematik, Afd. 3, VI. *Ulvaceae.* Lund's Univ. Arsskrift. Tome, XIX.
5. ..... (1899) Analecta Algologica. Continuatio V. Acta Reg. Soc. Physiogr., Lund. Tome, X.
6. ARESCHOUG, J. E. (1847–'50) Phycearum, quea in Maribus Scandinaviae Crescunt, Enumeratio.
7. ARNOLD, W. M. (1909) Algologische Mittilungen, 2. *Compsopogon chalybaeus* Kg., Trav. Soc. Nat. Univ. Imp. Kharkow, 43.
8. BATTERS, E. A. L. (1892) On *Conchocelis*, a new Genus of Perforating Algae. in Murray, George's Phycol. Mem. Pt. 1, London.
9. ..... (1896) Some New British Marine Algae, Journ. of Botany, vol. 34.

10. BATTERS, E. A. L. (1900) New or Critical British Marine Algae. Journal of Botany, vol. 38.
11. BENNETT, A. W. (1887) On the Affinities and Classification of Algae. Linn. Soc. Jour. Bot., XXIV, London.
12. BERTHOLD, G. (1880) Zur Kenntnis der Siphoneen und *Bangiaceen*, Mittheil. Zool. Stat. zu Neapel, 1. Leipzig.
13. ..... (1881) Die geschlechtliche Fortpflanzung der *Bangiaceen*. Mittheil Zool. Stat. zu Neapel. 2. Leipzig.
14. ..... (1882) Die Bangiaceen des Golfes von Neapel und Angrenzenden Meeres-abschnitte. Fauna u. Flora d. Golfes v. Naepel. VIII. Leipzig.
15. BOERGESEN, F. (1902) The Marine Algae in Botany of the Faeröes. Copenhagen.
16. ..... (1916) The Marine Algae of the Danish West Indies. Dansk Botanisk Archiv., Band, 3, No. 1a. Copenhagen.
17. ..... (1924) Marine Algae from Easter Island. Nat. Hist. Juan. Fernandez and Easter Island, II.
18. ..... (1927) Marine Algae from the Canary Island. Det. Kgl. Danske Vidensk. Seisk. Biol. Medd., V. 3.
19. ..... (1936) Some Marine Algae from Ceylon. Ceylon Journ. Sci. Sect. A. Botany Vol. XII, Pt. 2.
20. ..... (1937) Contributions to a South Indian Marine Algal Flora 1. Journ. Indian Bot. Soc., Vol. XVI, no. 1.
21. ..... (1939) Marine Algae from the Iranian Gulf. Dansk Scientific Investigations in Iran, Part. 1. Copenhagen.
22. BORNET, E. (1892) De Algues de Shousbae. Mem. Soc. Sc. Nat. Cherbourg, 28. Paris.
23. BORNET, E. et THURET, G. (1878) Etudes Phycologique. Paris.
24. ..... (1876–'80) Notes Algologique. Paris.
25. BORZI, A. (1891) Noterelle Algologische; *Porphyridium cruentum* Naeg. Nuova Notarisia, 2. Padova.
26. BRAND, A. (1908) Ueber das Chromatophore und die systematische Stellung der Blutalge (*Porphiridium cruentum*). Ber. Deutsch. Bot. Ges. 24a. Berlin.
27. ..... (1908) Weitere Bemerkungen ueber *Porphiridium cruentum* (AG.) NAEG., Ber. Deutsch. Bot. Ges. 26a. Berlin.
28. ..... (1917) Ueber Beurteilung des zellbaues kleiner Algen mit besonderen Hinweise auf *Porphyridium cruentum* NAEG. Ber. Deutsch. Bot. Ges., 35. Berlin.
29. BRÜHL, P. and BISWAS, K. (1923) Commentationes Algologicae 3. On a species of *Compsopogon* growing in Bengal. Journ. Depart. Sci. Calcatta Univ. Calcatta.
30. COHN, F. (1867) Ueber Osccillarien und Florideen. Bot. Ztg., 25, Leipzig.
31. ..... (1867) Beitrage zur physiologie der phycochromaceen und Florideen. Arch. Microskop. Anat. 3. Bonn.
32. COLLINS, H. et GUÉGUEN, E. (1933) Le florido side chez les Floridées, Compt. Rend Acad. Sci., 197. Paris.

33. COLLINS, F. S. (1901) The Algae of Jamaica. Proc. Amer. Arts and Sci. XXXVII, 9.
34. COLLINS, F. S. and HERVEY, A. B. (1917) The Algae of Bermuda. (Contrib. from the Bermuda Biol. Stat. Res. 69) Proc. Amer. Acad. Arts and Sci., LLIII. 1.
35. CROUAN, P .L. and H. M. (frères) (1867) Florule du Finistère. Paris.
36. DANGEARD, P. (1927) Recherches sur les *Bangia* et les *Porphyra*. Le Botanist, 18. Paris.
37. ..... (1930) Sur la mobilite de cèrtaines cellules du *Porphyridium cruentum* NAEG. Compt. Rend. Acad. Sc., 190. Paris.
38. ..... (1932) Sur quelques *Erythrotrichia* et *Erythrocladia* de Banyulus et du Croisic. Le Botanist, 24. Paris.
39. DARBISHIRE, O. (1898) Ueber *Bangia* qumila Aresch. eine endomische Alge der Ostlichen Ostsee. Wise Meeres. untersuch. N. F. abt. Kiel, 3, Kiel und Leipzig.
40. DE TONI, J. B. (1897) Sylloge algarum omnium hucusque cognitarum. Vol. IV (1897), and Vol. VI (1924).
41. DREBES, A. et SILIER, A (1856) Mémoire sur quelques points de physiologie des Algues. Compt. Rend. Séances Acad. Sc., 1. Suppl. Paris.
42. ELENKIN, E. et STARK, V. (1923) De *Asterocytis ramosa* (THWAITES) GOBI caeteris que speciebus hujus generis notula. Not. Syst. Inst. Crypt. Horti Bot. Petrop., z. Petropolis.
43. FARLOW, W. C. (1881) Marine Algae of New England and Adjacent Coast, Report of U. S. Fish Commission for 1879. Washington.
44. FELDMANN, M. J. (1937) Contributions à la flora algologique marine de l'Algérie. Les algues de Cherchell. Bull. Soc. Hist· Nat. Afrique du Nord, t XXII.
45. ..... (1937) Recherches sur la Végétation Marine de la Mediterrnnée. La côtes des Albéres. Paris.
46. ..... (1939) Le Algues Marines de la côtes des Albères. Revue Algologique, Tome, XI, Fasc. 3-4. Paris.
47. FOSLIE, M. (1890-'91) Contribution to the Knowledge of the Marine Algae of Norway, I (1890), East-finmarken. Tromsø Mus. Aseshhefter, vol. XIII; II (1891). Species from Different Tracts. ibid., vol. XIV.
48. FUNK, G. (1927) Die Algenvegetation des Golfes von Naepel nach neueren oekologischen Untersuchungen. Publ. Staz. Zool. Napoli-VII, Suppl.
49. GAIDUKOV, N. (1899) Zur morphologie und physiologie der Algen. *Porphyridium crūentum* NAEG. Arbeit. Ptersb. Ges. Naturf. 30, St. Petersburg.
50. GARDNER, N.L. (1927) New Rhodophyceae from the Pacific Coast of North America, II. Univ. Calif. Publ. Bot., Vol. 13, nc. 13, Berkeley.
51. GEITER, L. (1923) *Porphyridium aerugineum* n. sp., Oesterreich. Bot. Ztschr., 72. Wien.
52. ..... (1924) Ueber einige wenig bekannte Süszwasserorganismen mit roten oder Blaugrüppen chromatophoren. Revue Algologique, 1. Paris.
53. ..... (1927) *Porphyridium sordidum* sp. eine neue Suesswasser Bangiales, Archiv. für Protistenkunde, LXXVI. Gobbel.

