The Genus *Codium* in New Zealand
Part I. Systematics*

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Summary

THE genus *Codium* is represented in New Zealand waters by six species. The New Zealand members of *Codium adhaerens* (Cabr.) Ag have been split up into a northern and a southern variety, var. *convolutum* var. nov., type locality Motutapu, and var. *incrassatum* var. nov., type locality Stewart Island. The differences from *C. adhaerens* (s.str.) are not regarded as of sufficient magnitude to warrant the creation of new species. Gametangia are figured for the first time in *Codium cranwelliae*. *C. mamillosum* Harv. and *C. muelleri* Kuetz do not occur in New Zealand. Owing chiefly to the larger size of the utricles, the New Zealand members of *C. dichotomum* have been assigned to a new form, f. *novo-zelandicum*, type locality Lyttelton. In spite of great variation in utricle size and shape among individuals belonging to the *Codium fragile* assemblage, there are no constant differences on which to base the formation of new varieties. *C. fragile* var. *gracile* O. C. Schmidt has been raised to the rank of a separate species, under the new combination *Codium gracile*. No intermediate forms have been found which might be a connecting link between *C. fragile* and *C. gracile*. *Codium cuneatum* in New Zealand has typically thick, striated utricle apices, and has been described accordingly as f. *striatissimum* f. nov., type locality Bay of Islands.

INTRODUCTION

AN investigation of herbarium and preserved material of both overseas and New Zealand specimens has shown that six species of *Codium* inhabit New Zealand waters.

Dried material has been examined from the herbaria of the late R. M. Laing, the Botany Division of the Department of Scientific and Industrial Research, Professor V. J. Chapman, Mr. V. W. Lindauer, and from the writer's own herbarium. Preserved specimens have been collected mainly by the writer, excluding those from the Southern Fiords, Stewart Island, and the Subantarctic Islands.

Wherever possible, descriptions are based on material preserved in 5 per cent. formalin in seawater, since dried specimens are extremely unreliable as a basis for accurate measurements. Tissues removed from herbarium sheets were swollen as nearly as possible to normal size by boiling or placing for 24 hours in a solution of the detergent Ados No. 3.

CLASSIFICATION

Setchell (in Lucas, 1935) proposed a division of *Codium* into 2 sub-genera:

(a) *Tylecodium*—cushion-like forms with typically branched utricles;

(b) *Schizocodium*—dichotomous forms, with utricles mainly simple.

Schmidt, following De Toni, earlier recognised 4 sections, each of which he divided into 2 subsections. The most primitive group is regarded by him as that of the *Adhaerentia,* members of which are more or less flattened and crustose or sponge-like, with a surface region of palisade utricles and a subsurface region of medullary filaments. Attachment is effected by means of rhizoids over the entire lower surface. Slightly more advanced in complexity is the *Bursae* group,

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typified by globose, pyriform or oval thalli, either solid or with a central hollow. The area of attachment is here limited to a very small portion of the base. Schmidt visualises this type of thallus as having evolved from the *Adhaerentia* type through formation of a sphere, the surface of which is morphologically equivalent to the upper surface of the *Adhaerentia* thallus. The portion bordering on the hollow (when present) should therefore be equivalent to the *Adhaerentia* undersurface.

The section *Tomentosa* comprises erect or creeping cylindrical thalli with regular or irregular dichotomous branching. In this group, the *adhaerens* upper surface is represented by the outer surface of the cylinder. The centre of the structure forms the medulla, and is solid in contrast to the *Bursae* group, being composed of relatively densely intertwined, thread-like filaments. Attachment is effected by rhizoidal outgrowths from a basal disc. The highest degree of specialisation is seen in the *Elongata* section, where there has been a greater or lesser amount of compression of the *Tomentosa* cylinder.

Within each group the species are arranged according to the degree of complexity of utricle structure, utricles with varying shape and thickened or irregular membranes being regarded as more highly evolved than those with smooth straight walls and thin membranes. On the basis of the above assumptions, an artificial key has been constructed for identification of the New Zealand representatives.

KEY FOR *Codium* SPECIES IN NEW ZEALAND

A. Thallus flat or cushion-shaped	Subgenus *Tylecodium* Setchell *apud* Lucas
I Thallus flat, attached by entire lower surface .	Sectio *Adhaerentia* De Toni
1. Thallus firm, utricles narrow .	*Subsectio *Euadhaerentia* O C Schmidt
(a) Utricles branched, cylindrical	*C. adhaerens* (Cabr.), Ag
i Membrane thin	var *convolutum* var nov.
ii Membrane up to 30μ thick ..	var. *incrassatum* var nov
II. Thallus globose, oval or pyriform, hollow, attached by a portion of lower surface	Sectio *Bursae* De Toni
1. Thallus firm	Subsectio *Eubursae* O. C. Schmidt
(a) Utricles large, trabeculate	*C. cranwelliae* Setchell
B. Thallus erect or prostrate, cylindrical or compressed, usually dichotomously branched	Subgenus *Schizocodium* Setchell *apud* Lucas
III Thallus cylindrical	Sectio *Tomentosa* De Toni
1. Utricles elongate, clavate or cylindrical ..	Subsectio *Eutomentosa* O. C Schmidt
(a) Utricles with a more or less prominent mucro	*C. fragile* (Suring.) Harriot
(b) Utricles never mucronate, relatively large	*C dichotomum* (Huds) Gray f *novo zelandicum* f nov.
2. Utricles small .	Subsectio *Tenuia* O C. Schmidt
(a) Apices flattened or mucronate	*C gracile* (O. C Schmidt) comb. nov.
IV Thallus slightly to markedly flattened	Sectio *Elongata* De Toni
1. Segments very broad	Subsectio *Lata* O C Schmidt
(a) Thallus wedge-shaped below a dichotomy, utricles thickened in layers at apex	*C cuneatum* Setchell and Gardner f *striatissimum* f. nov

1. **Codium adhaerens** (Cabr) Ag

C. Agardh, 1822, vol. 1, p 457. Hooker, 1867, p. 714. Hooker and Harvey, 1855, vol 2, p 261. J Agardh, 1877, p 3, 1886, Avd. VIII, p. 37 De Toni, 1889, vol. 1, p. 489. Schmidt, 1923, p. 26, figs. 6–7

Agardhia adhaerens Cabrera, in *Phys. Sallsk. Arsber.*

* The subsections *Difformia, Mamillosum* and *Decorticata* are not represented in New Zealand.

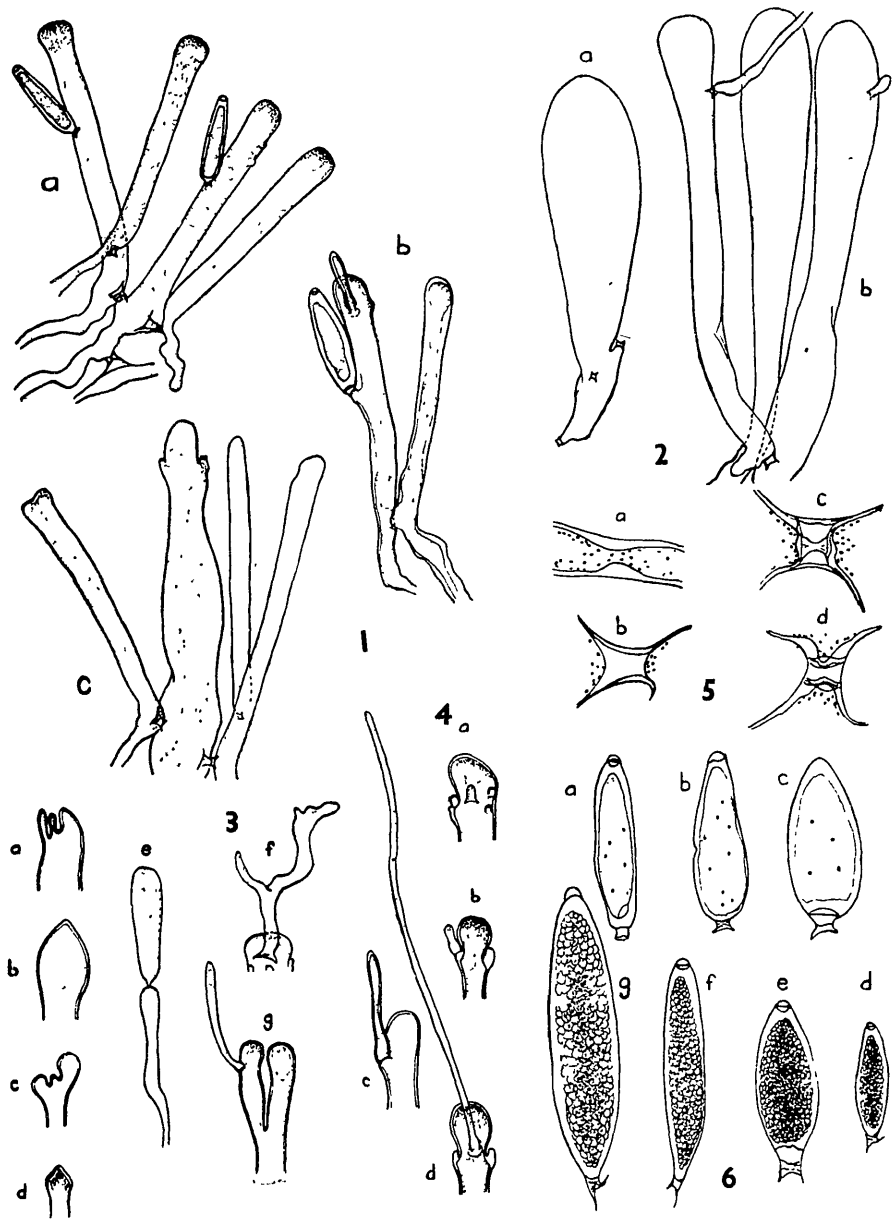


FIG 1—*Codium adhaerens* var. *convolutum*. a–c, palisade utricles from type specimen (× 46).
FIG. 2—Typical clavate utricles (× 46).
FIG 3—a–g, irregularities in structure of utricles (× 46)
FIG 4—Young and mature hairs and scars on palisade utricles (× 46).
FIG 5—Development of plugs in lateral filaments (× 210).
FIG. 6—a–c, male gametangia; d–g, female gametangia (× 93).

Codium arabicum Kuetz., 1856, vol. 6, t. 100, fig. 2.
Codium intertextum Collins and Hervey, 1917, p. 54.

