REPORT

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Anna Wentz for the degree of Master of Science. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of ~~Master of Science.~~

Josephine E. Tilden
Chairman

William S. Cooper

William Moore

May 31 1917

REPORT

of

COMMITTEE ON EXAMINATION

This is to certify that we the undersigned, as a Committee of the Graduate School, have given Anna Wentz final oral examination for the degree of Master of Science. We recommend that the degree of Master of Science be conferred upon the candidate.

Minneapolis, Minnesota

May 31 1917

Josephine E. Tilden
Chairman

William Moore.

William S. Cooper

A MORPHOLOGICAL STUDY OF SOME LITTLE KNOWN FORMS OF PACIFIC ALGAE

A THESIS SUBMITTED TO THE
FACULTY OF THE GRADUATE SCHOOL OF THE
UNIVERSITY OF MINNESOTA
BY

ANNA WENTZ

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE

MAY 17 1917

A MORPHOLOGICAL STUDY OF SOME LITTLE KNOWN FORMS OF PACIFIC ALGAE

Of the three species investigated, the first one belongs to the Myxophyceae or Blue-Green Algae, while the other two are members of the Chlorophyceae of Green Algae. The first and second forms are from Australia; the third was collected on the shores of Vancouver Island. Up to this time but little has been known of their structure and the present work is an attempt to give a definite and exact description of their morphological characters with drawings illustrating the different points.

The work has been carried on during the past year under the direction of Professor Josephine E. Tilden.

I. Brachytrichia quoyi

The material from which this study has been made was collected at Bathing Beach, Gull Point, Flinders, Victoria, Australia, February 4 1913, by Miss Josephine E. Tilden. "It was found in the form of small, brownish, wrinkled bunches, attached loosely on submerged stones and pebbles in shallow tide pools at mid tide. When loosened the colonies were observed always to float".

Brachytrichia quoyi has been found on the New England coasts of the United States but is not a common form. It has also been reported once or twice from the California coast. A list of literature and localities may be found in Tilden's Myxophyceae of North America.

In the Indian Ocean and in the southwestern portion of the

I

Miss Wentz
Pl. I

Master's
Thesis
(J. E. Tilden
Chairman)

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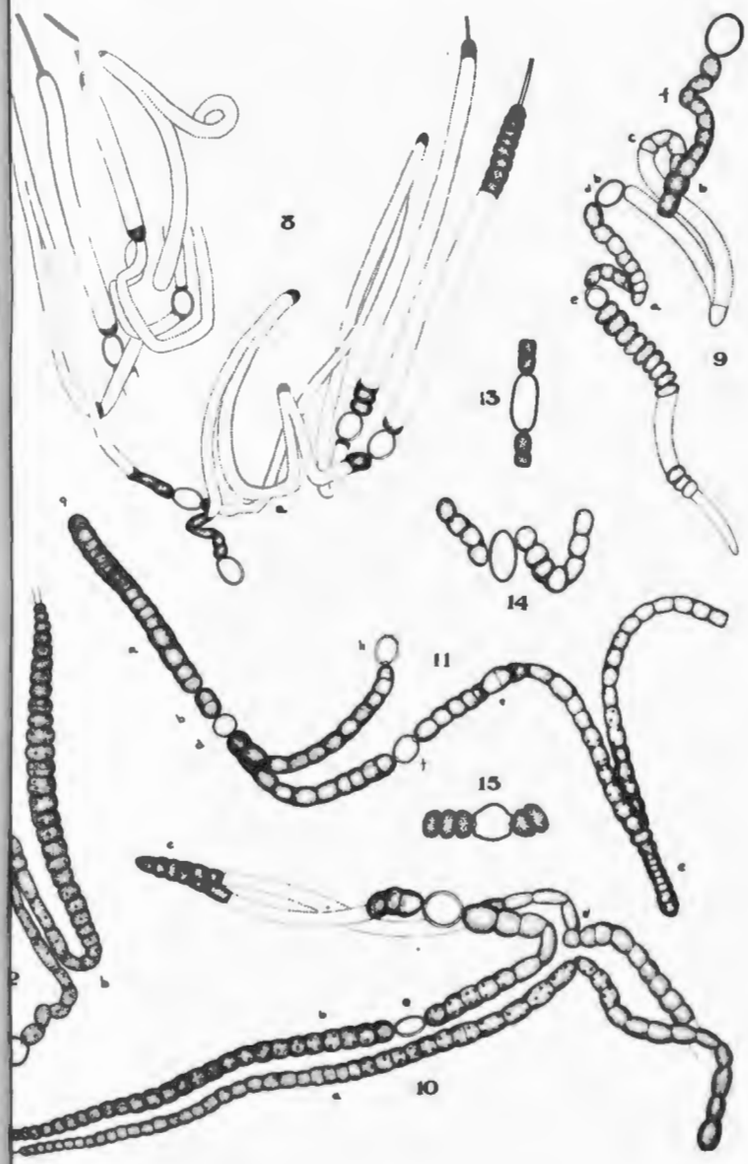