54. GOEBEL, K. (1876) Zur Kenntnis einiger Meeresalgen, 2. Ueber *Bangia* und *Porphyra*.. Bot. Zeitung, Bd., 36. Leipzig.
55. GRIFFITHS, B.M. (1915) On Gaucocystis Nostochinearum, Itzgsohn, Ann. of Botany., 29. London.
56. GRUBB, V. M. (1923) The attachment of *Porphyra umbilicalis* (L.) J. AG. Ann. of Botany, 37.
57. ..... (1924) Observations on the Ecology and Reproduction of *Porphyra umbilicalis* (L.) J. AG. Revue Algologique, I, 1. Paris.
58. HAMEL, G. (1924) Floridées de France, I. Revue Algologique, no. 4. Paris.
59. HANSGIRG, A. (1884) Systematik einige Suesswasseralgen Oesterreich. Bot. Ztschr., 34. Wien.
60. HARVEY, W. H. (1846–'51) Phycologica Brittanica, I–IV. London.
61. HAUCK, F. (1886) Die Meeresalgen Deutschlands und Oesterreich in Raben-Horst's Kryptogamen-flora von Deutschlands, Oesterreich und Schweizig. Vol. II. Leipzig.
62. HOWE, M. A. (1924) The Marine Algae of Peru. Mem. Torr. Bot. Club., Vol. XV. New York.
63. ..... (1918) Flora of Bermuda (Britton's Flora of Bermuda).
64. ..... (1920) Bahama Flora (Britton and Millspaugh's Bahama Flora).
65. HOWE, M. A. and HOYT, W. D. (1916) Notes on some marine algae from the vicinity of Beaufort North Carolina, Memoirs New York Bot. Garden. vol. VI. New York.
66. HUS, H. T. A. (1900) Preliminary notes on west coast *Porphyras*. Zoe, vol. V, nos. 4 and 5.
67. ..... (1902) On account of the Species of *Porphyra* found on the Pacific coast of North America. Proc. Calif. Acad. Sci. ser. 3, Bot., vol. II, uo. 6. San Francisco.
68. INAGAKI, K. (1933) Mar. Red. Algae of Oshoro Bay, Hokkaido and its Adjacent Waters (in Japanese). Inst. Alg. Research Bull., no. 2, Fas. Sci., Hokkaido Imp. Univ. Sapporo.
69. ..... (1935) Some marines algae recently discovered in Japan and new to Science. Sci. Pap. Inst. Algolog, Research, Fac. Sci. Hokkaido Imp. Univ., vol. I, no. 1. Sapporo.
70. ISHIKAWA, M. (1921) Cytological Studies on *Porphra tenera* KJELLMAN. Bot. Mag., Tokyo, vol. XXXV.
71. JANCZEWSKI, E. (1873) Etudes Anatomiques sur les *Porphyra*. Ann. Sc. Nat. Bot., ser, 5, 15. Paris.
72. JOFFÉ, R. (1896) Observation sur la fécondation des *Bangiacées*. Bull. Soc. Bot. France, 43. Paris.
73. JOHNSON, T. (1894) The systematic position of the *Bangiaceae*. Nouva Notarisia, 5. Padova.
74. JÒNSSON, H. (1901–'03) The marine of Iceland. Bot. Tidskrift.
75. KAWABATA, S. (1936) A List of Marine Algae from the Island of Sikotan. Sci. Pap. Inst. Algolog. Research, Fac. Sci. Hokkaido Imp. Univ., vol. L. no. 2. Sapporo.

76. KJELLMAN, F. R. (1883) The Algae of the Arctic Sea. Kongl. Sv. Vet-Akad. Handl., vol. XX no. 5. Stockholm.
77. ..... (1889) On Beringhafvets Algenflora. Kong. Sv. Vet-Akad. Handl., vol. XXIII, no. 8. Stockholm.
78. ..... (1897) Japanska Arter Af Slägtet *Porphyra*. Bihang Till. K. Sv. Vet. Akad. Handl., Bd. 23, Afd. III, no. 4. Stockholm.
79. KNIEP, H. (1928) Die sexuallität der niedren Pflanzen. Jena.
80. KUETZING, F. T. (1843) Phycologia generalis oder Anatomie, Physiologie und Systematik der Tange. Leipzig.
81. ..... (1845) Phycologia germanica, d.i. Deutschlands Alger in bündigen Beschreibungen, nebst einer Anleitung Zun Untersuchungen und Bestimen dieser Gewächse fur Anfanger. Nordhausen.
82. ..... (1849) Species Algarum. Leipzig.
83. ..... (1853, 1869) Taublae Phycologicae oder abbildungen der Tange, Vol. III, XIX. Nordhausen.
84. KUFFERATH, H. (1913) Note sur la physiologie et la morphologie de *Porphiridium cruentum* NAEG. Bull. Soc. Roy. Bot. Belg., 52. Bruxelles.
85. KUNIEDA, H. (1939) On the life-history of *Porphyra tenera* KJELLMAN. Jour. College of Agriculture Tokyo Imp. Univ., vol. XIV, no. 5. Tokyo.
86. KYLIN, H. (1907) Studien ueber Algenflora der Schwedischen Westküste. Akad. Abhandl. Upsala.
87. ..... (1917) Ueber die Keimung der Florideensporen. Arkiv. f. Bot. XIV, 22. Stockholm.
88. ..... (1925) The Marine red Algae in the Vicinity of the Biological. Station at Friday Harbor, Washington. Lunds Arsskr. N. F. Avd. 2, Vol. XXI, no 9. Lund.
89. ..... (1939) Anatomie der *Rhodophyceae*. Handb. der Pflanzenanat. Bd. IV' 28. Berlin.
90. LAKOWITZ, D. (1907) Die Algenflora der Danziger Bucht. Westpreuss. Bot. Zool. Ver. (mit Unterstutzung d. Provinzial-Komm. zur Verwaltung d. Westpreuss. Provinzial-Museum.)
91. LE JOLIS, A. (1863) Liste des algues de Cherbourg. Mém. Soc. Imp. Sc. Nat. Cherbourg, Vol. X.
92. LEVRING, T. (1937) Zur Kenntnis der Algenflora der norwegischen westküste. Lund Universitetes, N.F. Avd. 2, Bd., Nr. 8. Lund.
93. ..... (1940) Studien ueber die Algenvegetation von Blekinge Südschweden. Lund.
94. LEWIS, H. and ZIRKLE, G. (1920) Cytology and Systematic position of *Porphyridium cruentum* NAEGELI. Amer. Journ. of Botany 17, Lancaster.
95. LYNGBYE, H. C. (1819) Tentamen Hydrophytologie Danicae, contineus omnia drophyta cryptogamia Daniae, Holsatiae, Faeroae, Islandiae, Groenlandiae hucusque cognita, systematice disposita; descripta et iconibus illustrata, ad-jectis simul speciebus Norvegicis. Copenhagen.
96. MARTENS, C.V. (1866) Die preussische Expedition nach Ost-Asien. Botanische Theil., Tange. Berlin.
97. MONTAGNE, C. (1850) Cryptogamia Guyanensis. Ann. Sc. Nat. Botanique, 3 – e, ser. 14. Paris.

98. NAEGELI, C. (1849) Gattungen einzelliger Algen. Zeitschrift für Wiss. Bot. Zurlich.
99. NAGAI, M. (1933) Meeresalgen aus Kamtschatka. Trans. Sapporo Nat. Hist. Soc., Vol. XIII.
100. ..... (1941) Marine Algae of the Kurile Islands, II. Journ. of Fac. Agric., Hokkaido Imp. Univ., Vol. XLVI, pt. 2. Sapporo.
101. NEWTON, H. (1931) A Handbook of the British Sea-weeds.
102. OKADA, Y. (1944) Note on *Bangia atropurprea* (ROTH) AG. found in Japan. (in Japanese). Journ. of Japanese Botany, Tokyo, vol. XX, no. 4. Tokyo.
103. OKAMURA, K. (1902–'16) Nippon Sorui Meii (in Japanese). Tokyo.
104. ..... (1909) Asakusanori (in Japanese). Tokyo.
105. ..... (1915–'21) Icones of Japanese Algae, Vol. III, no. VII, Vol. IV, no. V. Tokyo.
106. ..... (1930) Sorui Keitogaku (in Japanese). Tokyo.
107. ..... (1930) On the Algae from the Island Hatidyô. Rec. Oceanogr. wk. Jap. Tokyo. Vol. II, no. 2.
108. ..... (1936) Nippon Kaisosi (in Japanese). Tokyo.
109. OKAMURA, K. and ONDA, K. and HIGASI, M. (1920) Preliminary Notes on the Development of the Carpospores of *Porphyra tenera* KJELLMAN. Bot. Mag. Tokyo, Vol. 34. Tokyo.
110. OLTMANNS, F. (1922–'23) Morphologie und Biologie der Algen. 2 Aufl. Jena.
111. PASCHER, A. (1940) Zur Kenntnis der Suesswassertetrasporen. I. Beih. Bot. Zentralbl., Abt. A. 60.
112. PASCHER, A. and PETROVA, J. (1931) Poren apparate und Bewegung bei einer neuen Bangiale (*Chroothece mobilis*). Arck. fur Protistenkunde, 74. Jena.
113. REINKE, J. (1878) Ueber die Geschlechtpflanzen von *Bangia fuscopurpurea*. Jahrb. Wiss. Bot., 11. Leipzig.
114. ROSENBERG, M. (1933) Über die Bewegung der Einzelzellen von *Asterocytis smaragdinum*. Reinsch. Arch. f. Protistenkunde, 85. Jena.
115. ROSENVINGE, L. N. Grønlands Havalger. Med. om Grønland, Vol. III. Kjøbenhavn.
116. ..... (1909) The Marine Algae of Denmark, Vol. I, pl. 1. Kjøbenhavn.
117. ..... (1925) Remarque sul les Protoflorideae. Nouva Notariria. Ger. XXVI.
118. ..... (1927) On Mobility in the Reproductive Cells of the *Rhodophyceae*. Bot. Tidsskrift. XL. Kjøbenhavn.
119. RUPRECHT, F. J. (1851) Tange des Ochotischen Meeres. Middendorf's Siberische Reise, Vol. 1.
120. SCHILLER, J. (1925) Rhodophyta (*Rhodophyceae*). Spezieller Teil. Pascher's Suesswasserflora, 11. Jena.
121. SCHMIDLE, W. (1905) Algologische Notizen. 16 Allgem. Bot. Ztg. Karlsruhe.
122. SCHMITZ, FR. (1882) Die chromatophoren der Algen. Verleichende Unter-

suchengen über Bau und Entwicklung der Chlorophyll-korper und der Anarlgen Farbstoffkorper der Algen. Verhandl. d. naturlichen Ved. d. preussisch. Rheinlande u, Westfalens. 40 Jahrg. Bonn.