(a) var. **convolutum** var. nov. Plate 32, fig. 1, text-figures 1–6

Thallo prostrato cum paucis vel multis irregularibus lobis radialibus et convolutionibus, ad 20 cm. dia., 2 cm. crasso; utriculis saepe infra apicem constrictis, corona capillorum circumventis.

Thallus dark green, prostrate, adhering closely to substratum when young, becoming loosely attached or free when old, with few to many irregular radial lobes and corrugations, up to 20 cm. in diameter and 2 cm. thick; outer surface firm, slippery to touch; external layer of palisade-like, densely packed, branched utricles, 420–900μ long, sometimes as much as 1,280μ long, 28–100μ, rarely 200μ wide; plastids aggregated near apices of utricles; apex varying greatly in shape from swollen and rounded with a constriction below to flat or slightly depressed; membrane thin (1–5μ), hairs or scars forming a ring round subapical region; hairs up to twice length of utricles, 41–1,320μ long and 15–30μ wide, apex flat or rounded; plastids scattered throughout; subsurface region of clavate utricles with thin membranes and few plastids, up to 1,400μ long and 170μ wide; central filaments 15–75μ in diameter; gametangia pedicellate, 1 per utricle, cylindrical or fusiform, attached between $\frac{1}{2}$ and $\frac{1}{3}$ distance from apex of utricle, 240–425μ long and 40–140μ wide.

Type specimen in Herb. Auck. Inst. and Mus., Coll. L. M. Cranwell, Home Bay, Motutapu, 23.5.32; Fascicle XI, no. 252, in Herb. V. W. Lindauer, Algae Novae-Zelandiae Exsiccatae as *C. adhaerens*, Fascicle V, no. 107, Algae Novae-Zelandiae Exsiccatae, and no. 794, personal collection of V. W. L., as *C. coronatum* Setch.

Distribution. Local: North Cape to Banks Peninsula. Frequent. Endemic.

This variety is distinguished from *C. adhaerens* "sensu stricto" by the intense degree of folding and generally greater robustness of mature thalli, together with the single ring of hairs and the often constricted region below the apices of utricles.

The apparent discrepancies in external form and internal structure led other workers to regard var. *convolutum* as a new species, but an examination of preserved material from Plymouth, England, a dried specimen from Clare Island, and also a portion of the type specimen of *C. adhaerens* from the Agardh herbarium at Lund has led to the conclusion that the differences between these forms and the New Zealand plants are not of sufficient magnitude to warrant the creation of a new species. The degree of folding of the thallus has been regarded as a specific character in the past, and yet plants of *adhaerens* have been observed growing where one half is extremely irregular in outline, reflecting either its greater age or the microtopographical variation in the rock surface underneath, while the other half on an even ledge shows hardly an undulation of the surface, or at most a series of parallel radiations. Further, young plants are usually smooth, the degree of folding often being an indication of age. A group of palisade utricles and a large clavate utricle are figured from the type specimen of *C. adhaerens* to emphasize the essential similarity with utricles from the New Zealand variety (Text-fig. 7). The only noteworthy difference is in the presence of a double ring of spirally arranged hair scars on the clavate utricle from the type specimen.

Within the utricles a striated appearance may result from the orientation of the plastids with their long axes parallel to that of the utricles, just as Williams (1925, p. 100) describes for the gametangia of *C. fragile.*

A number of abnormalities in shape of utricles are illustrated in Text-figure 3, a–g. A, b, and d, all come from young plants (about 1 month old) growing at Whangaparaoa Heads, in the Hauraki Gulf. B and d are reminiscent of the *fragile* type of apex. There is no close connection with the latter species, yet the occasional manifestation of such structures within the relatively primitive *adhaerens* thallus indicates a latent character within the genus which later becomes expressed as the major utricle type in more highly evolved species such as *C. fragile* and *C. gracile.*

The oddly branched structure arising from near the apex of a clavate utricle shown in f appears to be a secondarily developed rhizoidal filament. C and f were both found in a preserved specimen from Lyall Bay, Wellington. Broadly speaking, the greatest number of irregularities in shape and structure of utricles were found in portions of the plant from near the lower surface.

Var. *convolutum* has been found fertile in April, May, August, October, and November. Monoecious plants are exceptional, only one plant having been found to date with both male and female gametangia (cf., however, Schussnig, 1950, p. 56, who states that male and female gametangia may reach maturity at different times).

It is closely related to *C. lucasii* Setchell of South and East Australia and Lord Howe Island. In their usual form the utricles of *C. lucasii* strongly resemble those of *C. adhaerens* var. *convolutum,* differing only in their smaller size and lightly thickened, alveolate inner membranes, and their shorter and broader gametangia. It will be seen from Text-fig. 6, however, that this form of gametangium is quite typical in both male and female plants of the New Zealand *adhaerens.* Other writers have emphasized that shape of the gametangium is not a reliable criterion on which to base the limits of a *Codium* species. The description of the habitat given by Lucas (1935, p. 202) is also in close agreement. To quote his own words: "It always appears in the same habitat at low tide level, extending over ledges or on faces of rock, adapting itself closely to the inequalities of the rock surfaces; of variable outline, often ribbon-like, but with rounded edges and lobes . . . The substance is tough and leathery, the surface smooth and slippery, and the colour a dark, almost black, green." In the light of the above comparison, therefore, the differences appear to be more on the subspecific level, in which case *C. lucasii* should be ranked as a variety of the widespread *adhaerens.*

A further affinity may be traced with *C. cerebriforme* Setchell from Juan Fernandez (Setchell, 1941, p. 588, Pl. 34, figs 1–3, Pl 39, figs. 1–5). In his Plate 34 the plants appear to have been swollen or else were preserved originally. In the opinion of the writer there is every likelihood that this contorted, brain-like appearance is simply due to the effect of a release in tension, and hence turgor, in the attachment region of the thallus upon its removal from the substrate. On the whole, the utricles of *C. cerebriforme* are longer and narrower than those of *C. adhaerens.*

In a letter to Mr. V W. Lindauer, Setchell identified the adherent *Codium* No. 505, 3, Herb. V.W.L. as *C. coronatum* Setch., "or at least a species very close to it." All the specimens referred to *C. coronatum* in the herbaria of Mr. Lindauer have since been examined and compared with a portion of the

type specimen (No. 261420, Herb. Univ. Calif.) from Tahiti. As a result, the conclusion is reached that the New Zealand plants show no constant difference in utricle structure from ordinary *C. adhaerens*, although there may be a preponderance of wider utricles with numerous hair scales just below the apex. Setchell (1926, p. 82) distinguishes between an earlier "effuse" stage (utricles clavate-cylindrical) and a later "coxcomb" stage with inflated utricle and conical or rounded apices. Whether *C. coronatum* Setch. is a valid species or not is a problem which needs further investigation, but in the portion of the type examined many cylindrical *adhaerens* utricles were observed. It is interesting to note that No. 7990 Herb. Lindauer (personal collection) was found growing "attached to sticks and wrapped around them" at Indigo's Bay, Urupukapuka, Bay of Islands.

(b) var. **incrassatum** var. nov. Text-figures 8–9

Thallo firmiore quam in var. convoluto, minus distincte lobato; utriculis ampullaceis, membrana distincte crassata.

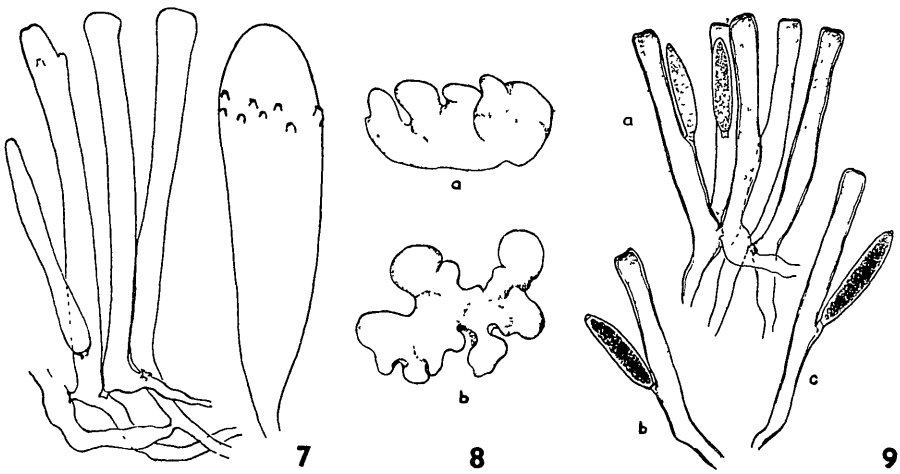


FIG. 7—*Codium adhaerens*. Utricles from the type of the species, No. 15465, Herb. J. Ag (× 45).
FIG. 8—*Codium adhaerens* var. *incrassatum* a, outline of type specimen from Stewart Island (No. 927, Herb Dellow) (× ½). b, outline of plant from Campbell Island (Coll J. H. Sorensen, 28 11.47) (× ½).
FIG. 9—a, utricles with male gametangia. b, c, utricles with slightly larger female gametangia (× 45).

Thallus dark green, firmer than in var *convolutum*, applano-pulvinate, often crescent-shaped, lobed at margins; lobes more regularly dichotomous, 1–2 cm. broad, with truncated apices, separate for most of their length; utricles 900–1,300μ long and 50–100μ wide, cylindrical in lower portions, narrowing to form an apex like a bottle-neck; membrane varying from 1–30μ thick, flat or slightly depressed, often stratified and alveolate; hairs absent; clavate utricles not seen; central filaments 15–60μ in diameter; gametangia cylindrical-fusiform, 230–320 x 45–75μ, occurring singly at or below middle of utricles.

Type specimen No. 927, Herb. Dellow, in Herb. Auck. Inst. and Mus., Coll. E. Willa, Half Moon Bay, Stewart Island, Dec 1949.

Distribution Local: Timaru, Stewart Island, Chatham Islands, Campbell Island, St. Clair (Dunedin). General. Pacific Ocean, Nauru Island?

Miss U. C Smith collected this variety from Stewart Island in 1897 (specimen No. 39384, Herb Univ. Calif.) and Setchell had decided that it differed sufficiently from the northern group to warrant the creation of a new species.

Var. *incrassatum* is reminiscent of *C. perrinae* Lucas in the almost crescentic habit of the thallus (Text-fig 8), the absence of hairs and the foveolate membranes. But the spongiose texture and larger utricles with their subgaleate apices are distinct enough to mark *C. perrinae* apart from the New Zealand varieties of *adhaerens*.