Miss Wentz
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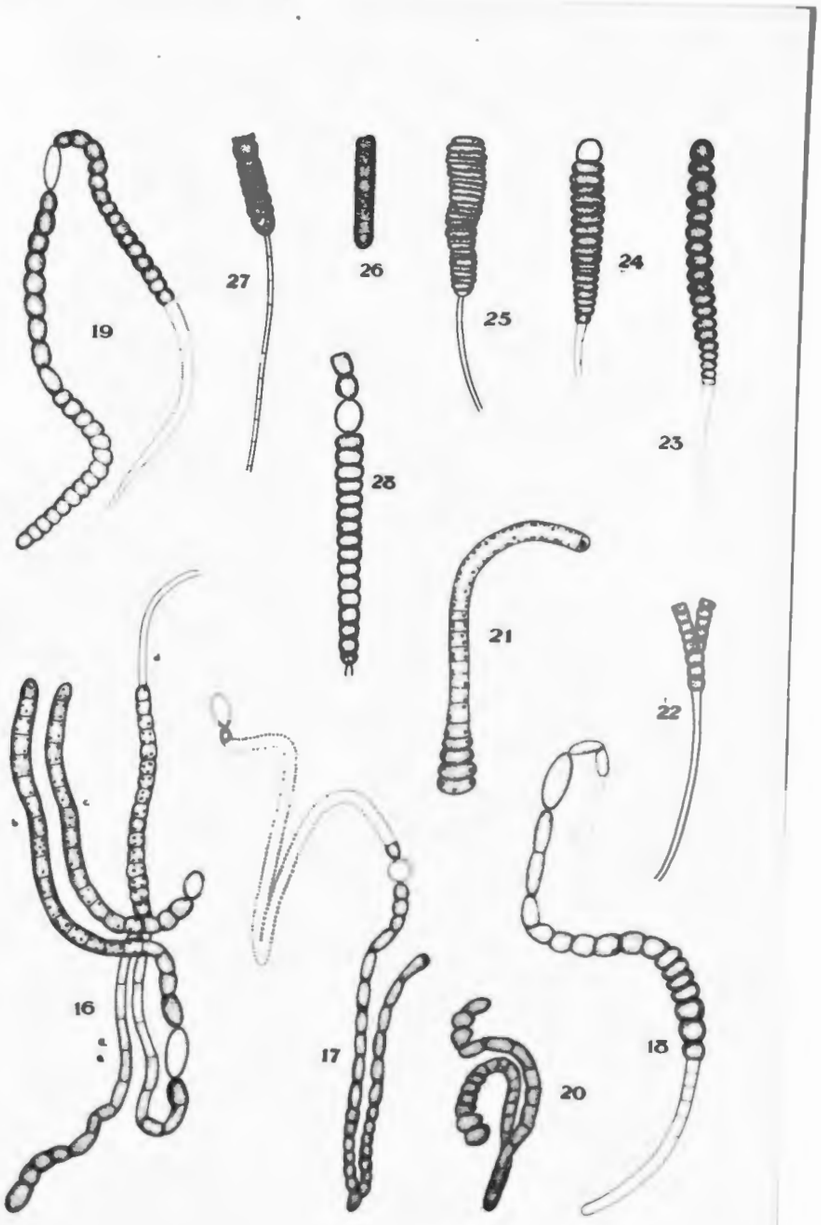
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Miss Wentz
Pl. III