123. SCHMITZ, FR., HAUPTFLEISCH, P. und FALKENBERG, P. (1896–'97) *Rhodophyceae*. in ENGLER's die naturlichen Pflanzenfamilien nebst ihren Gattungen und Wichtigeren Arten insbeson dere den Nutzpflanzen, 1. Teil. Abt. 2.

124. SCHREIFFEL, A. (1934) *Bangia atropurpurae* (ROTH) AG. in Balaton (Plattensee) Arbeiten des ungarischen biolog. Forschungs. Instit. 7. Tihang.

125. SEGAWA, S. (1935) On the Marine Algae of Susaki, Prov. Idzu, and its Vicinity. Sci. Pap. Inst. Algolog. Research, Fac. Sci. Hokkaido Imp. Univ., vol. I, no. 1. Sapporo.

126. ..... (1941) New or Noteworthy Algae from Izu, I. ibid. Vol. II. no. 1.

127. SETCHELL, W. A. and GARDNER, N. L. (1903) Algae of Northwestern America. Univ. Calif. Publ. Bot., vol. I, no. 3. Berkley.

128. ..... (1920) Phycological Contributions. 1. ibid. vol. VII, no. 9.

129. SINOVA, E. S. (1940) Les Algues de la mer du Japon. Transac. of the Pacific Committee Academy, Sci. of the Ussr.

130. ..... (1940) The Algae of the Commander Islands. ibid.

131. SURINGER, W. (1878) Algae Japonicae. Musei Botanici Lugduno-Batavi. Harlemi.

132. SVEDELIUS, N. (1911) *Rhodophyceae* in ENGLER's die naturlichen Pflanzenfamilien ;-Nachtrage zum L, Teil. 2, Abt. Leipzig.

133. TAKAMATU, M. (1938) Marine Algae from the Sanriku Coast, Northeastern Honshû, Japan. Saito Hoonkai Museum Research Bulletin, no. 14. Sendai.

134. ..... (1938) Marine Algae from Tsugaru Srtait, Northeastern Honshû, Japan. ibid. no. 14.

135. ..... (1939) Marine Algae from the Coast of Japan Sea, in Northeastern Honshû, Japan. ibid. no. 17.

136. TANAKA, T. (1944) The Japanese Species of Protoflorideae. Sci. Pap. Inst. Algolog. Research, Fac. Sci., Hokkaido Imp. Univ., Vol. III, no. 1. Sapporo.

137. ..... (1944) The Japanese Species of Protoflorideae, I (in Japanese). Journ. Japanese Bot., Vol. 20, no. 4, Tokyo.

138. ..... (1944) The Japanese Species of Protoflorideae, II (in Japanese). Journ. Japanese Bot., Vol. 20, no. 5. Tokyo.

139. ..... (1950) On the Species of *Bangia* from Japan. Bot. Mag. Tokyo., Vol. 63, no. 747–748. Tokyo.

140. ..... (1951) The Species of *Erythrotrichia* from Japan (1) Acta Phytotax. Geobot., Vol. XIV, No. 3. Kyoto.

141. TAYLOR, W. R. (1928) The Marine Algae of Florida with Special Reference to the Dry Tortugas. Carnegie Instit. Washington, Publ. XXV, 379.

142. ..... (1929) Notes on the Marine Algae of Florida. Bull. Torr. Bot. Club. LVI.

143. ..... (1937) Marine Algae of the Northeastern Coast of North America. Ann. Arbor.
144. THAXTER, G. (1900) Notes on the Structure and Reproduction of *Compsopogon*. Bot. Gazette, 29. Chicago.
145. THURET, G. A. (1855) Note sur un Nouveau Genre d'Algues de la Famille des Floridées. Mem. Soc. Imp. d. Sci. Nat. de Cherbourg. III. Paris.
146. TOKIDA, J. (1932–'34) The Marine Algae from Robben Island, Saghalien. (1932) Bull. School Fish., Hokkaido Imp. Univ., Vol. II; Suppl. Report (1934) Vol. IV. Sapporo.
147. ..... (1935–'38) Phycological Observations II (1935) (On the Structure of *Porphyra Onoi* UEDA). Trans. Sapporo Nat. Hist. Soc., Vol XIV; IV (1938) ibid., Vol. XV. pt. 4. Sapporo.
148. TSENG, C. K. (1936) Notes on the Marine Algae from Amoy. Chinese Mar. Biol. Bull., Vol. I, no. 1. Amoy, China.
149. UEDA, S. (1929) On the life-history of *Porphyra tenera* KJELLMAN. Journ. Imp. Fish. Inst., XXIV. Tokyo.
150. ..... (1932) *Porphyra* of Japan (in Japanese). Bull. Jap. Sci. Fish., Vol. 28, no. 1. Tokyo.
151. ..... (1937) Studies of the life-history of *Porphyra tenera* KJELLMAN (in Japanese). Bull. Jap. Soc. Fish., Vol. VI, no. 2. Tokyo.
152. VISCHER, W. (1934) *Porphyridium cruentum* NAEGELI. Verh. Schweiz Naturforsch. Ges., 115. Lausanne.
153. ..... (1935) Zur Morphologie, Physiologie und Systematik der Blutalge, *Porphyridium cruentum* NAEGELI. Verhandl. Naturf. Ges, in Basal, 46.
154. WEBER VAN BOSSE, A. (1921) Liste des Algues du Siboga, II. Siboga Expedittie, LIXa.
155. WEST, G .S. (1916) Algae. Vol. I. Cambridge.
156. WILLE, N. (1900) Algologische Notizen 3. *Asterocytis ramosa* (THW.) GOBI Nyt. Magaz. fur Naturvidensk, 38. Kriestiana.
157. WOLOSZYNSKA, J. (1935) *Bangia atropurpurea* (ROTH) AGARDH in Polen Arch. d'hydrob. et d'chtyologie 9. Suwolki.
158. YAMADA, Y. (1934) The Marine Algae of the Northern Kuriles (in Japanese). Bull. Biogeogr. Soc. Japan., Vol. IV, no. 4. Tokyo.
159. ..... (1934–'35) Marine Algae from Urup, the Middle Kuriles, especially from the vicinity of Iema Bay (in Japanese) (1934). Inst. Alg. Research Bull., Fac. Sci., Hokkaido Imp. Univ., no. 3; (also in English) (1935), Sci. Pap. Inst. Alg. Research, Fac. Sci., Hokkaido Imp. Univ., Vol. I, no. 1. Sapporo.
160. ..... (1936) Notes on Some Japanese Algae VI. Sci. Pap. Inst. Algolog. Research, Fac. Sci., Hokkaido Imp. Univ., Vol. 1, no. 1. Sapporo.
161. YAMADA, Y. and TANAKA, T. (1938) The Marine Algae from the Island of Yonakuni. Sci. Pap. Inst., Algolog. Research, Fac. Sci., Hokkaido Imp. Univ., Vol. II, no. 1, Sapporo.
162. ..... (1944) Marine Algae in the Vicinity of the Akkesi Marine Biological Station. Sci. Pap. Instit. Algolog. Research, Fac. Sci., Hokkaido Imp. Univ., Vol. III, no. 1. Sapporo.

163. YENDO, K. (1909–'16) Notes on Algae New to Japan, I–IV. Bot. Mag. Tokyo, Vol. XXIII–XXX. Tokyo.
164. ……(1913) Some New Algae from Japan. Nyt, Mag. f. Naturvidensk, Vol. LI. Christiana.
165. ……(1920) Novae Algae Japonicae Decas, I–III. Bot. Mag., Vol. XXXIV. Tokyo.
166. ZOPF, W. (1882) Zur Kenntnis der Spaltalgen (*Schizophyceae*). Bot. Centralbl. Jahrg., III, X, 1. Leipzig.

# PLATE

*Cymbsophora Oishii* OKAMURA. Slightly reduced.