Gametangia have been found in preserved plants from St. Clair, Dunedin (coll. M. Naylor, 23.6.51). All the plants examined were dioecious. Most of the female gametangia were slightly larger than the male, and had their point of attachment slightly lower down on the utricles (Text-fig 9 b, c).

In the herbarium of Mr. V. W. Lindauer there is a single specimen (No. 9729, personal collection) from Nauru Island, collected by W. Nevile on December 21, 1947. It resembles *C. adhaerens* var *incrassatum* in all features save in the more frequent occurrence of irregularly thickened, foveolate apices to the utricles. If this plant belongs truly to the var. *incrassatum* group then the distribution pattern of the latter is strangely scattered. Surface temperatures of the sea cannot be the only major factor in limiting it to the southern latitudes of New Zealand, since Nauru lies nearly on the equator If it does belong to this assemblage, it is conceivable that the plant may have been growing at a much greater depth in the sublittoral than the corresponding variety in New Zealand waters

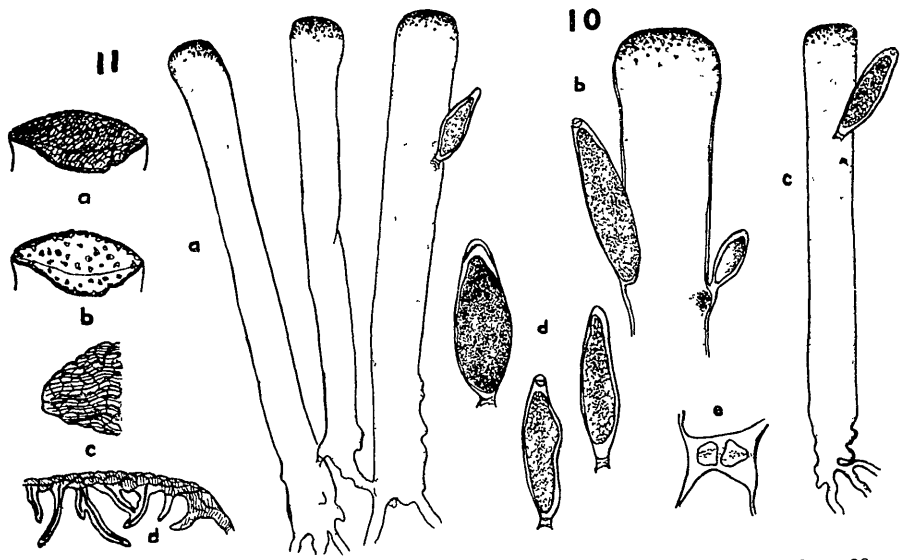


FIG 10—*Codium cranwelliae* a–c, utricles, d, gametangia, e, plug. (a, c, × 14, b, d, × 28; e, × 210)
FIG 11—a–c, utricle apex, a, c, focussed up to show striated appearance, b, focussed down to show trabeculae in surface view. d, trabeculae in longitudinal view. (a, b, × 28; c, d, × 210)

2. **Codium cranwelliae** Setch. Plate 32, figure 2, text-figures 10–11.
Setchell, 1940, p 446, figs 1–5.

Thallus light greyish-green, globose, spongiose, ovoid to round with 1–3 lobes, 0 5–5 0 cm long, 0 5–3 0 cm. broad, 2 0–4 0 cm. high, erect, attached relatively loosely to substratum over a small portion of base; tips of utricles glistening, visible to naked eye; utricles "megistophyse", 4,000–6,500μ long, 400–625μ wide, sparsely branched, more or less cylindrical with irregular projections from base; apex rounded or flattened, apical and subapical membrane up to 10μ thick with branched and unbranched lamellate trabeculae projecting into utricle cavity;

hairs absent; plastids discoid to elongate, sometimes polygonal through mutual pressure, as much as 10μ long and 5μ wide; medullary filaments 35–70μ in diameter, densely intertwined; gametangia ovoid to fusiform, in patches over exposed portion of thallus, on a short pedicel, 700–780μ long and 200–300μ wide, usually 1, occasionally 2 per utricle, attached between 1,000 and 1,300μ from apex; diameter of pore 70–85μ.

On rocks and under ledges just above low water neap tide mark down to a considerable depth in the sublittoral.

Type Locality: Poor Knights Islands, New Zealand.

Type specimen No. 564498 in Herb. Univ. Calif.

Distribution. Local: Tapeka Point, Long Beach, Russell (Bay of Islands); Wainui Bay, Northland; Poor Knights Islands; Oruawharo Bay, Great Barrier Island. Endemic.

The affinities of *C. cranwelliae* are discussed by Setchell (*op. cit.*, p. 447). It shows all the main features of the Bursae group, including the cushion-like shape, small attachment area and dense intertwining of central filaments. Setchell does not stress the point that *C. cranwelliae* agrees more closely with O. C. Schmidt's subsection Eubursae, and with *C. bursa* in particular, than with *C. mamillosum* Harv., in respect to its comparatively firm thallus and smaller utricle dimensions. In the Dominion Museum Herbarium at Wellington there is a single specimen of *C. mamillosum,* distributed by Harvey under the number 578. Harvey (1858) states that *C. mamillosum* has not been found fertile, and yet an examination of this specimen showed fully developed gametangia 630–640 x 250–260μ wide, swollen in the centre and narrowing abruptly at either end. They are similar in size and shape to those of *C. cranwelliae,* but are attached slightly lower down the utricle, about one third the total distance from the apex. Another difference between the two species is apparent in the construction of the base of the utricle. In *mamillosum* the central or lateral filaments emerge smoothly from the base, whereas in *cranwelliae* there is a series of knob-like projections below and for several hundred μ up the sides of the utricles. Each knob is potentially capable of giving rise to a filament (Text-fig. 10 a). At the bases of most mature utricles there are at least 4–6 filaments, but usually a plug (if present at all) is formed in only one of them. The basal attachment filaments are smooth or irregular in outline, with walls thickened up to 10μ.

Gametangia vary in shape—the majority are swollen in the centre and taper at either end. It was not possible to tell with certainty the sex of those shown in Text-fig. 10 a–d, but judging by their dark green colour and rather dense contents they were presumably female. In Text-fig. 10 b, the unequal development of two gametangia on the same utricle is clearly indicated. The left hand one has reached maturity, as evidenced by the development of the apical pore, while that forming to the right has barely severed protoplasmic connection with the main portion of the utricle, and plug formation has not yet taken place. The phenomenon of development of more than one gametangium on an utricle at different time intervals is a frequent one in *Codium*: among the New Zealand species it has been found in *C cranwelliae, C. fragile, C. dichotomum* and *C. gracile* (Text-figs. 12 b and 18 e).

The outstanding feature which separates *C. cranwelliae* from other members of the Bursae group is undoubtedly the presence of lamellate ingrowths or trabeculae from the inside wall of the membrane at the utricle apices. Each

trabecula may be simple or branched, and consists of a central tube or core which connects with the outer surface of the apex. Unlike the trabeculae in *Caulerpa,* they are limited in growth up to a length of about 50μ. The central core is surrounded by an opaque, homogeneous or stratified layer up to 5μ in diameter (Text-fig. 11 d).

The effect of dropping a coverslip on utricle apices is shown in Text-fig. 11 a and b. The head becomes compressed and flattened, one to several crease-lines being formed as a result across the central region. When focussed up, the outer surface of the membrane appears to be covered with a layer of roughly hexagonal, cell-like compartments, each of which is 5–20μ in diameter. Superposed upon the whole is a series of fine, wavy striations. From each compartment a trabeculate process may grow inwards into the apical cavity. The segregated appearance of the membrane is again in evidence when it is examined in longitudinal view after the apex has been ruptured. Wall structure in *Codium* utricles has been studied in detail recently by Silva (1951, pp. 87–94). He finds that the processes arising at the apices of *cranwelliae* utricles are truly trabeculate in structure; that is, they are formed by "deposition of successive lamellae around a conspicuous axial filament which may be traced from the primary membrane to a depression in the tip of the projection" (Silva, *op. c.,* p. 93, figs. 20, 21). It is further emphasized that the axial canals, which are analogous to pits in walls of higher plants, do not open either into the utricle cavity or at the outer wall surface, as Setchell (1940) indicated in his text-figures 3–5. Also contrasting with Setchell's views is the fact that branched trabeculae result from anastomoses of two or more simple trabeculae, rather than by forking of a single projection.

The function of the trabeculae is still a matter for speculation. There have been several theories put forward regarding the trabeculate growths within the "branches" of *Caulerpa.* Fritsch (1935, p. 383) has summarised the views held up to that time. It has been proposed that the trabeculae

(a) facilitate diffusion of mineral salts more rapidly than in the cytoplasm (Noll, 1888); (The fact that in *Codium cranwelliae* the trabeculae are restricted to the apex and do not bridge the utricle cavity nullifies the importance of the above hypothesis for this species.)

(b) provide an enlargement of surface area as in the surface of a multicellular plant;

(c) form a mechanical device to resist turgor pressure due to an occasional high osmotic pressure of the cell sap (Janse, 1890), provided that such is the case.

As Fritsch points out, the various theories are not necessarily contradictory. In *C. cranwelliae* the explanation in favour of mechanical support against internal turgor may be correct, since the size of the utricles is very great in proportion to the thickness of either lateral walls or apical membranes. However, the absence of any strengthening processes in the apices of *C. mamillosum,* in which the utricles are even larger, indicates that a teleological explanation of such a phenomenon should be accepted with caution.

3. **Codium dichotomum** (Huds.) S. F. Gray. Plate 33, fig. 1, text-figure 12
Gray, 1821, p. 293, pl. 1. Kylin, 1949, p. 67, fig. 65.
Codium dichotomum (Huds.) Setch. Setchell, 1931, p. 357. Suneson, 1939, p. 57, fig. 1A. Lund, 1940, p. 5, pls. I–III, figs. 1–7.
Spongia dichotoma Hudson, 1762, p. 489.
Fucus tomentosus Hudson, 1778, p. 584.

Codium tomentosum (Huds.) Stackhouse, 1797, p. xxiv, Tab. vii; *pro parte.* (Hooker and Harvey, 1855, p. 261); Hooker, 1867, p. 714. Schmidt, 1923, p 39, figs. 20–21. De Toni *e* Forti, 1922, p. 92.

f. **novo-zelandicum** f. nov.

Utriculis et gametangiis maioribus quam in f. typico; canalibus carentibus crassatis membranis apicalibus.