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Miss Wentz

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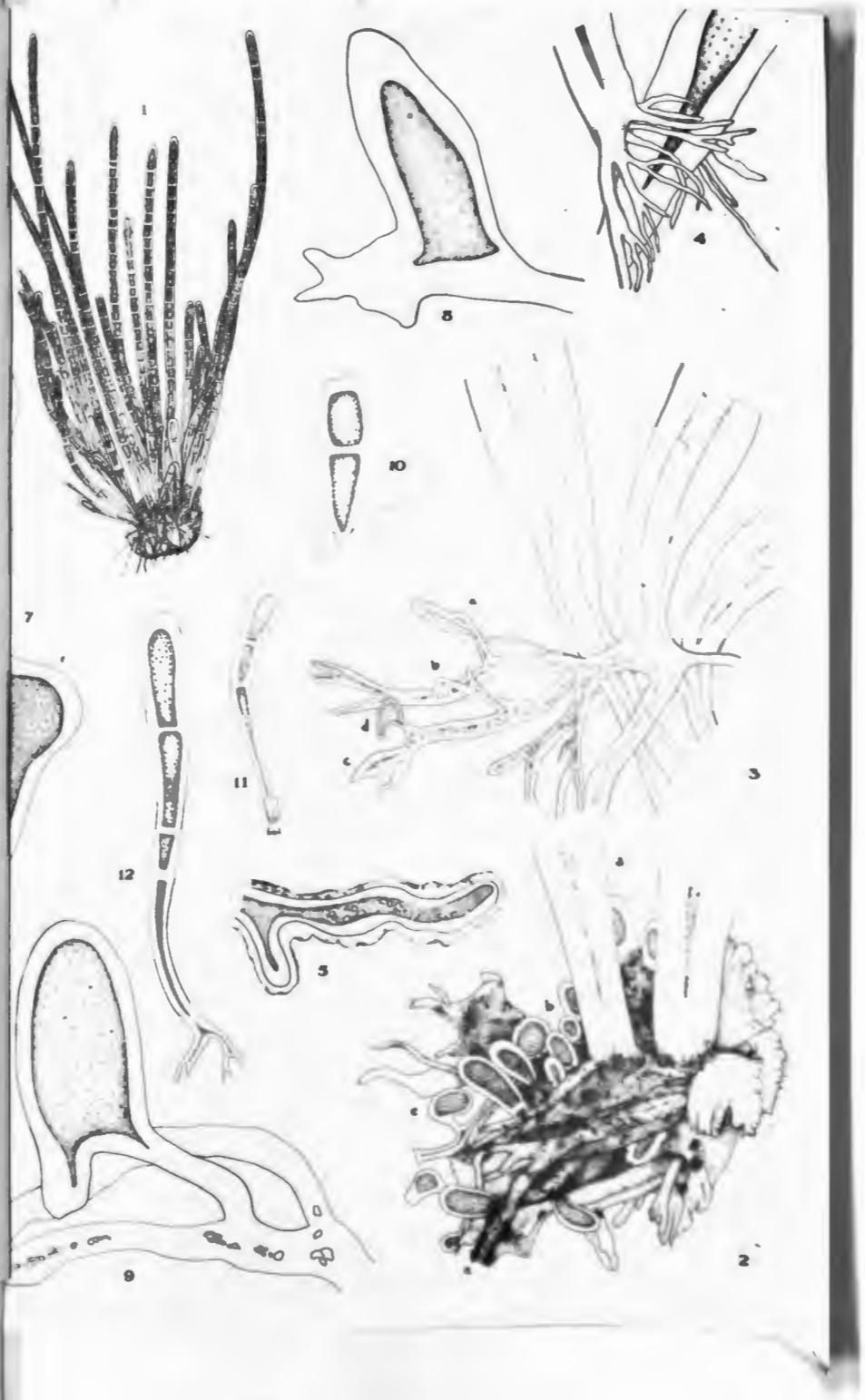
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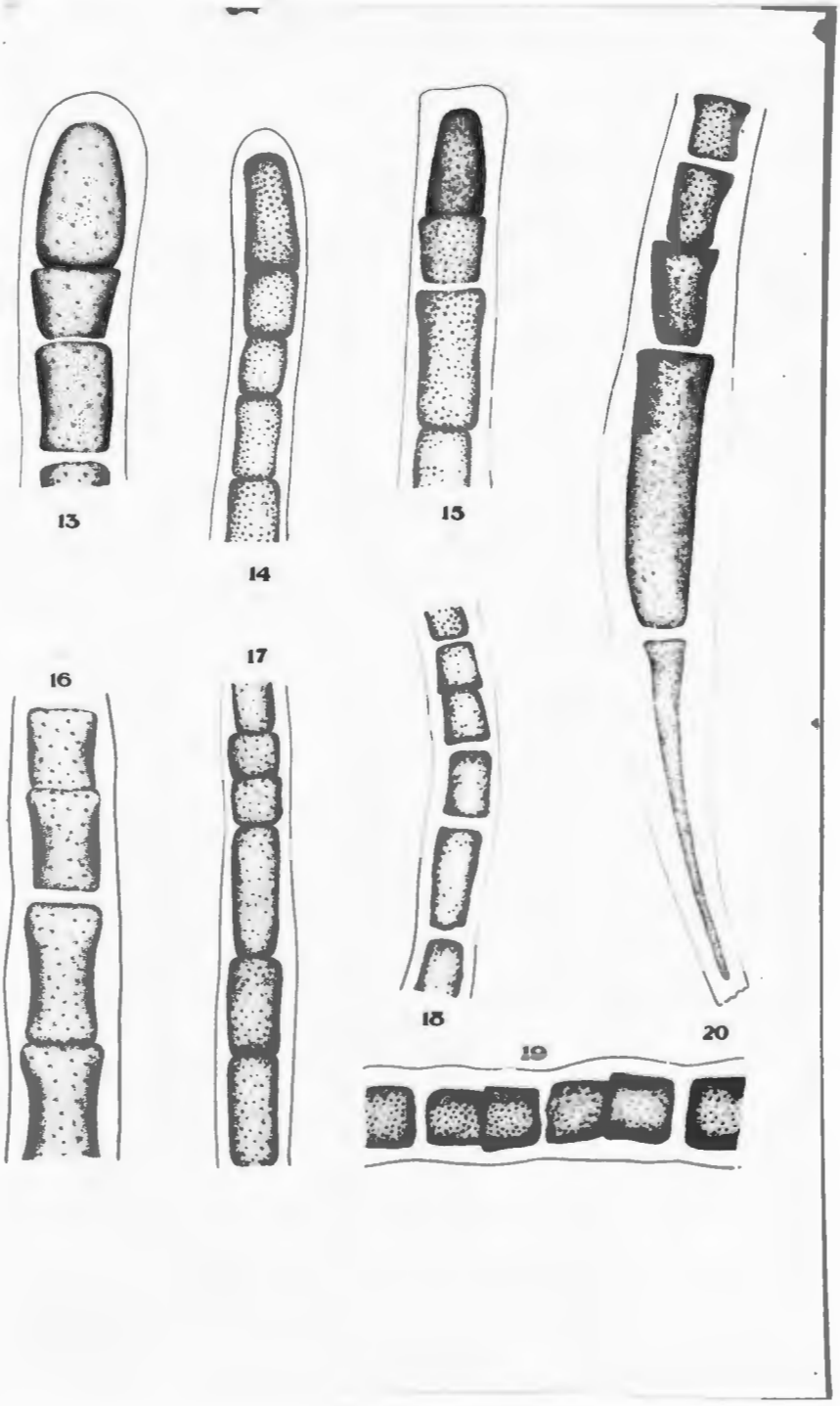
Miss Wentz