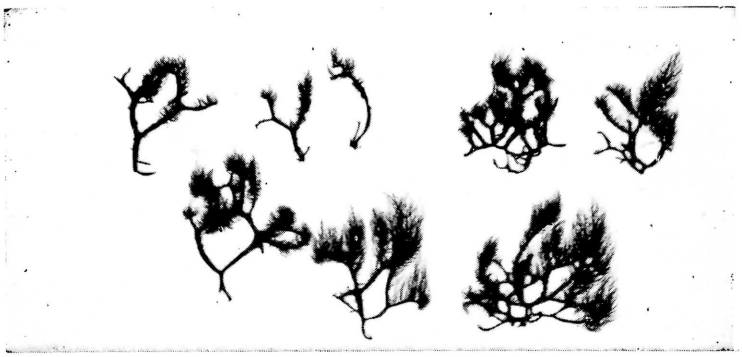
PLATE 1

## PLATE 2

1. *Bangia gloiopeltidicola* TANAKA. × 4/5.

2. *Bangia fusco-purpurea* (DILLWYN) LYNGBYE. × 4/5.

PLATE 2



1

2

## PLATE 3

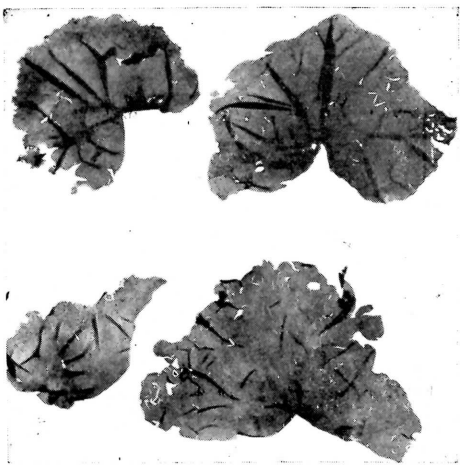
1. *Porphyra Okamurai* UEDA. Slightly reduced.
2. *P. suborbiculata* KJELLMAN. × ⅔.
3. *P. suborbiculata* KJELLMAN *f. latifolia* TANAKA. × ½.
4. *P. suborbiculata* KJELLMAN. × ⅔.

PLATE 3

1

2

3



4

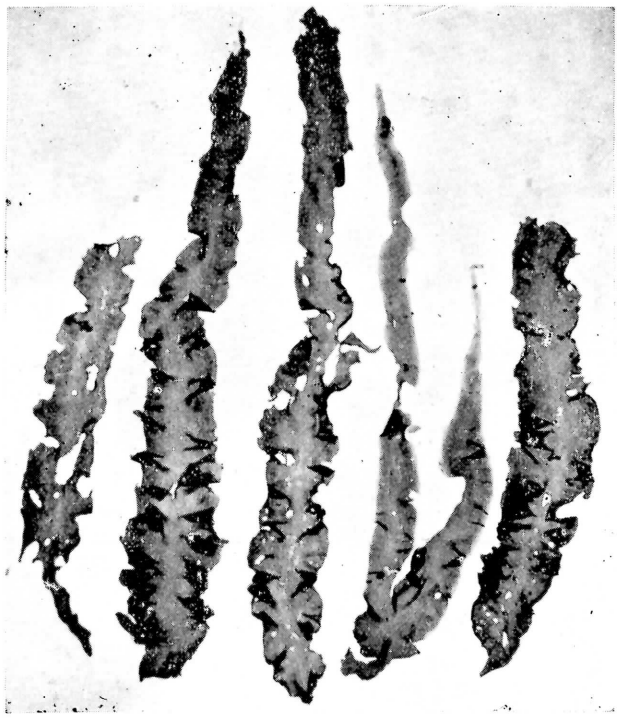
## PLATE 4

1. *Porphyra dentata* KJELLMAN. One male and four female plants. × 4/5.

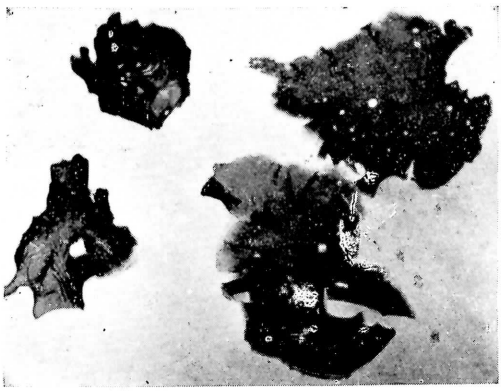
2. *P. crispata* KJELLMAN. × 4/5.

3. *P. crispata* KJELLMAN. × 1/2.

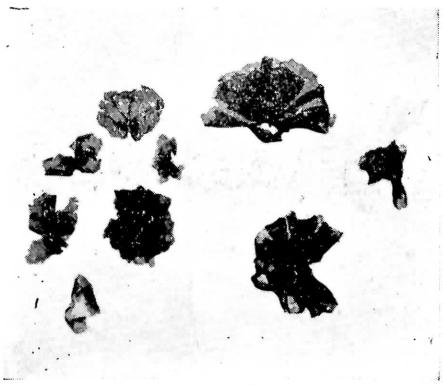
PLATE 4



1



2



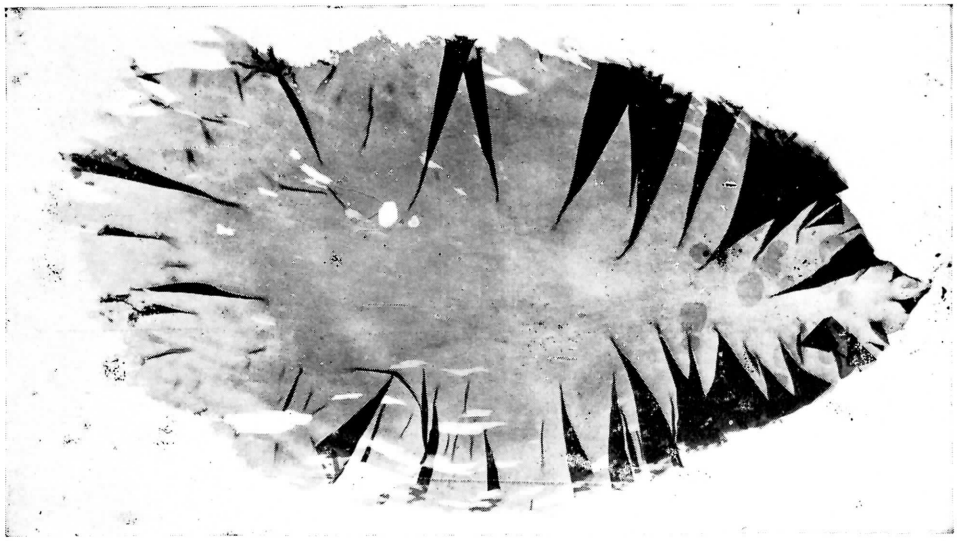
3

## PLATE 5

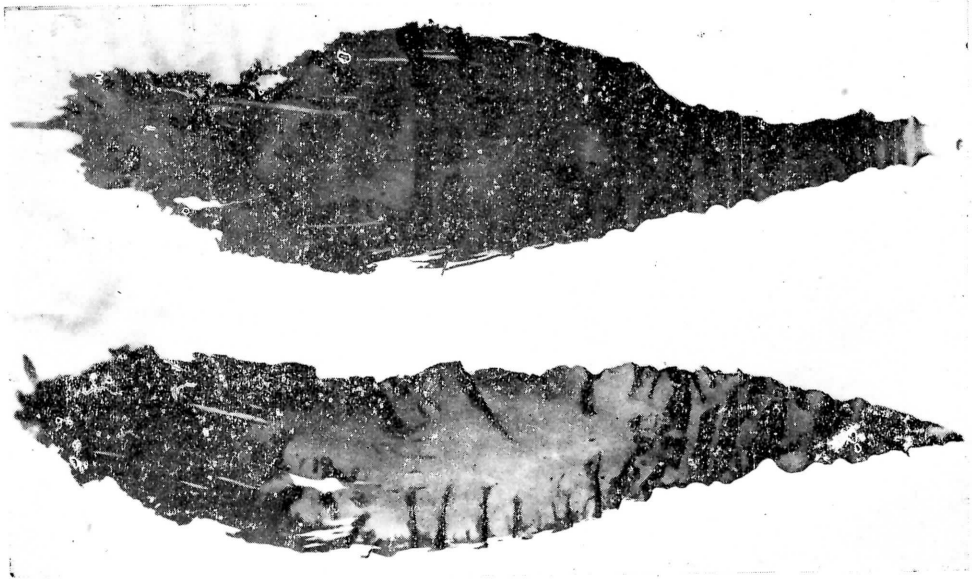
1. *Porphyra yezoensis* UEDA *f. Kinositai* YAMADA et TANAKA. × 1/3.

2. *P. yezoensis* UEDA. × 3/5.

PLATE 5



2



1

## PLATE 6

1. *Porphyra ochotensis* NAGAI. A male plant. × ½.