Utricles and gametangia larger than in f. *typicum*; grooves lacking in thickened apical membranes. Thallus erect, cylindrical, up to 18 cm. long, regularly 4–7 times dichotomously branched; main branches 1–3 cm. long between forkings,

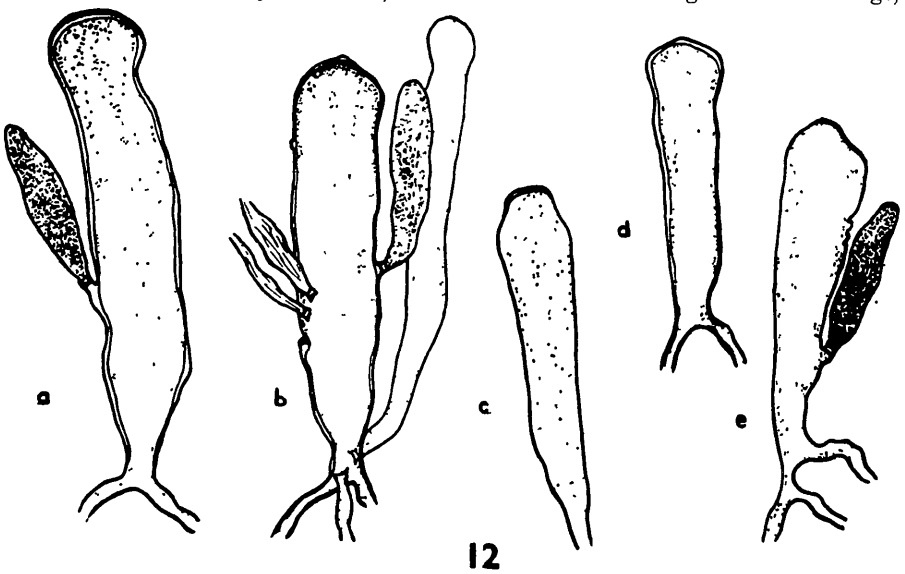


Fig. 12—*Codium dichotomum* f. *novo-zelandicum*. a–e, utricles and male gametangia from type specimen (× 55).

slender or somewhat thickened, 1–5 mm. in diameter; utricles of New Zealand plants 700–1,100μ (av. 870μ) long, 140–240μ (rarely 410μ) wide at apex, 70–100μ at base, apices rounded or bluntly acuminate; membrane 7–15μ thick, smooth or occasionally perforated with a pore; hair scars occasionally present, c 150μ from apex; plastids discoform, up to 6μ in diameter; central filaments 30–70μ in diameter, gametangia large, cylindrical-fusiform, 300–420μ x 80–150μ, sometimes swollen below, attached about or just below middle portion of utricles, 1–4 per utricle.

Type locality: Governor's Bay, Lyttelton.

Type specimen coll. R. M. Laing, Governor's Bay, Lyttelton (in Herb. R. M. Laing, Auckland University College).

Distribution. Local: Lyall Bay, Evans Bay, Petone (Wellington); Picton; Nelson; Governor's Bay (Lyttelton); Kermadec Islands and probably elsewhere. General: Widely distributed.

Setchell (1931, pp. 355–7) showed that the long-accepted binomial *Codium tomentosum* must be discarded for the new combination *Codium dichotomum,* owing to the fact that the plant designated *Fucus tomentosus* by Hudson in 1778 and *Codium tomentosum* by Stackhouse in 1797 was identical with that described earlier in 1762 by Hudson as *Spongia dichotoma.* It has been pointed out more recently by Papenfuss (1944, p. 338) that Setchell overlooked Gray's earlier com-

bination of *Codium dichotomum* published in his "Natural Arrangement of British Plants" in 1821.

Although Laing (1926, p. 132) states that the "forma typica" (presumably Schmidt's var. *typicum*) does not occur in New Zealand, nevertheless the plants examined agree quite well with Schmidt's description, except that the utricle size is usually considerably larger. The same holds when a comparison is made with the various forms described by Vouk (1936, p. 15) from the Adriatic. In fact, the upper limit given by him for utricle length coincides with the lower limit in the New Zealand specimens. Schmidt (1923, p. 41) notes that in spite of the variation in external form, such as is found in many other broadly defined species and which causes them to be split up into separate species on closer investigation, in the "tomentosum" representatives there is no constant difference which can be used as an adequate basis for further creation of new species. The tendency for utricles of this group to be slightly constricted below the apex is displayed in the New Zealand plants, and the position of attachment of the gametangia likewise agrees with that in plants examined and figured by Schmidt (*op. c*)

How much significance can be attached to Vouk's schema for the development of thallus types in *C. dichotomum* is not certain, for much depends on the age at which a plant is collected, as well as on local habitat conditions, not to mention the mode of pressing and spreading out on a herbarium sheet. The outline of New Zealand specimens appears to be roughly halfway between f. *dichotomum* and f. *intermedium* (Vouk, *op. c.*). F. *dichotomum* is distinguished by more or less long intermediate branch segments, the terminal ones being of equal length. F. *intermedium* has both terminal and intermediate segments of unequal length. However, it is apparent from a plant collected by Miss L. B. Moore at Picton (No. 46213, Herb. Botany Division, D.S.I.R.) that the two forms can both occur on the one plant.

From notes on the herbarium sheet, Laing seems to have been of the opinion that the plant collected by him at Governor's Bay, Lyttelton (Pl. 33, fig. 1) was a new variety of "*tomentosum*", or possibly of *C. contractum* Kjellm ; but any relationship with the latter is obviated by the absence of flattening beneath the main forks.

A structure not figured by either Schmidt or Vouk is that of an utricle branching directly from the base of another utricle, without any intervening stretch of lateral filament (Text-fig. 12 b). Branching of a similar nature is shown by Lund (1940, p. 8, fig. 1 d) from a plant of *C. dichotomum* found growing in Hirsholmene Harbour, Denmark Most of the utricles figured by him are shorter and fatter than those in the New Zealand specimens, although considerable polymorphism exists here also The prevalence of pointed apices in utricles from young shoots, even mucronate in some cases, indicates a close relationship with *C. fragile*, whether by reduction from it or as its evolutionary predecessor. The mucronation in Danish plants is quite prominent in some utricles. The fact that it occurs among plants from New Zealand waters makes a distinction between *C. fragile* and *C. dichotomum* often very hard to make, especially as many *fragile* utricles are rounded at the apex (cf. p. 38). Lund has experienced the same difficulty (*op. c.*, p. 12). An examination of one plant from the Chatham Islands (No. 46896, Herb. Botany Division, D.S.I.R.) showed utricles with the dimensions of *dichotomum*, but slightly pointed at their apices except for those bearing gametangia, the latter being smoothly rounded. In one case a pore was seen in the thickened apical membrane,

Apices with marked layering and longitudinal grooving figured by Lund (p. 11, fig. 3) have not been seen, nor have any vegetative propagules been observed to date. Again, like the Danish plants, plugs are formed mostly in the secondary lateral branches from utricle bases rather than in the pith filaments from which the utricles were originally formed. Only male gametangia were seen in the plants examined (Text-fig. 12 a, b, e). These are larger than usual for *C. dichotomum,* and display, like *C. cranwelliae,* the phenomenon of unequal development when two or more are borne on one utricle. In shape they bear a closer resemblance to those drawn by Schmidt than to those from Danish plants, the latter being shorter, rounder and with more sharply pointed distal ends.

In summarizing, the main features which distinguish the New Zealand plants belonging to the *dichotomum* assemblage are:

(i) the occurrence of larger utricles and gametangia;
(ii) the lack of vegetative propagules;
(iii) the absence of grooves in thickened apical membranes.

These facts are considered a sufficient basis on which to justify the creation of at least a new form, f. *novo-zelandicum.* An examination of a much greater amount of material is necessary to ascertain whether the plants merit varietal status.

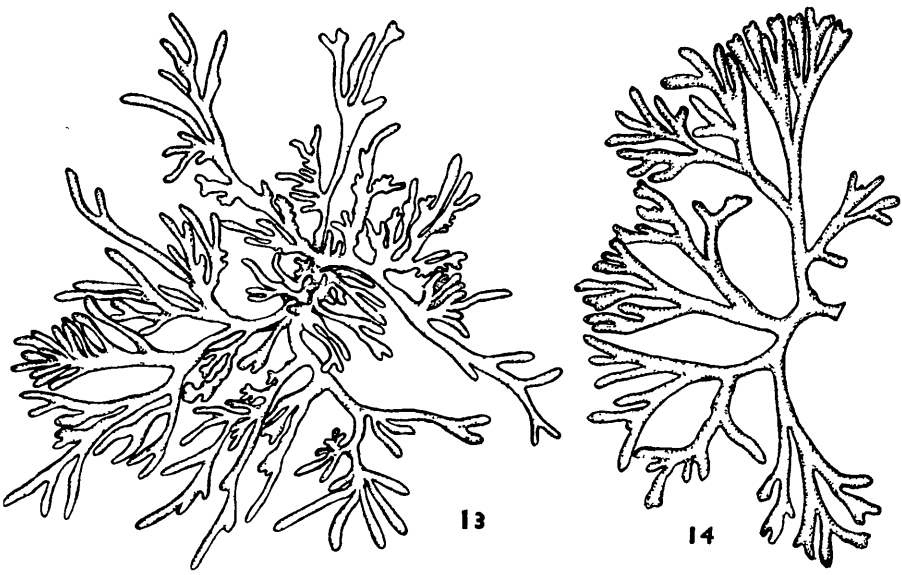


FIG. 13—*Codium fragile.* Plant growing about M L.W.N, Wattle Bay, Manukau Harbour (Coll. J. M. Hastings, No. 427, Herb. Dellow). (× ½.)

FIG 14—*Codium fragile.* Plant from drift, Lyall Bay, Wellington. (Coll. J. E. Morton; No. 465, Herb. Dellow) (× ½.)

4. **Codium fragile** (Suringar) Hariot, 1889, p. 32. var. **typicum** Schmidt, 1923, p. 47, figs. 29–31. Plate 33, fig. 2, text-figures 13–17

Smith, 1930, p. 228, fig. 3. Lund, 1940, p. 21, pls. 4–5, figs. 8–9. Kylin, 1949, p. 67.