Pl. V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Wentz

VI

Pacific Ocean the species is more common. Agardh (1824) lists Nostoc quoyi from madrepore rocks, Mariana Islands (Gaudichaud). De Toni (1907) mentions other collectors. The same work contains descriptions of two other species of Brachytrichia: B.Balani from European and African coasts and B. maculans from the Indian ocean.

The colonies of Brachytrichia quoyi from the Australian material are small, 2 cm. or more in diameter and about 1 cm. in thickness. They are gelatinous, hollow and much convoluted. The convolutions are distended, and when dented in, immediately assume their original form. The basal parts of the convolutions seem to be caught down loosely here and there, so that in general appearance the colony often resembles a small brain.

In the jelly-like matrix of the colony the trichomes are so matted together that it is difficult to make a temporary mount such that individual trichomes can be followed throughout their length. The best method is to cut off a minute portion, crush it under a cover-glass with a rotary motion, tease it out with a needle, then replace the glass. A large cover-glass should be used in order to prevent the drying out of the mount, since the trichomes are easily moved, and once lost among the others, are almost impossible to find again.

In a water mount the edge of the matrix can seldom be seen without staining slightly. Of the two stains used, erythrosin and gentian violet, the former proved to be the better. In most of the work unstained material was used, but for the purpose of observing the position of the trichomes within the matrix, stained sections embedded in paraffine were made. Even this method was some what unsatisfactory since all parts of a trichome do not lie in

the same plane and in no section are all the cells cut through their greatest diameter. However, a fairly good idea of the position of the trichomes can be obtained by the stained water mount. Great care must be used in its preparation if a whole trichome is to be observed, for the individual plants are very easily broken.