2. *P. ochotensis* NAGAI. A female plant. × ⅓.

PLATE 6

2

1

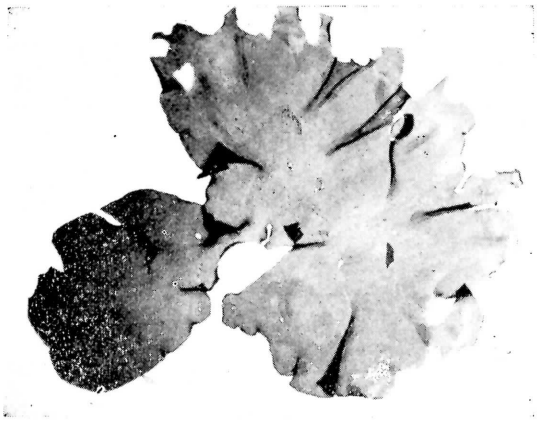
## PLATE 7

1 - 2. *Porphyra seriata* KJELLMAN. × 4/5.

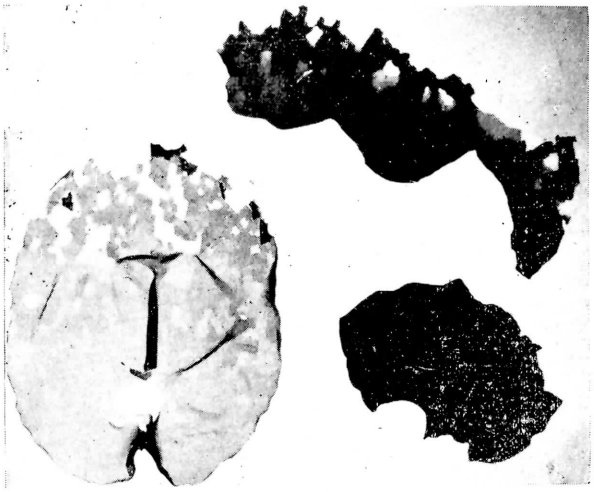
3. *Porphyra yezoensis* UEDA. × 1.

Specimens from Fusan, Corea.

PLATE 7



1



2

3

## PLATE 8

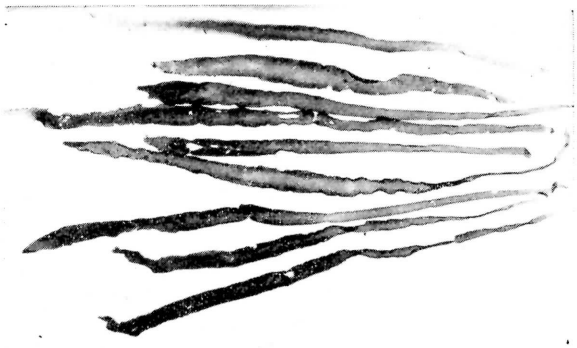
1. *Porphyra pseudolinearis* Ueda. × 3/5.

   Three male and one female plants from Uppurūi, Izumo prov.

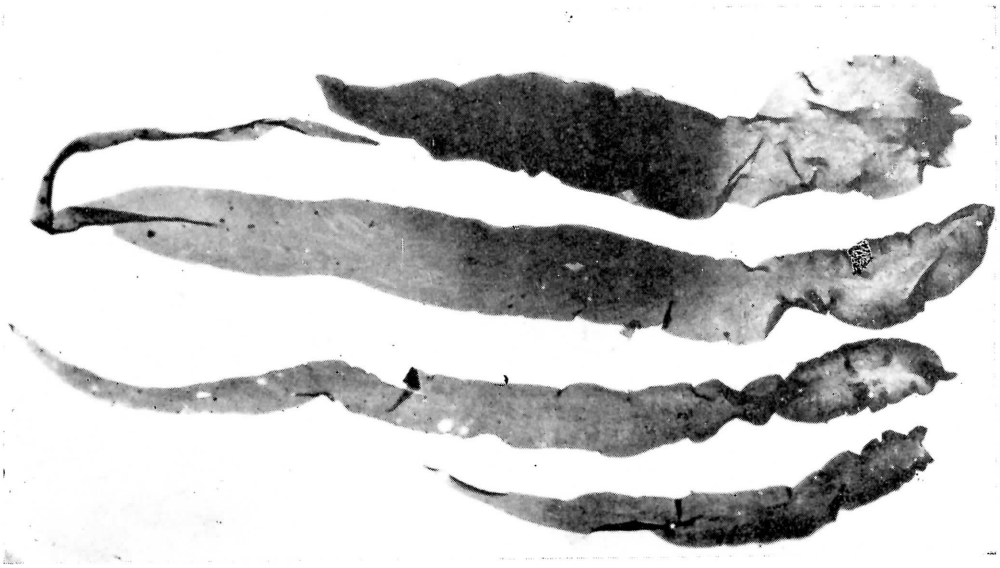
2. *P. pseudolinearis* UEDA. × 1.

   Small plants from Uppurui, Izumo Prov.

LATE 8



2



1

## PLATE 9

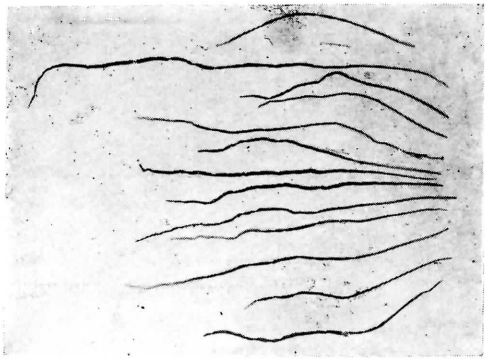
1. *Porphyra pseudolinearis* UEDA. × 2/3.

   One female and three male plants from Oshoro, Hokkaido.

2. *P. pseudolinearis* UEDA. × 1.

   Small plants from Uppurui, Izumo Prov.

PLATE 9



2

1

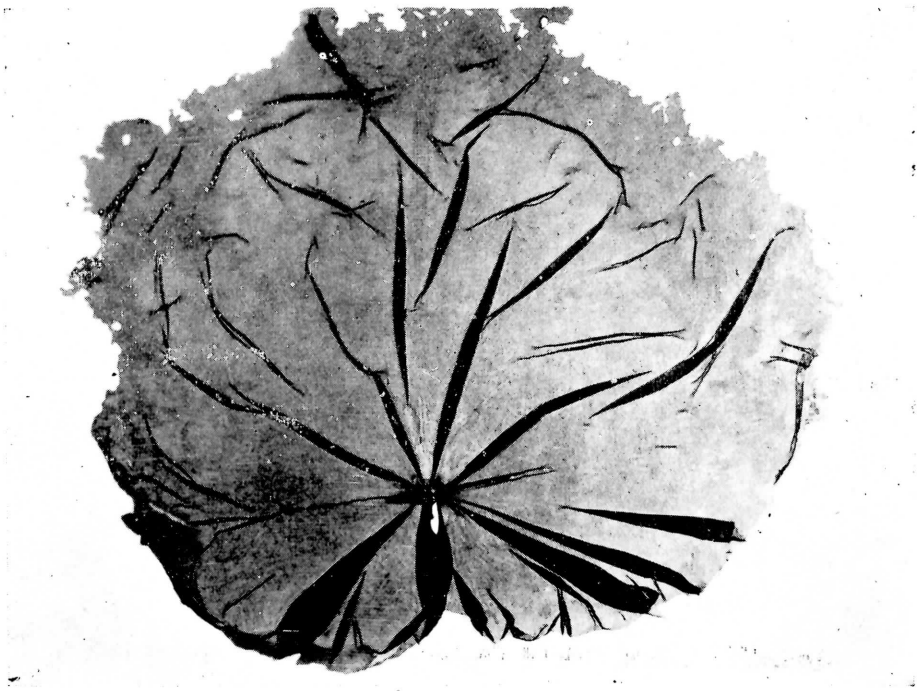
## PLATE 10

1. *Porphyra tenera* KJELLMAN. Long type. × 2/3.

2. *P. tenera* KJELLMAN. Round tpye. × 2/3.

PLATE 10

1



2

## PLATE 11

1. *Porphyra tenera* KJELLMAN. Specimen from Moppo, Corea. × 1/3.

2. *P. tenera* KJELLMAN. Growing on the frond of *Myelophycus caespitosus* KJELLMAN. × 2/3.

3. *P. tenera* KJELLMAN. Growing on the frond *Ishige Okamurai* YENDO. × 1.