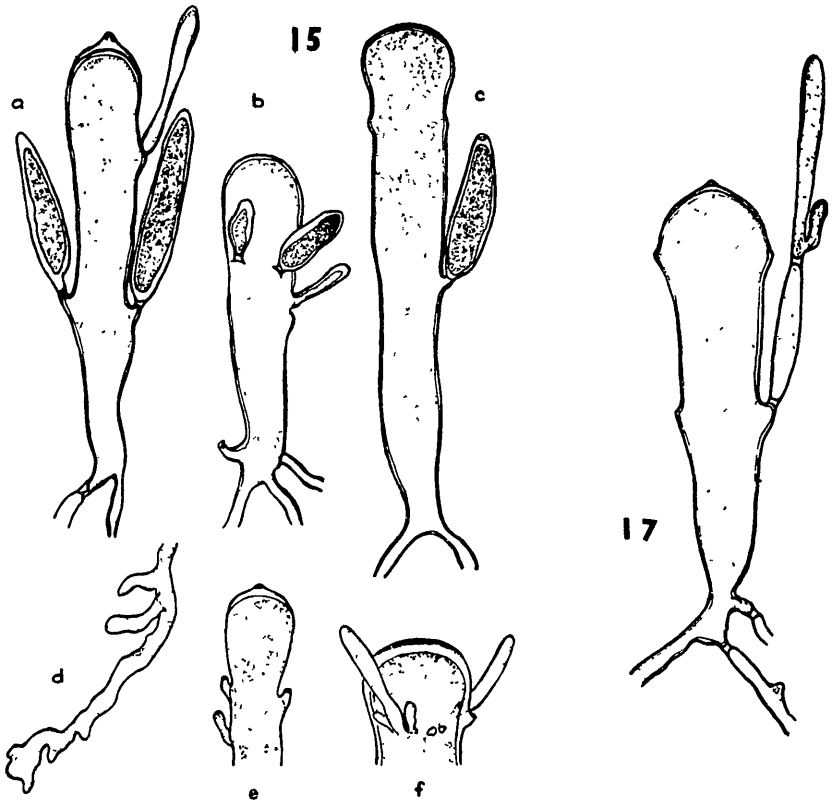
Acanthocodium fragile Suringar, 1867.

Codium mucronatum J. Agardh, 1887, p. 43, Tab. 1, figs. 2–3. Reinbold, 1899, p. 288. Hurd, 1916, p. 109, pls. 19–24.

var. *Tasmanicum* J. Ag., *op. c.*, p. 44, Tab. 1, fig. 2; Cotton, 1912, pl. 8, fig. 7.

var. *californicum* J. Ag., *op. c.*, p. 44, Tab. 1, fig. 3; Cotton, *l.c.*, fig. 8.

var. *novae zelandiae* J. Ag., *op. c.*, p. 44; Cotton, *op. c.*, fig. 6.



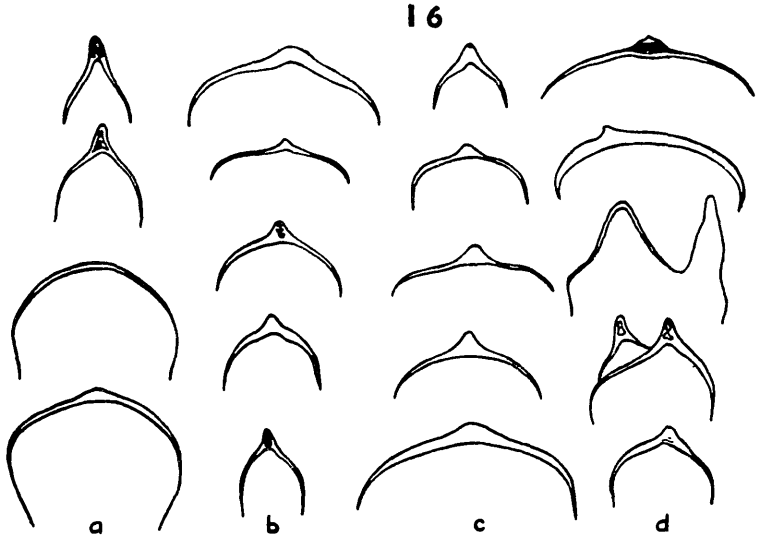


FIG. 15—*Codium fragile.* Structure of utricles, male gametangia and rhizoidal filaments. a, c, d, e, from North Island plants, b, f, from Southern Fiords plants (× 50).

FIG. 16—Variation in structure of apical membranes in plants from: a, Piha; b, West Coast (Auckland), c, Lyall Bay (Wellington); d, Campbell Island (× 100).

FIG. 17—Utricle from a Southern Fiords plant showing development of a vegetative propagule in place of a normal gametangium (× 50).

var. *atlanticum* Cotton, 1912, p. 114, pl. 7, 8, figs. 3–5.
var. *tomentosoides* van Goor, 1923, p. 136, fig. 1, c.
Codium tomentosum (Huds) Stackhouse, 1797, p xxiv, Tab. vii, *pro parte;* J. Ag., 1877; Hooker, 1867, p. 714; (Hooker and Harvey, 1855, vol. 2, p. 261); De Toni *e* Forti, 1922, p. 92.

Thallus erect, dark green, cylindrical, regularly or irregularly dichotomously branched; branches 10–25 cm. tall, 2–10 mm. in diameter, terete, broader and sometimes slightly flattened below a major dichotomy, arising from a small prostrate holdfast 1–3 cm. in diameter, 1 to several plants arising from the same holdfast; surface of branches often covered with a dense tomentum of hairs; utricles unbranched, cylindrical-clavate or pyriform, varying in length from 750 to 1,500μ (rarely 2,980μ), and in diameter from 30 to 350μ (rarely 580μ), usually narrower at base; apical membrane 8–40μ thick, with or without a prominent mucro; pores or stratifications occasionally present; hairs attached between $\frac{1}{3}$ and $\frac{1}{4}$ total length of utricle from apex, slightly swollen at base, rounded at apex, 150–500μ (rarely 1,600μ) x 25–40μ, plastids present; central filaments 40–60μ in diameter; gametangia 1–3 per utricle, ovate-fusiform, attached between $\frac{1}{3}$ and $\frac{1}{2}$ distance from base to apex, 300–500μ long and 90–120μ wide.

In pools and on rocks exposed at low water neap tide mark, often in close proximity to sand.

Distribution. Local: East and west coasts of North and South Islands, Stewart Island, Chatham Islands, Campbell Island. General Atlantic Ocean. Denmark, Netherlands, Ireland, South Africa (Luderitz Bay), South America (Tierra del Fuego); Indian Ocean: Cape of Good Hope, Natal, Kerguelen, Australia; Pacific Ocean: Magellan Straits, California to Alaska, Japan, Australia

In a species possessing so wide a range in New Zealand waters alone, one would expect to find considerable variation in external morphology, and such is certainly the case (Plate 33, fig. 2, text-figs 13–14) It is probable that increasing exposure to buffeting by waves induces a more simple, thick-set, regularly branched thallus than a sheltered habitat in which wave action is relatively gentle. Plants gathered at Pihama, Taranaki (No. 8334, Herb. Lindauer, personal collection, Pl. 33, fig. 2) and at Lyall Bay, Wellington (No. 465, Herb. Dellow, in Herb. Auck. Inst. and Mus., text-fig. 14) show a typical *fragile* thallus from an exposed habitat; nevertheless, in both specimens there is a distinct tendency towards sub-dichotomous or even unilateral branching. With increasing shelter, more and more irregular branching is apparent. Further, a mechanical stimulus such as that provided by a partial covering of sand, or appearance of a wound due to breaking off of a segment, may induce the development of several branches from that point. In extreme cases a main branch will give rise to laterals massed on one side only. A plant gathered in the drift at Tucker Cove, Campbell Island (Coll. J. H. Sorensen, 23.6.47, in Herb. Botany Division, D.S.I.R.) was examined in detail. It is obviously a fragment of a larger plant in which some external stimulus has promoted an abnormal development of lateral branches, the main branch being covered with wart-like outgrowths. Each of these is seen to be capable of forming a lateral. Similar projections are scattered over the ultimate segments. The utricles in such laterals do not show any striking difference from those in the main dichotomies. Lund (1940, p. 20) prefers to explain the production of an irregular branching system on the basis of density of the *Codium* population within a community, plants growing in isolation varying more widely in the type of branching than those which, through a close aggregation with their neighbours, produce thalli with

TABLE I—VARIATION IN MICROSCOPIC DIMENSIONS OF *CODIUM FRAGILE* WITHIN NEW ZEALAND WATERS

LOCALITY	COLLECTION	UTRICLES			MEDULLARY FILAMENTS	GAMETANGIA	
		Length	Breadth	Membrane		Length	Breadth
Piha	Coll. L. M. Cranwell Herb. A.I.M.*	1200–1420μ	30–240μ	6.5–39μ	47–57μ	390–412μ	92–112μ
West Coast (Auckland)	Coll. L. M. Cranwell 020/31 Herb. A.I.M.	966–1278μ	43–241μ	8–21μ	26–41μ		
Wattle Bay (Manukau Harbour)	Coll. J. M. Hastings 427 Herb. U.V.D.	540–1065μ	42–156μ	19–28μ	30–52μ	327–355μ (dioecious)	86–133μ
Lyall Bay (Wellington)	Coll. J. E. Morton 465 Herb. U.V.D.	780–1207μ	43–340μ	14–40μ	32–43μ	425–500μ (dioecious)	93–114μ
Cole Head (Southern Fiords)	Coll. H. H. Allan Herb. B.D., D.S.I.R.	700–1200μ	42–227μ	3–29μ	21–57μ	240–383μ (dioecious)	85–100μ
Shoal Point (Campbell Island)	Coll. J. H. Sorensen Herb. B.D., D.S.I.R.	1562–1760μ	45–355μ	10–36μ	40–70μ	454–511μ (monoecious)	112–170μ
Campbell Island	Herb. B.D., D.S.I.R.	1620–2980μ	42–582μ	10–30μ	28–85μ	497–682μ (dioecious)	100–170μ

* Herb. A.I.M.—Herbarium of the Auckland Institute and Museum.
Herb. B.D., D.S.I.R.—Herbarium of the Botany Division, Department of Scientific and Industrial Research.
Herb. U.V.D.—Herbarium of U. V. Dellow, in Herb. A.I.M.

long segments to ensure more favourable growth conditions for a greater surface area. This may quite possibly be the case where *C. fragile* grows in sufficient numbers for one thallus to be in contact with the next, or with other species of similar life form; but in localities where it has been observed growing in this country (Piha, Manukau Harbour) the plants were few in number and quite far removed from one another.