The closely crowded trichomes tend to lie parallel within the matrix, having a somewhat radial arrangement. In general the ends point towards the surface of the colony. Some of them project beyond the surface giving the colony the hairy appearance seen under a high power dissecting microscope.

The trichomes consist of vegetative cells of various sizes and shapes, with heterocysts distributed in more or less definite positions. Some of the vegetative cells form a peculiar y-shaped portion. For lack of a better term, "y-segment" will hereafter be used to designate such a region. Sometimes the vegetative cells form a simple terminal segment.

The cells which lie deep within the matrix vary greatly in size and shape, measuring from 2.8 mic. in diameter by 8.4 mic. in length to 5.6 mic. in diameter by 6.3 mic. in length. Some of the cells in the forked portion of the "y-segment" are considerably longer than broad and so clear that cross walls are at times invisible. In a few cases the trichome was slightly less than 2.8 mic. in diameter. The cell contents were clear and no cross walls could be seen. The longitudinal walls in these cells were nearly parallel. Different shapes and sizes of these cells may be seen in some of the figures. They are quadrate, oblong, spatulate (especially those adjoining the heterocyst), spherical, spheroid flattened, ventricose and distorted (Plate I.fig. 5 and 7). The cell next to

the heterocyst is usually larger than the others in this region and has its larger end next to the heterocyst. The vegetative cells have thin walls.

Sometimes the cell contents are clear and colorless. In other cases fine or coarse granules are present.

The heterocysts have somewhat thick walls. They also vary in size and shape, but their position is practically constant, that is, between each two "y segments" when in series; between a "y segment" and a simple terminal portion; or between two simple terminal portions; or just at the base of a series of actively growing cells in a simple terminal (Plate II. fig. 10 e). Plate II. fig. 11 d shows a cell which apparently is changing into a heterocyst as it has the shape of a heterocyst and is in a position where one might occur, that is, next to a chain of hormogones.

In size heterocysts vary from 4.3 to 7.2 mic. in diameter and from 5.6 to 14 mic. in length.

The cells in the "True branch" portion of the "y segment" vary in number from one to many, and they exhibit great variation in shape. They taper from the base to the apex as shown in the drawings and by the following measurements:

basal cell	apical cell
4.3 x 4.3 mic.	2.6 x 2.4 mic.
5.6 x 2.8	2.8 x 2.5
8.5 x 4.8	3.5 x 1.6
10.3 x 2.2	4.2 x 2.0

The cells of the simple terminal free portions vary in the same way except that next to the heterocyst they resemble more the cells in the "y segments".

The hairs are composed of very long narrow cells. The cross walls can not always be seen. These hairs taper gradually to the

free outer end, which is often invisible. The manner of attachment varies also. In some cases the cells near the apex gradually diminish in length until they merge finally into the cells of the hair. Their granular contents disappear; at least they become very clear and transparent. In other cases the change from ordinary cells to hair cells is extremely abrupt. The apical cell is usually rounded at the distal end (Plate III. fig. 24,25,27). ~~Plate III. fig. 18~~ Fig. 18 in Plate II shows some unusually large cells at or near the apex which have the characteristics of hair cells except for size.

Hormogones are developed in the simple terminal portions of the trichomes and in the "true branches" of the "y segments". The hormogones contain in general from 7 to 19 cells each. These cells nearly always contain several large granules and are the most actively growing parts of the whole plant. Plate II. fig. 11, a,b,c shows the formation of several hormogones from a "y-segment". When the hormogones are mature and ready to leave the parent plant, the hair apparently drops off.

New plants are formed in two ways: a trichome may break apart at a bend thus forming two separate plants, or hormogones may be produced in the usual way from which develop young individuals.

The most interesting feature of this plant is its method of branching and this process has been studied with considerable care.

A mature plant may be described as being made up of from one to many "y segments" joined to each other by heterocysts. Such a series usually ends in a simple terminal section with a heterocyst between (Plate II. fig. 9,10,11). A trichome may also sometimes consist of two simple terminal sections united at their bases by

a heterocyst (Plate III. fig.19). As seen in a mount, two simple terminal sections usually lie parallel and side by side, but in neighboring trichomes. Their cells are similar in size, shape and general characteristics, while the cells nearest the uniting heterocyst have the same general characteristics as those near the heterocysts joining the "y segments". Evidently, then, these simple terminal sections and the "y segments" have the same origin, the former calling to mind the false branching of Scytonema, while the latter in part finally comes to be similar to the true branching found in Stigonema.