PLATE 11

1

2

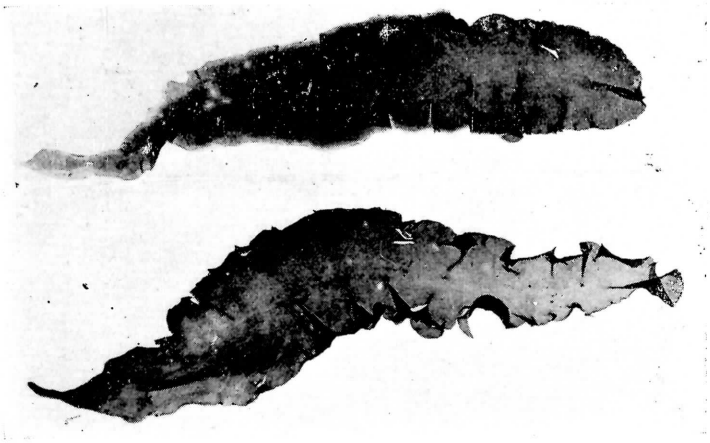
3

## PLATE 12

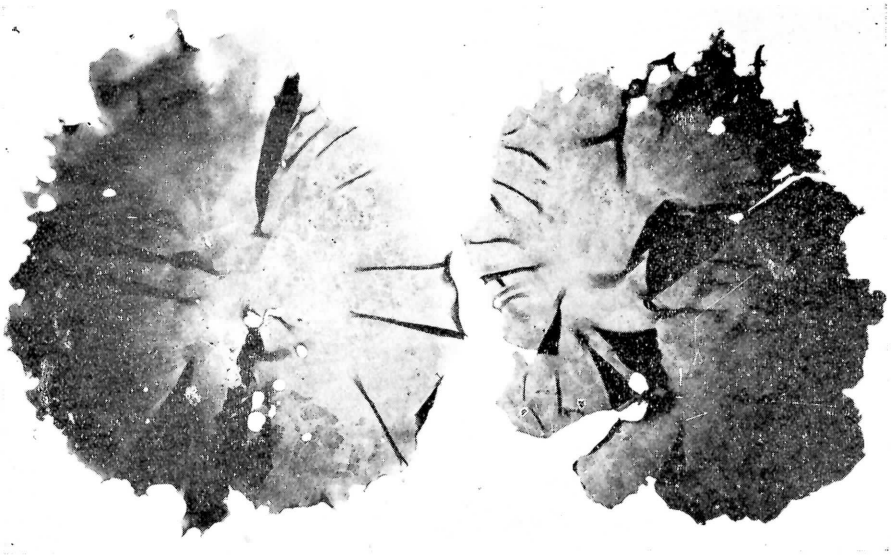
1. *Porphyra crassa* UEDA. Male and female plants. × 3/4.

2. *P. angusta* KJELLMAN. × 2/3.

PLATE 12



2



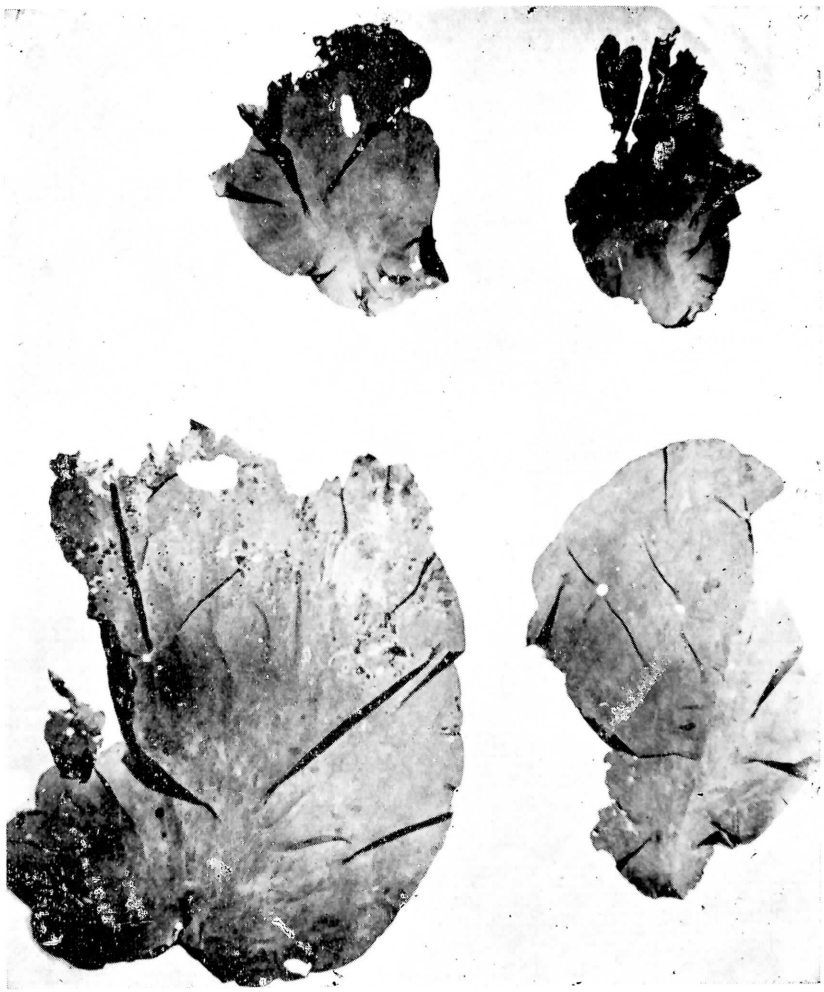
1

## PLATE 13

1. *Porphyra umbilicalis* (L.) J. AGARDH *f. laciniata* (L.) THURET. × 3/4.
   Specimens from Muroran, Hokkaido.

2. *P. umbilicalis* (L.) J. AG. *f. laciniata* (L.) THURET. × 2/3.
   Specimen from Kurile Islands.

1



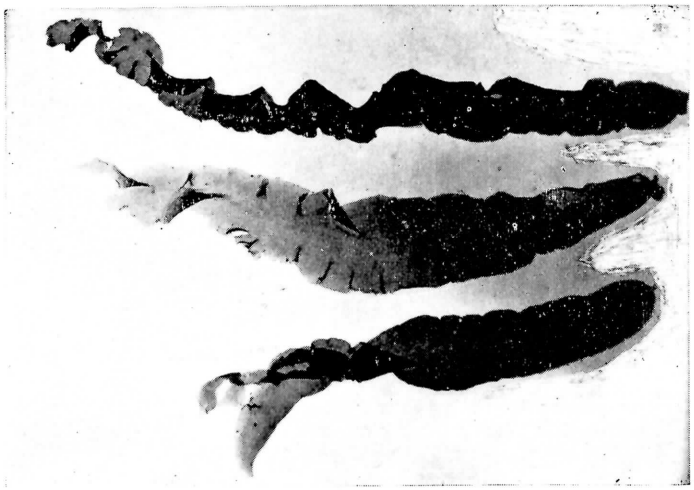
2

## PLATE 14

1. *Porphyra umbilicalis* (L.) J. AGARDH *f. vulgaris* (AG.) THURET. × ½.
   Specimen from Urup, Kurile Islands.

2. *P. umbilicalis* (L.) J. AGARDH *f. linearis* (GREV.) HARVEY. × ¾.
   Specimen from Akkesi, Hokkaido.

PLATE 14



2

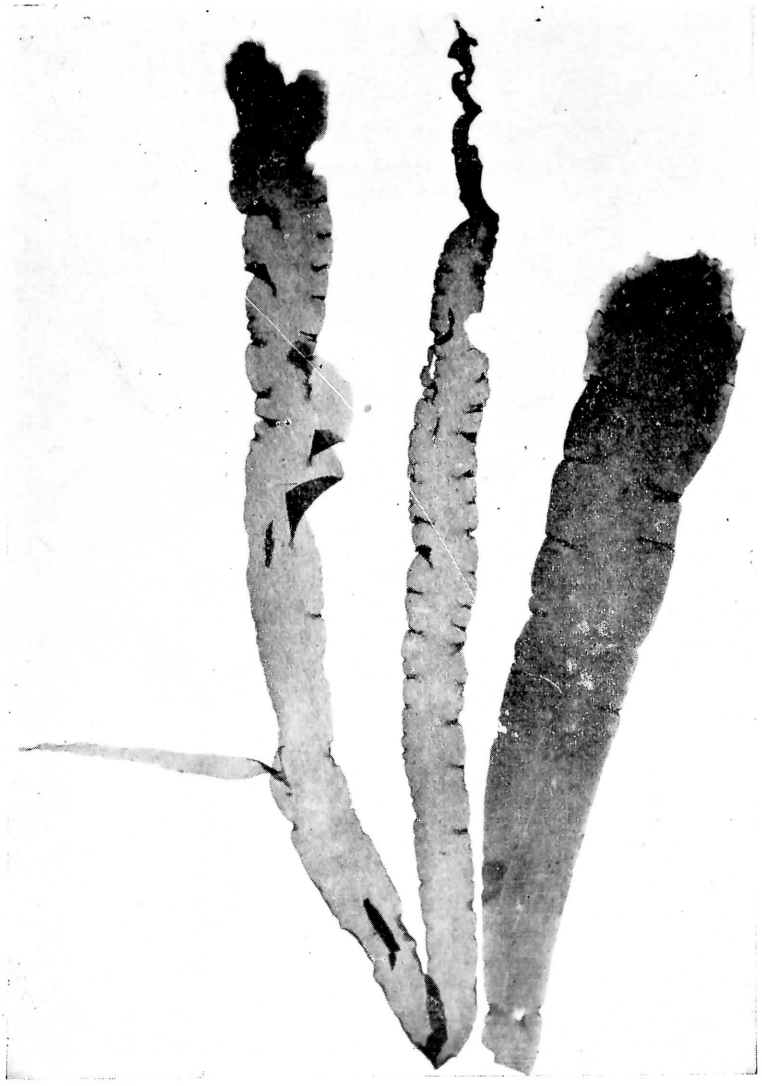
1

## PLATE 15

1. *Porphyra umbilicalis* (L.) J. Ag. *f. laciniata* (L.) Truret. × 2/3.
   Specimen from Onahama, Iwaki Prov.