Text-figures 15 and 16 illustrate the shape and size of utricles, gametangia, hairs and apical membranes to be found in New Zealand representatives of *C. fragile*. Figure 15 a and e, are drawn from a plant collected at Lyall Bay, Wellington, b and f from a Southern Fiords plant, and c from a Piha representative (west of Auckland). The utricle in a, with its moderately thickened mucron, narrow base, attached hair and two male gametangia is the nearest approach to the conventional idea of the appearance of a *fragile* utricle. A glance at b and f shows important differences at once: shorter length, rounded apices, and a higher point of attachment for both hairs and gametangia. On the same plant, however, were found "typical" *fragile* utricles up to 1,200μ long, with a mucro 30μ thick and with gametangia attached in their normal position about equidistant from base and apex of the utricle. Any attempt to create varieties on such individual differences must accordingly be made with great caution. All parts of the plant should be examined, especially since utricles from near the holdfast often differ in size and shape from those near the distal end of the ultimate segments. Mucronate and non-mucronate utricles occur both at the tips and base of the same plant, but in general greater plasticity in size and shape is apparent near the lower portion of the thallus.

Table I has been compiled from results of an examination of representative plants collected in localities ranging from the Auckland district to as far south as the Subantarctic Islands. Breadth of gametangia in each case was measured at the widest diameter. Table I proves that the differences between the forms are not of a fundamental nature—the most notable feature is the occurrence of mostly larger utricles and gametangia in the Campbell Island specimen.

In the plants studied in detail, the amount of variation in construction of the apical membrane showed a remarkable correlation with the degree of irregularity of branching of the thallus. Text-figure 21 indicates that again the greatest number of irregularities occurs in plants from Campbell Island (column d). Apices in columns a and b were drawn from west coast specimens—a, was collected from near Piha (020/31, Herb. Auckland Institute and Museum), b, from the Manukau Harbour, and those in column c from the Lyall Bay specimen (No. 465, Herb. Dellow).

Plugs are rare in central filaments of the frond, although near or within the holdfast they may be found in greater abundance. The New Zealand plants agree with those described by Hurd from Puget Sound and by Lund from Denmark in the more frequent formation of plugs between utricles and lateral branches than between utricles and medullary filaments.

A specimen from the Cape Expedition (1943) was notable for the extremely large size of utricles, medullary filaments and gametangia. Maximum utricle length was here almost 3 mm. Some of the female gametangia examined showed a further peculiarity in having up to 3 lenticular pores through which liberation of the gametes might be effected.

In only one plant of any of the New Zealand Codiums has there been observed an abnormal vegetative development of a gametangium. In a plant from the

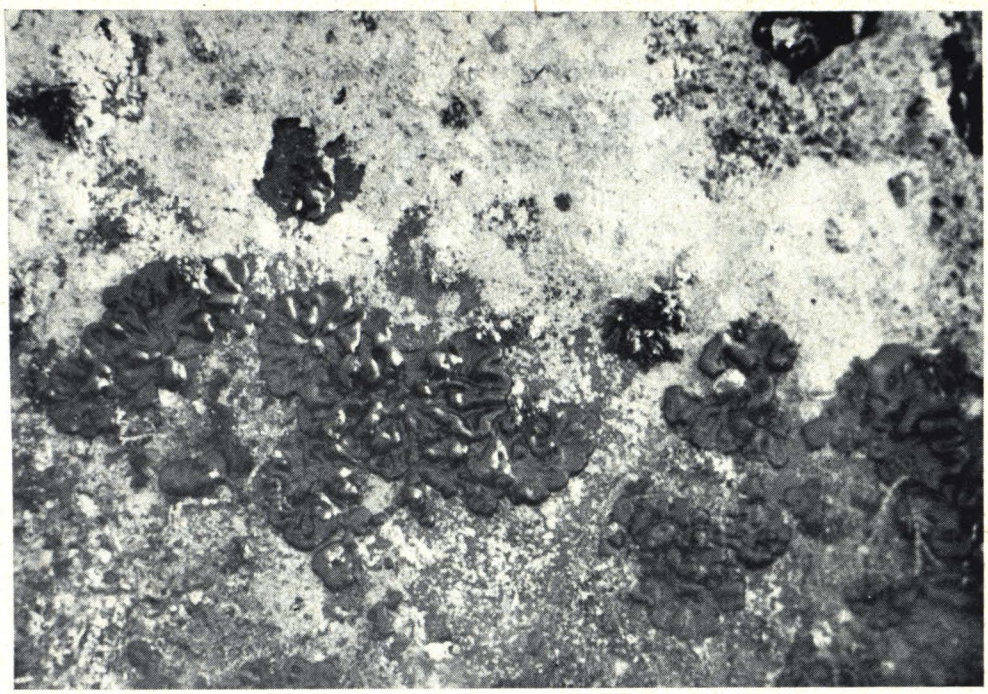


FIG. 1—*Codium adhaerens* (Cabr.) Ag. var. *convolutum* Dellow. Plants growing in association with barnacle and *Corallina-Hormosira* communities, Clifton Beach. Auckland. ($\frac{1}{8}$ natural size.)

FIG. 2—*Codium cranwelliae* Setch. Topotypes growing beneath an overhanging ledge just above low water mark, Poor Knights Islands. Negative by L. M. Cranwell. ($\frac{1}{5}$ natural size.)

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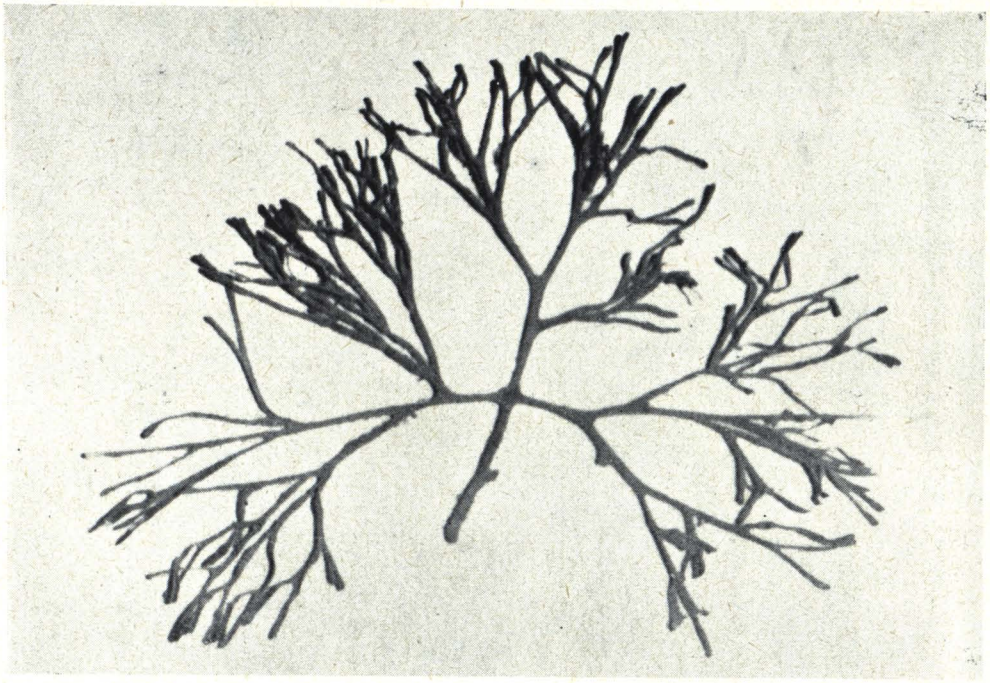

FIG. 1—*Codium dichotomum* (Huds.) Gray f. *novo-zelandicum* Dellow. Type specimen. Coll. R. M. Laing, Governor's Bay, Lyttelton (Herb. Laing). ($\frac{1}{3}$ natural size.)

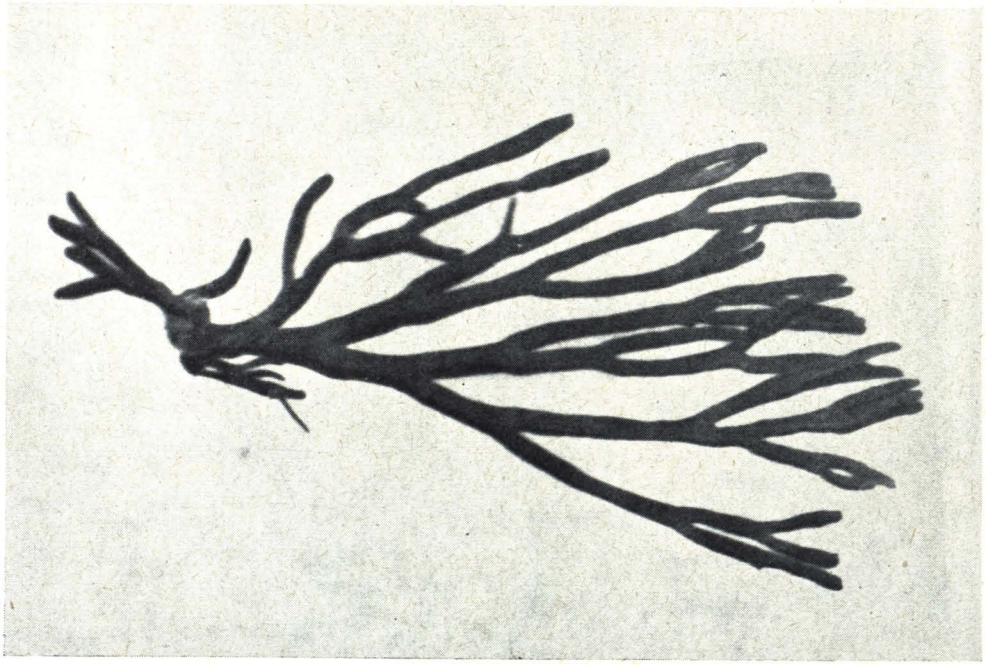

FIG. 2—*Codium fragile* (Suring) Hariot. Drift, Julian's Beach, Pihama, Taranaki. Coll. V. W. Lindauer, 18.2.47 (No. 8334, Herb. Lindauer, personal collection). ($\frac{4}{7}$ natural size.)