Thuret (1880) in his description of Hormactis Balani states "that there are two cells which contribute to this formation. One of them elongates laterally in contact with the wall which separates it from its partner and divides by an oblique section into two wedge-shaped segments. The segment of the new formation constitutes the simple part of the branch. Then the remaining cell as well as the synergic cell, grow simultaneously and symmetrically producing each one of them a lateral protuberance which elongates and divides into cells. At the summit the two protuberances are united by the cell detached from the first cell. This cell remains sometimes undivided, but generally it elongates and divides and produces either a hair or a branch. Sometimes the two associated cells develop laterally and divide exactly at the same time and in the same manner. There does not then exist a single cell which joins them. Each one of them grows in an independent manner, and makes two separate collateral branches exactly similar to the twin branches of Scytonema".

From observations made on the Australian material, another theory has occurred to the writer. Deep within the matrix where

the trichomes are much crowded, the cells between the two heterocysts often become pushed out of line and a sharp bend is produced as in the case of false branching in Scytonema. Up to this point cell division has taken place in a plane at right angles to the direction of growth of the trichome. Now, apparently, in response to some stimulus the cell at the bend changes its direction of growth and divides in a plane parallel to the direction of growth of the trichome. In other words, the trichome at this point begins to behave as does the basal cell of a branch in Stigonema. The method is characterised as "true" branching in the Myxophyceae.

In some cases two adjoining cells at the bend may separate - after the manner of twin "false" branches in Scytonema - and continue to divide rapidly. In this way, finally, the two simple terminal portions of separate but neighboring trichomes are formed.

In the first instance, the cell lying at the sharpest part of the bend, the "cap" cell, becomes somewhat unusual in shape, rounded on the upper side, while the adjoining cells, pushed up, as it were, by those behind, appear to join it, not at the ends but on the lower side. This cell then apparently assumes an entirely different direction of growth. It divides into two cells, and these dividing in turn, a new branch is produced, exactly as a"true" branch is formed in Stigonema. Different steps in the formation of these "true" branches are to be found in the plates (Plate I. fig. 6 a and b; Plate II. Fig. 9 f, 10 d, 11 e). Fig. 6. Plate I. shows a bend which might eventually have been broken apart to form false branches. Plate II. fig. 9 a and Plate III. fig. 17a, show a "cap" cell before division. Plate I. fig. 4 c; Plate II. fig. 9 b and 12 a; Plate III. fig. 20 a, repre-

represent the "cap" cell after division into two cells. A three-celled stage is shown in Plate III. 22 a, and a four-celled stage in Plate II. fig. 10 c. Many celled stages may be seen in Plate II, fig. 11 g and in several other figures.

In either case, these newly formed regions of the trichome may produce hormogones with a hair at the apex (Plate I. fig. 4 b and d. Plate II. fig. 11 a,b,c. Plate III. fig. 26).

In considering the opinion of Thuret, it must be remembered that he made his observations upon very young plants which were not yet in some cases contained wihtin a commonn matrix but which displayed individual sheaths. It may be noted that the "bends" occur between heterocysts as in Scytonema, but that more than one bend and consequently more than one branch, whether "true" or "false" may occur between two heterocysts, thus causing the unusual occurrence of "y segments" or a "y segment" and a terminal with no heterocyst.between, as indicated in Plate II. fig. 8 a and 9 c.

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Explanation of Plates

Plate I

Fig. 1. Brachytrichia quoyi. Characteristic habit sketch.

Fig. 2. Position of plants within the matrix. From paraffine sections stained with gentian violet.

Fig. 3. Position of plants within the matrix. From a temporary mount in water. No stain. Matrix visible in places.

Fig. 4. Portion of plant showing two cells (c) of the unforked portion of a "y segment", a true branch, and a simple terminal portion with two hormogones (b); a heterocyst between.

Fig. 5-7. Somewhat abnormal cells in a much crowded part of a plant.

Fig. 6. Series of cells from part of plant lying deeply imbedded in the matrix.

Plate II.

Fig. 8. Five different plants or parts of plants in nearly normal relative positions.