2. *P. umbilicalis* (L.) J. Ag. *f. linearis* (Grev.) Harvey. × 1.
   Specimen from Akkesi, Hokkaido.

1



2

## PLATE 16

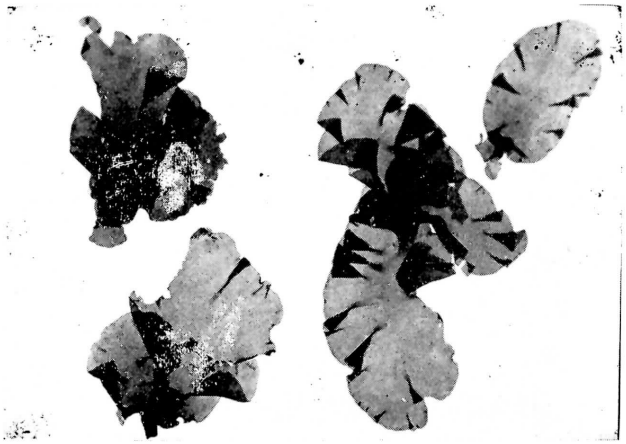
1. *Porphyra Onoi* UEDA. × ½.

   Specimens from Akkesi, Hokkaido.

2. *P,* *Onoi* UEDA. × ½.

   Specimens from Oshoro, Hokkaido.

PLATE 16



1

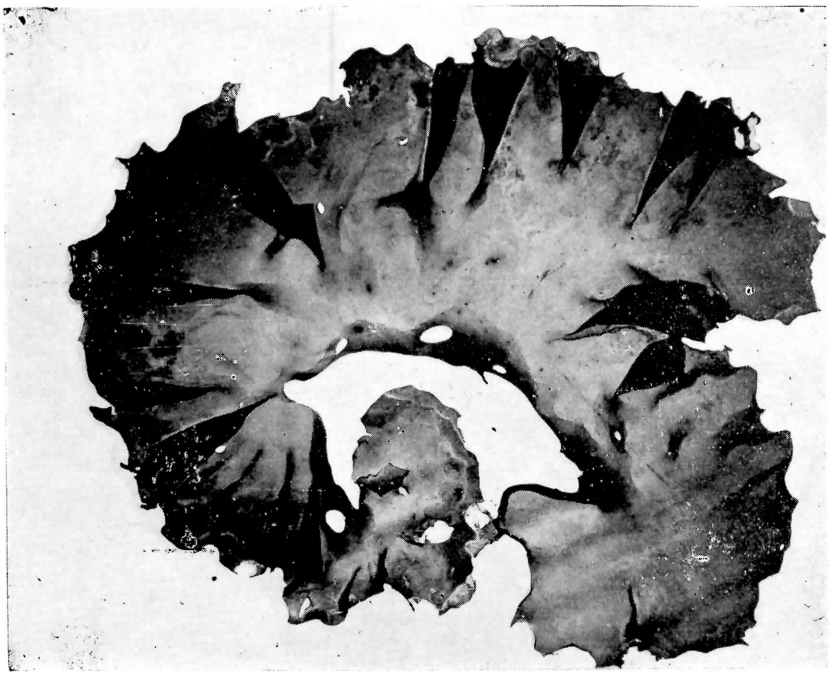
2

## PLATE 17

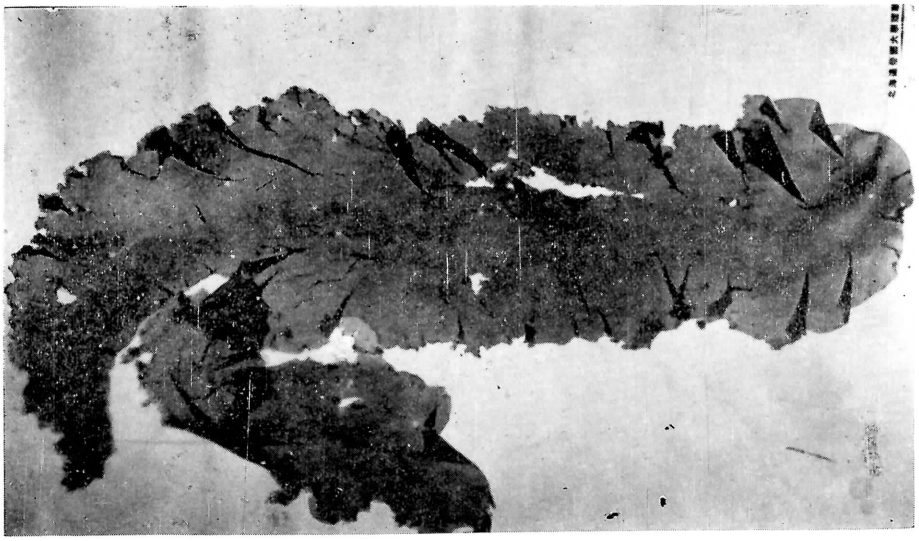
1. *Porphyra amplissima* (KJELLMAN) SETCHELL et HUS. × 2/5.
   A male plant.

2. *P. Tasa* (YENDO) UEDA. × 5/8.

PLATE 17



2



1

## PLATE 18

*Porphyra bulbopes* (YENDO) OKAMURA. × 2/3.

Whole plants showing a straight limiting line into a male and female portions.

PLATE 18

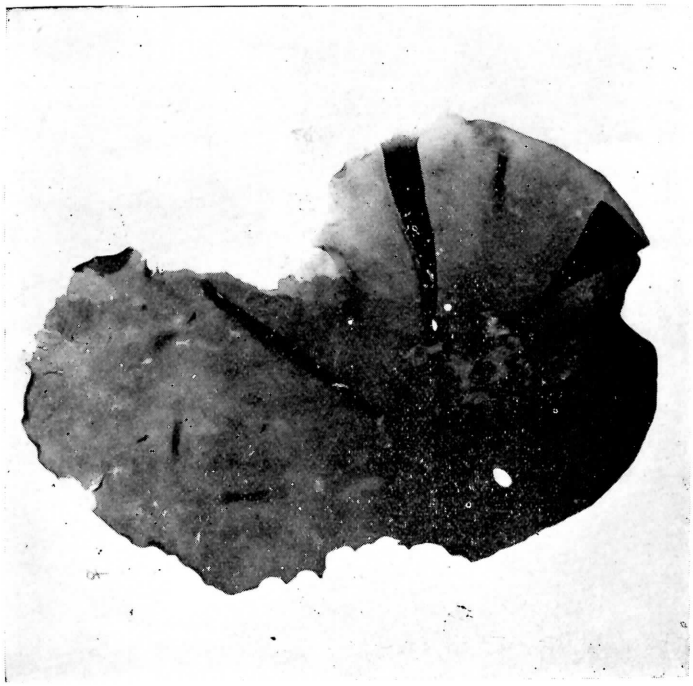
# PLATE 19

*Porphyra bulbopes* (YENDO) OKAMURA

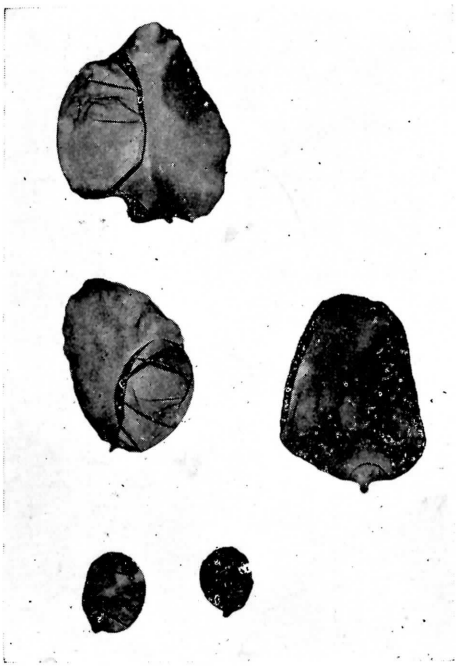
1 and 3. Whole plants showing a straight limiting line into a male and female portions. × 2/3.