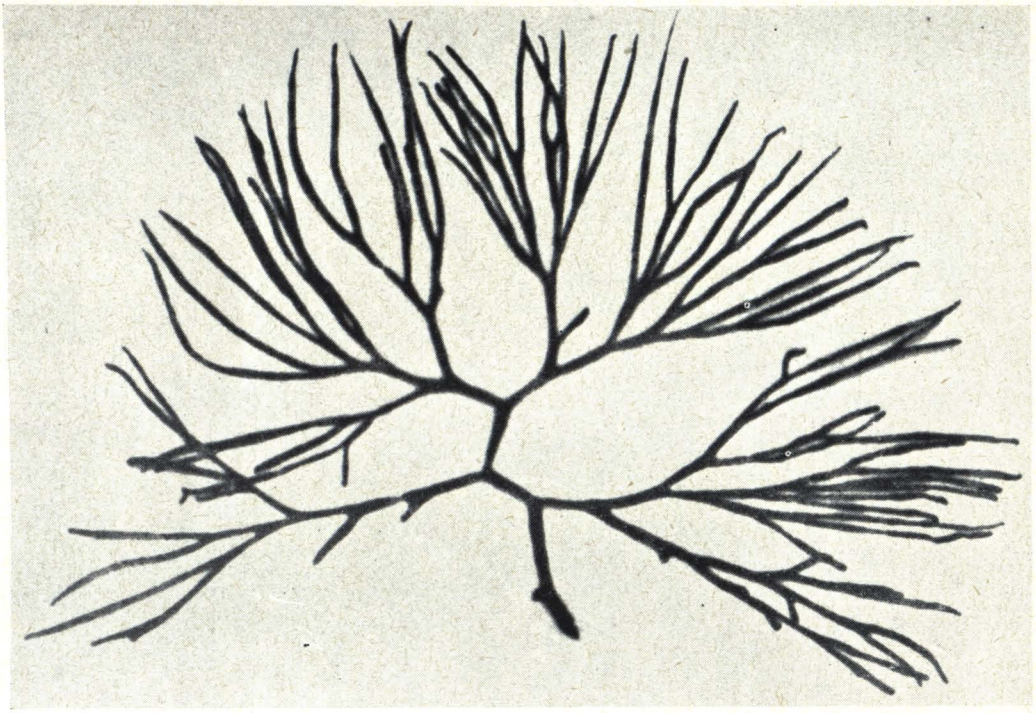

FIG. 1—*Codium gracile* (O. C. Schmidt) Dellow. Drift, Long Beach, Russell, Bay of Islands. Coll. V. W. L., 13.9.47 (No. 794, Herb. Lindauer, personal collection). (⅝ natural size.)

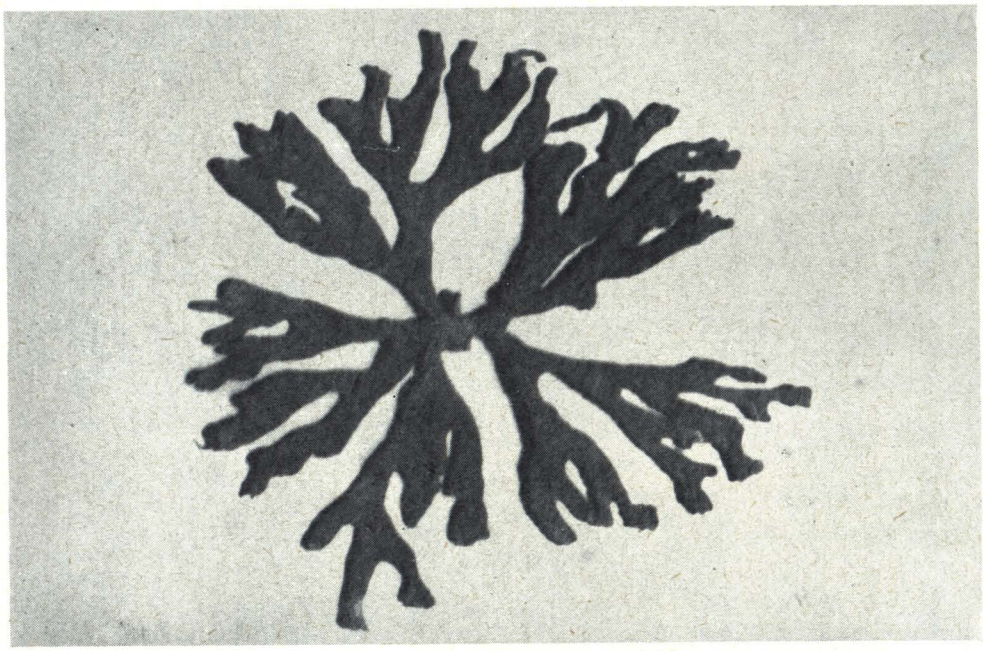

FIG. 2—*Codium cuneatum* Setch and Gard. f. *striatissimum* Dellow. Mature plant from drift, Matauhi Bay, Russell, Bay of Islands. Coll. V. W. L., 24.2.37 (No. 759, Herb. Lindauer, personal collection). (⅝ natural size.)

Southern Fiords a gametangial pedicel was found supporting not a gametangium but a vegetative filament, separated into compartments by two plugs, one near the base and the other about equidistant from either end of the filament (Text-fig. 17). From the distal compartment a young utricle was forming at the base in the usual sympodial manner. Similar structures, including at least one fully mature and mucronate utricle, arising from the points of origin of the normal gametangia were located on several other utricles from the same plant.

While no explanation for their formation is forthcoming at present, it is worth noting that vegetative propagula or daughter thalli (Brutkörper, according to Schmidt, 1923, pp. 10–12, figs. 4–5) have been reported to occur in *Codium pilgeri* Schmidt, *C. isthmocladum* Vickers, and more recently in *C. dichotomum* (Lund, 1940, p. 17, fig. 7). It is not certain whether the filaments and utricles on the Southern Fiords plant of *C. fragile* are capable of separate existence.

In the majority of fertile plants examined only one kind of gametangium was found. However, monoecious plants have been collected at Timaru (No. 42043, Herb. Botany Division, D.S.I.R., Coll. R. Mason, 20.11.43) and at Campbell Island (Coll. J. H. Sorensen, 23.6.47). In view of the fact that the New Zealand *C. fragile* has been found fertile in February, March, April, May, June, August, November and December, it is fairly safe to assume that gametangia can be produced at any season. In these respects it is in complete accord with the same species from Denmark.

5. **Codium gracile** (O. C. Schmidt) comb. nov. Plate 34, fig. 1; Text-figs. 18–19.
Codium fragile var. B. *gracile* O. C. Schmidt, 1923, p. 48, fig. 32.
Codium mucronatum var. *novae-zelandiae* J. Agardh, 1887, p. 44?.

Thallus slender, erect, regularly dichotomously branched, dark green, up to 45 cm. long, 1–4 mm. in diameter, terete, solid; holdfast slightly irregular in outline; utricles small, clavate or pyriform, 300–570μ long, 64–230μ broad near apex, 40–100μ broad near base; apex varying from widely blunt and slightly depressed to narrow and sharply mucronate; membrane 6 0–8 0μ thick; hairs and hair scars absent; plugs at base of utricles 16–20μ in diameter; medullary filaments 20–30μ in diameter; gametangia ovate-fusiform, 1–2 per utricle. attached one-third to two-thirds total distance from apex, 170–270 x 50–100μ, pedicellate; pores 20–30μ in diameter.

Type locality: Bay of Islands (Herb. Heydrich—VI, 1894, in Herb. Beriol).

Distribution. Local: Long Beach, Waitata (Bay of Islands); Buffalo Beach (Mercury Bay); Breaker Bay, Lyall Bay, Evans Bay, Wellington. Endemic.

Codium gracile may be distinguished superficially from *C. fragile* by its more slender, tapering branches, and in microscopic features by the much smaller size of its utricles and gametangia, greater maximum thickness of the apical membrane, and by the absence of hairs. This last fact may be due to the probable deep-water habitat of *C. gracile*, since up till now no plants have been found growing attached. A number of unusually large plants were found by the writer during December, 1949, cast up in the drift on Buffalo Beach, Mercury Bay, after a heavy easterly gale. These measured up to 45 cm. long and showed a very regular pattern of dichotomous branching.

Utricles from the holdfast are mostly narrower and possess a much more prominent mucro than those from other parts of the thallus. In such thickened apices, pores may be present, due to the unequal pressure in deposition of successive stratified layers. There appears to be an inverse relationship between

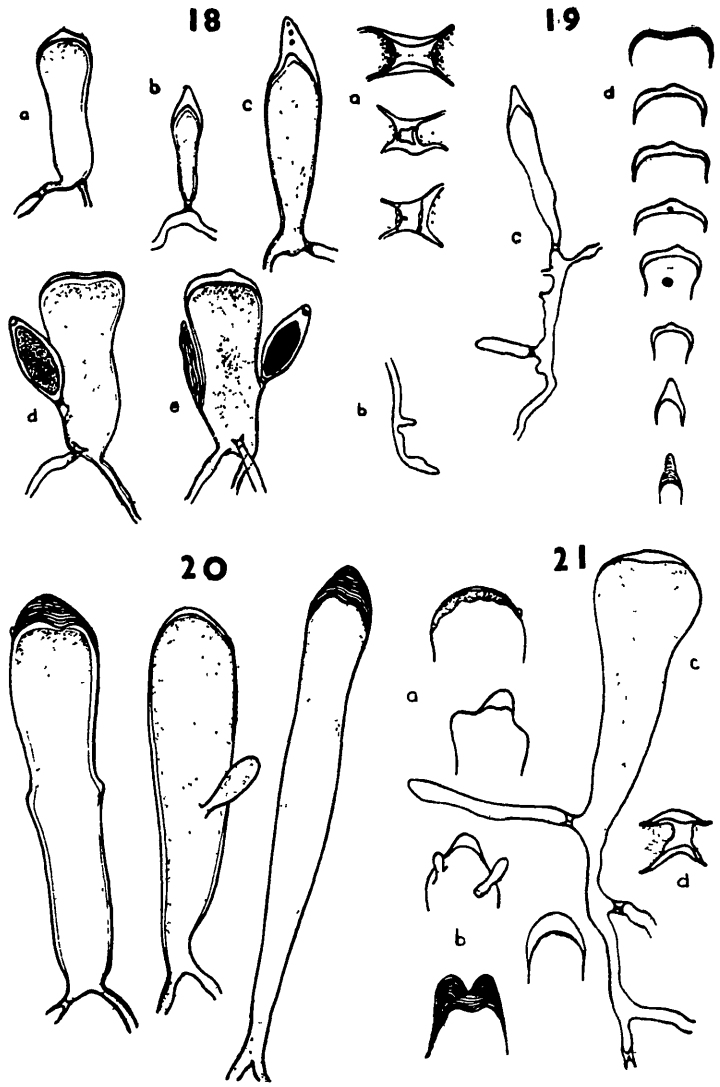

FIG 18—*Codium gracile* Utricles and gametangia a, d, e, 6 cm from the tip of an ultimate dichotomy; b, c, from holdfast (× 50).

FIG. 19—a, formation of plugs; b, rhizoidal filament. c, lateral development of utricles, d, variation in structure of apical membrane (a, × 220, b, c, d, × 50).