Fig. 9. An entire plant.

Fig. 10. Parts of two plants, originally joined in one.

Fig. 11. Plant showing three hormogones, a, b, c; a possible heterocyst, d; and a possible beginning of a "true" branch, e.

Fig. 12. Portion of a plant having a simple terminal portion or false branch and a "y segment" with no heterocyst between them.

Fig. 13-15. Three types of heterocyst.

Plate III.

Fig. 16. Portions of two plants.showing special peculiarities.

Fig. 17. Portion of a plant showing normal characteristics.

Fig. 18. Portion fo plant showing peculiar apical cells.

Fig. 19. Plant made up of two false branches joined at their bases by a heterocyst.

Fig. 20. A "y segment".

Fig. 21. Apical portion of plant.

Fig. 22 . Portion of a "y segment" showing attachment of hair.

Fig. 23. Another method of attachment of hair.

Fig. 24,25,28. Various shapes and sizes of cells.

Fig. 26. A hormogone.

Fig. 27. A hormogone with a hair. still attached.

AN INTERESTING FORM OF HORMISCIA (UROSPORA) FROM PUGET SOUND

During the summer of 1914 Dr. T.C.Frye and Mr.S.M.Zeller made a careful study of a green alga which had been found growing abundantly in the vicinity of Puget Sound Marine Station. Based on a study of this material they published a description of a new species, Hormiscia tetraciliata(Frye and Zeller 1915).

Some years previous to this Miss Josephine E. Tilden, July 1 1898, had collected an alga of striking appearance, on an island two miles east of Oak Bay, Victoria, British Columbia. At that time Miss Tilden made a brief examination of the material and published the results in her American Algae (1900), determining the plant temporarily as Urospora wormskjoldii (Mert.) Kolderup Rosenvinge var. vancouveriana n.var.

At the request of Miss Tilden the writer has made a series of observations upon the Vancouver material and compared the results with those of Dr.Frye and Mr. Zeller. It seems probable that the two plants are one and the same species, but whether Hormiscia or Urospora is the proper generic name, it is not in the province of this article to determine.

The two original descriptions are given below.

Hormiscia tetraciliata sp. nov. (Frye and Zeller). Marine. Filaments simple,moniliform, cylindrical, varying in diameter from 25 mic. at the base to 220 mic. at tip as a maximum, 6 cm. or less long, attached by the base to stones or shells or Ulva lactuca in the lower littoral region; holdfast a tuft of branched nonseptate

rhizoidlike diverticula arising one or two from each of the lower fifteen or fewer cells, descending within the sheath and projecting from its base, each branch flaring trumpetlike at its base. Cells from half to twice as long as wide, more or less barrel-shaped; all cells above the holdfast region similar, capable of division and of producing zoospores or gametes; sheath in older cells as much as 15 mic. thick; chloroplast a rather close net, with many pyrenoids, lining the cell wall. Asexual reproduction by akinetes or by zoospores; zoospores very many in a cell, pearshaped but the marrow end tapering into a long threadlike projection, varying to more nearly spherical, tetragonal in cross section, at the large end with four cilia about as long as the body, without "eye spot". Gametes very many in a cell, spherical but without threadlike projection like that in the zoospores, with red "eye spot", with four cilia shorter than the body.

Urospora wormskjoldii (Mert.) Kolderup Rosenvinge var vancouveriana n.var. (Tilden). Frond attached, soft, gelatinous, dark green; filaments unbranched, 1-1.5 dm. in length, of different sizes, narrow at base, above dilated and moniliform; articulations at base 75-130 mic. in width, near apex (filled with macrozoogonidia) up to 3 mm. in width; lower and median articulations cylindrical, upper articulations ventricose, either spherical or ovoid-ellipsoid, equal up to three times longer than broad; basal cells 14-20 in number, giving off rhizoidal filaments which grow downward and attach the plant to substratum (as in Bangia); macrogonidia ovoid, with four cilia at anterior end, and with posterior end drawn out into a spine, 10-12 x 28-32 mic. Attached to stones and shells on a sandy slope just uncovered at low tide.

Measurements given in the above description concerning the size of the upper coenocytes (articulations) were taken in the field. In the preserved material examined recently, no plants longer than 10 cm. were found. In this material the filaments are found to break very easily.

Original investigations on the Vancouver material.