2. Five plants showing the inflated portions. × 1/2.

PLATE 19



1



2

3

# PLATE 20

*Porphyra bulbopes* (YENDO) OKAMURA.

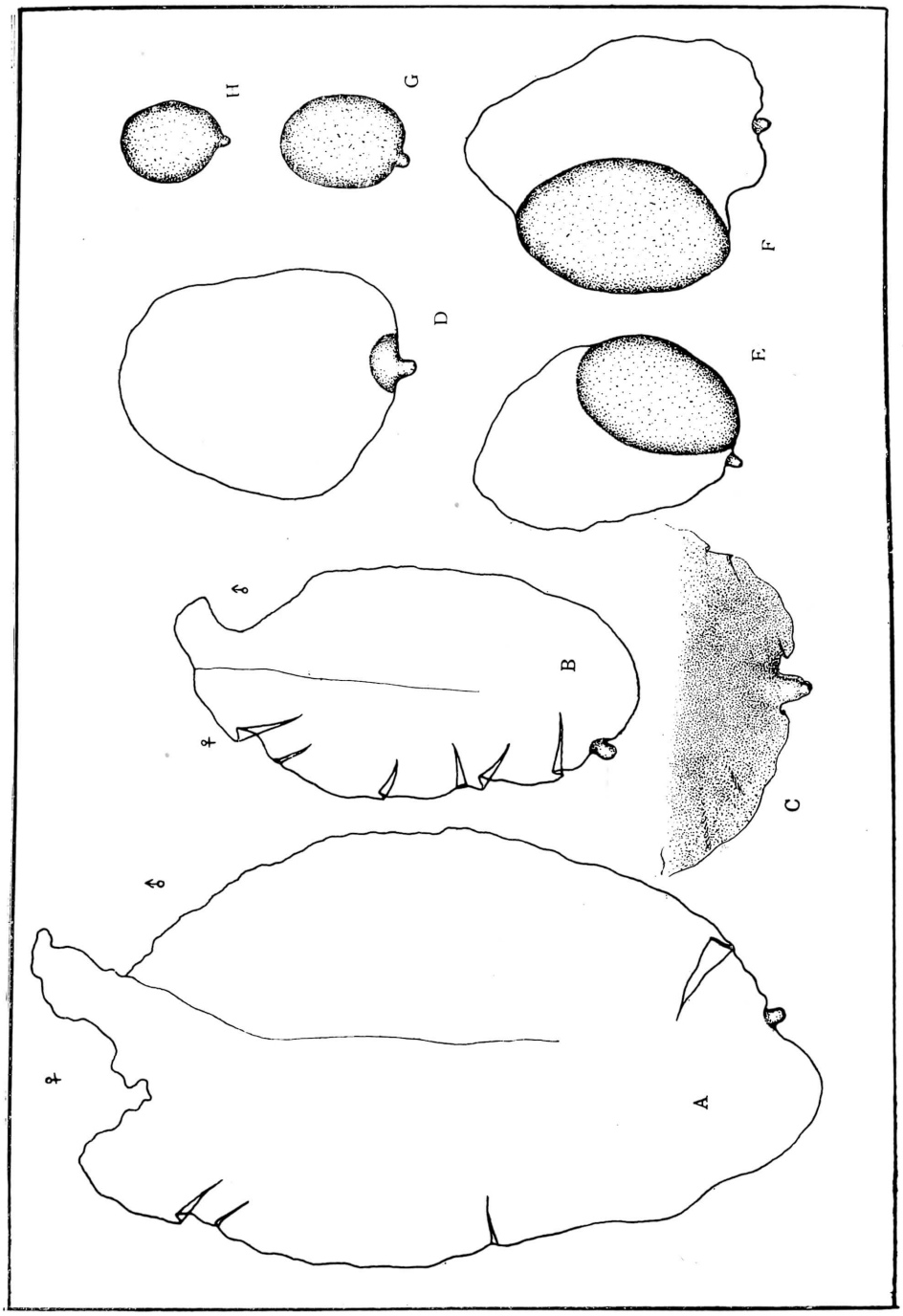
A – B. Sketch of the plant showing the male and female portion. × 4/5.

C. Basal portion of the frond. × 1½.

D – H. Several plants showing the inflated portion at the lower and side portions (D.E.F.) and on nearly the whole area (G.H.) × 4/5.

(Del. by Y. Okada)

PLATE 20



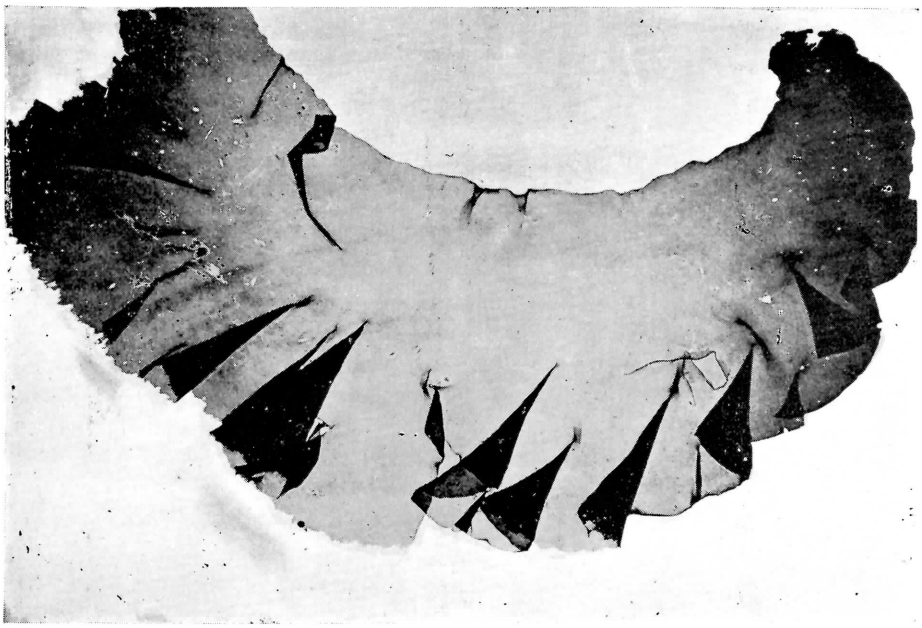
# PLATE 21

*Porphyra variegata* KJELLMAN.

1. One matured cystocarpic frond. × 2/3.

2. Six young plants. Each frond shows a limiting line into a māle and female portions. × 2/3.

PLATE 21



1

2

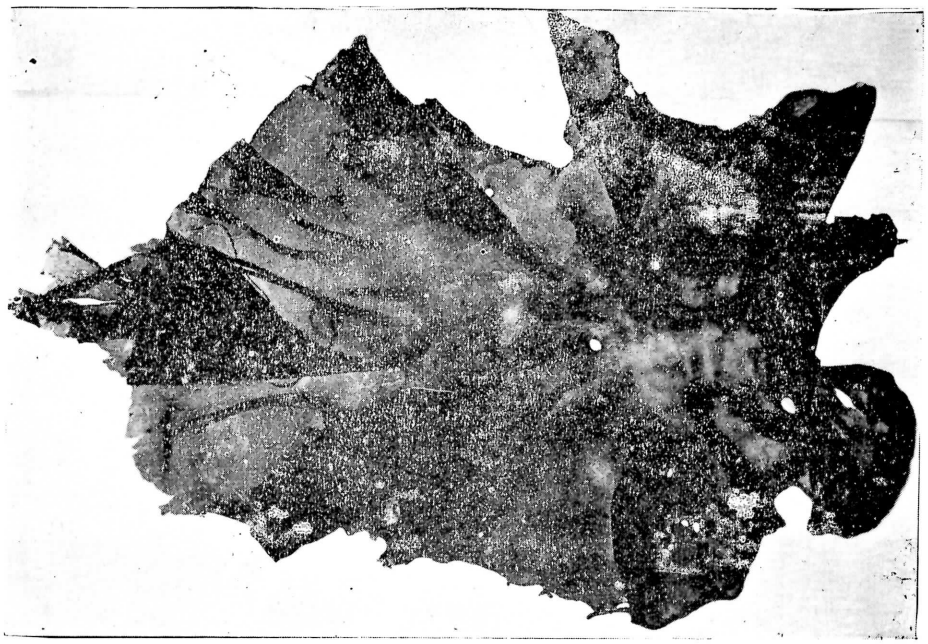
## PLATE 22

1. *Porphyra amplissima* (KJELLM.) SETCHELL et HUS *f. lanceolata* NAGAI. × ½.

2. *P. amplissima* (KJELLM.) SETCHELL et HUS *f. crassa* KAWABATA. × ½.

PLATE 22

1



2

## PLATE 23

*Porphyra amplissima* (KJELLMAN) SETCHELL
et HUS *f. elliptica* NAGAI. × 2/5.

PLATE 23