FIG. 20—*Codium cuneatum* f. *striatissimum*. Utricles and young gametangium (× 50).

FIG. 21—a, b, variations in structure of apical membrane; c, sympodial development of utricles; d, immature plug (a, c, × 50; b, × 100, d, × 220).

utricle size and membrane thickness (in mature utricles), those with thickest and most strongly pointed apices being much smaller in diameter, and vice versa. Text-fig. 18 b shows an utricle from the holdfast of a large plant which, though only 270μ long and 60μ in widest diameter, has already obtained a membrane thickness of 30μ. That in Fig. 18 c has reached a thickness of almost 80μ.

A few monoecious plants are known. Plants with both male and female gametangia have been collected at Terekino Bay and Princess Bay, Wellington (Nos. 23577 and 52008, Herb. Botany Division, D.S.I.R.) and at Buffalo Beach,

Mercury Bay (No. 861, Herb. Dellow, in Herb. Auck. Inst. and Mus.). Fertile plants are recorded for January, March, June and December.

O. C. Schmidt included the members of this group within the broad specific boundaries of *Codium fragile.* More recently Setchell wrote in a letter to Mr. Lindauer that var. *gracile* was "not properly of the *Codium fragile* cycle." Since Schmidt's varietal name of *gracile* is the earliest in the literature with reference to this section of the species, it has been retained for the specific designation rather than Setchell's manuscript name, in accordance with Article 58 of the International Rules of Botanical Nomenclature (1935, p. 18).

An examination of specimen No. 15614 from the herbarium of J. Agardh showed that the utricles agree perfectly in dimensions and appearance with those of *C. gracile,* although Agardh has assigned it to *C. mucronatum* var. *novae zelandiae* and the plant was on the same sheet as a specimen of *C. fragile* (*sensu stricto*) collected in New Zealand by F. von Mueller in 1885. Whether Agardh included the *gracile* forms in his general conception of *C. mucronatum* var. *novae zelandiae* is not certain from his description, because he gives no actual measurements, but the above suggests that such was the case, indicating that he was not aware of the essential differences between these two groups.

Confusion has arisen in the past concerning the supposed occurrence of *C. muelleri* Kuetz. (= *C. schmidtii* Vouk) in New Zealand waters. Agardh (*op. c.,* p. 42) reports it from the Chatham Islands, at the same time noting the difficulty of assigning plants from this locality to either *mucronatum* or *muelleri* (p. 45). "Quae ex insula Chatam habui, a Travers lecta, nonnulla cum forma Novae Zelandiae conguere mihi adparuerunt, alia ad Cod. Muelleri pertinere videntur." A number of specimens in the Laing Herbarium from Wellington beaches had also been assigned to *C. muelleri* by W. A. Scarfe (unpub.), but in none of the plants examined was there seen the umbonate thickening which is so typical of the inner apical membrane of *C. muelleri.* A comparison of the New Zealand plants concerned with material of *C. muelleri* from Kangaroo Island, South Australia, shows that the former belong without doubt to *Codium gracile.* Scarfe was obviously confused between *C. dichotomum* and *C. gracile* on the one hand and between *C. gracile* and *C. muelleri* on the other.

6. **Codium cuneatum** Setchell and Gardner, 1924, Vol. 12, p. 708, Pl. 16, figs. 34–35, Pl. 34.

Lucas, 1935, vol. 60, pp. 205–6, pl. 6, fig. 1, text-fig. 5.

Silva, 1951, vol. 25, p. 99, pls. 3–6, text-figs. 23–32.

f. **striatissimum** f. nov. Plate 34, fig. 2; Text-figs. 20–21

Thallo minore quam in f. typico; utriculis longioribus et angustioribus, maxime striatis; gametangiis affixis aequo spatio inter basem et apicem.

Thallus smaller than f. *typicum;* utricles longer and narrower, heavily striated; gametangia attached midway between base and apex. Mature plants erect, flabellate, as a rule regularly dichotomously branched, forked near base, 10–15 cm. high; branches coarse, flattened, wedge-shaped, up to 3 cm. broad below a dichotomy, angles rounded; terminal segments very short, sometimes almost pointed at apices; attachment by a small, disc-like holdfast; utricles unbranched, 500–1,400μ long, 40–300μ wide (up to 450μ at distal end), rounded or galeate at apex, never mucronate; membrane varying greatly in thickness from 6–70μ, thickened membranes striated, occasionally alveolate on inner surface; utricles rarely double-headed; hairs short, arising near apex of utricles;

gametangia attached midway between base and apex of utricles, mature gametangia not seen.

Type specimen No. 759, Herb. Lindauer (personal collection). Drift, Matauhi Bay, Russell (Bay of Islands). Collected by V. W. Lindauer, 27.7.37.

Distribution.

(a) *C. cuneatum* f. *striatissimum*. Local: Matauhi Bay, Russell (Bay of Islands). Endemic.

(b) *C. cuneatum* f. *typicum*. General: Indian Ocean: British India, Bali; Pacific Ocean: Gulf of California, East Australia, Lord Howe Island.

Codium cuneatum with its broadly flattened, wedge-shaped branches, stands quite apart from other New Zealand Codiums. Setchell and Gardner (*op. c.*, p. 709) express the view that the nearest relative of *C. cuneatum* is *C. platylobium* Binder, although intermediate segments of the latter are longer and less sharply cuneate, and the ultimate segments are more attenuated.

The New Zealand plants are small in comparison with the type specimen of f. *typicum* from Smith Island, in the Gulf of California, and also with plants from Lord Howe Island, which Lucas (1935, p. 206) states are about a foot high. Nevertheless, in young plants examined the amount of thickening deposited on the inner apical membranes was as great as in any of the utricles examined from the mature Matauhi Bay specimen (Plate 34, fig. 2). A further difference from f. *typicum* is provided by the utricles, which do not resemble in all respects those figured by Setchell or Lucas, being mostly longer and narrower, often with an almost galeate crown at the apex (Text-figs. 20, 21). Lucas's plants from Lord Howe Island contain utricles with very thin membranes, while those from Smith Island, California, apparently do not measure over 12μ. The occurrence of double-headed utricles, though rare, is not restricted to *C. cuneatum*. In the New Zealand species they have been noted in *C. fragile* and in *C. adhaerens* var. *convolutum* (Text-figs. 3 a, c, g; 16 d). The heavily striated, two-headed apex in Text-fig. 21 b came from a very young plant only 2 inches high (No. 373 in Herb. V. W. Lindauer, personal collection).

An interesting feature which Lucas found in the Lord Howe plants was the presence of thin, branched, trabeculate outgrowths from the inside of the apical membrane. These were not found in either a portion of an isotype of f. *typicum* (No. 221032, Herb. Univ. Calif., Johnston No. 47, collected in June at Smith Is.), or in any of the New Zealand plants of f. *striatissimum*.

Silva (1951, p. 94, figs. 27–29) notes thickened membranes with scalariform or chambered pores in specimens of *C. cuneatum* from the Gulf of California. The position of attachment of the gametangia is much lower down on the utricles in the New Zealand plants than in those from Smith Island, California, or from Lord Howe Island. These facts all combine to set the New Zealand plants apart as a separate form. Until more specimens are found it cannot be established with certainty that the differences are sufficiently constant to warrant varietal status.

The identity of the New Zealand plants was established by Setchell, when he wrote in a letter to Mr. Lindauer: "Your specimens do not approach the number of dichotomies of the type material, but they come very close to it and especially in the matter of utricle shape, dimension, hairs, gametangia, etc." It is shown above that the differences are of a wider nature than Setchell indicated, the same range of variation in utricle size and shape being found in the plants examined.

TABLE II—COMPARATIVE SURVEY OF *CODIUM* SPECIES IN NEW ZEALAND

	C. adhaerens	*C. cranwelliae*	*C. dichotomum*	*C. fragile*	*C. gracile*	*C. cuneatum*
THALLUS Form	firm, prostrate, cushion-like, lobed or crescent-shaped	Soft, globose, ovoid-spherical	erect, robust, dichotomous, cylindrical	erect, robust, dichotomous, cylindrical	erect, slender, dichotomous, cylindrical	erect, dichotomous, flattened, cuneiform
Colour	dark green	light green	light green	dark green	dark green	light green
Height	up to 2 cm.	up to 4 cm.	up to 18 cm.	up to 25 cm.	up to 45 cm.	up to 16 cm.
Diameter	up to 20 cm.	up to 5 cm.	up to 0.5 cm.	up to 1 cm.	up to 0.4 cm.	up to 3 cm.
UTRICLES Length	420–900μ (–1,280μ)	4,000–6,500μ	700–1,100μ	750–1,500μ (–2,980μ)	300–570μ	500–1,400μ
Diameter	28–100μ (–200μ)	400–625μ	70–240μ (–410μ)	30–350μ (–580μ)	40–230μ	40–300μ (–450μ)
Apex	flat, rounded or slightly depressed	slightly flattened	rounded or bluntly pointed	rounded or mucronate	wide, flat or narrow, mucronate	rounded or galeate
Membrane	2–5μ (var. *convolutum*) 2–30μ (var. *incrassatum*)	2–10μ	7–15μ	8–40μ	6–80μ	6–70μ
HAIRS Length	41–1,320μ		(only scars observed)	150–1,600μ		(only scars observed)
Diameter	15–30μ			25–40μ		
PITH FILAMENTS	15–75μ	35–70μ	30–70μ	40–60μ	20–32μ	20–50μ
TRABECULAE		in apices of utricles				
GAMETANGIA Shape	cylindrical-fusiform	ovate-fusiform	cylindrical-fusiform	ovate-cylindrical-fusiform	ovate-fusiform	(Mature gametangia not seen)
Number	1 per utricle	1–2 per utricle	1–4 per utricle	1–3 per utricle	1–2 per utricle	
Position	at or above centre of utricle	1,000–1,300μ from apex	at and below centre of utricle	at and below centre of utricle	at and below centre of utricle	at middle of utricle
Length	240–425μ	700–780μ	300–420μ	300–500μ	170–270μ	
Diameter	40–140μ	200–300μ	80–150μ	90–120μ	50–100μ	
VEGETATIVE BUDS				rare		

Admittedly the records are very sparse, *C. cuneatum* f. *striatissimum* having been found only twice: in February and July of the year 1937, and both times in the same locality. The possibility must not be overlooked that the plants may have been carried a long distance by the East Australian current which sweeps past Lord Howe and Norfolk Islands, skirts the south-east coast of Australia, and is thence deflected towards New Zealand, rounding the coastline formed by the North Auckland Peninsula.

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