In a matured filament, each of the first few basal cells, up to thirteen or more in number, send out a single projection from its lower end, This projection gradually lengthens, pierces the walls of the cells below it, and working its way over, under, or around those next below, finally reaches the object to which it becomes attached. Each of thse holdfast branches is at its lower end surrounded by a specially thickened cellulose wall, and the end itself is slightly enlarged, while the contents have a slight tendency to branch (Plate I. fig. 2 b). At some point, between the origin and the substratum, many of the holdfast divisions branch once, possible twice. It was very difficult to represent the appearance of the much-branched holdfast, the rhizoids were so intertwined and often covered with debris. Some of them could not be traced throughout the length. The contents of the rhizoids are similar to those of the cells from which they took their origin.

The cells next above the basal (haptera) cells are purely vegetative. It ought to be stated here that these cells should properly be called coenocytes since a number of nuclei are present in each one. These coenocytes vary from quadrate or cylindrical, with slight constrictions at the septa, to slightly ventricose with slight constrictions. The nearer the coenocytes are to the tip of the plant, the more ventricose, the more constricted at the septa,

and the greater the size, until at or near the tip, the coenocytes, which are usually gonidangia in this locality, are spherical or nearly so and measure as much as 3 mm in diameter. The constrictions between these coenocytes is so great that they are very easily separated. Between some there seem to be two end walls. Probably at maturity they break apart and float away in the water, thus assisting in the distribution of the species. Their walls measure as much as 36.5 mic. in thickness.

Each gonidangium produces large numbers of zoogonidia. These zoogonidia are ovoid. Their greatest diameter is from one-third to one-fifth their length, from the anterior end. The body comes to a point posteriorly and terminates in a stiff "hair" which is about one-fourth the length of the body portion. At the anterior end is a roundish projection from the base of which arise four cilia. These have a length about equal to that of the body. The zoogonidia, not including the posterior bristle, are 25.2 - 28 mic. long and 8.4 - 11.2 mic. wide at their greatest diameter. Miss Tilden's measurements are greater, due to the fact that she included the bristle in the measurement of the gonidium. Within the gonidangium the zoogonidia are arranged in groups of many individuals with their tapering posterior parts to the center.

Akinetes were found in this material, but gametes were not seen.

To show comparison more easily, the main points in the two above descriptions, are given in tabular form below.

	U.wormskjoldii var vancouveriana	H. tetraciliata
Number of basal cells	14 - 20	6 - 15
Diameter of filaments	Varying from 25 mic. at base to 3 millimeters near apex	Varying from 25 mic at base to 220 mic. at tip

Length of filaments	1 - 1.5 decimeters	6 cm. or less

The size of the zoogonidia are not given for the Hormisica material.

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Explanation of Plates

Plate IV

Fig. 1. Urospora wormskjoldii var vancouveriana.

a. Lower part of a typical filament.
b. Middle portion of the same filament.
c. Upper third of the same plant.

Fig. 2. Lower portion of a filament showing the two lowest purely vegetative cells, and so far as was possible, details of haptera.

Fig. 3. Typical gonidangia.

Fig. 4-6. Gonidia.

A CHAETOMORPHA OR CHAETOMORPHA-LIKE FORM FROM AUSTRALIA

The third and last alga studied belongs also to the family Cladophoraceae. Miss Tilden collected this material at Kiama, New South Wales, Australia, on September 24 1918. The plants occurred in small groups or colonies or were scattered. The individuals were stiff and stood upright. They were found at low tide in tide pools sheltered in front from the splashing of the heavy waves.

The colonies examined consisted of from few to many somewhat stiff filaments held firmly together by interwoven masses of branching rhizoids which arise from the lower end of the basal coenocyte. From the rhizoids arise buds which develop into new plants. The longest filaments measured were 3 cm. high. The plants have their greatest diameter in the upper part of the basal coenocyte or in the lower or middle part of the coenocyte next to the basal. Above these two the diameters average about the same throughout. In the older filaments the coenocytes are slightly larger in the central portion than at the ends. The apical coenocyte is from 1 1/2 to 3 times the diameter, while the others are equal to to twice as long as broad. In the older filaments the diameters measure 280- 784 mic.

The walls of the coenocytes are strikingly lamellate and vary in thickness from 42- 15 mic. The dividing walls may reach 140 mic. in thickness. In a rapidly growing filament there are sometimes as many as six or more coenocytes with no wall yet formed between them (Plate VI. fig. 17).

The contents of the basal coenocyte occupy a long, somewhat funnel-shaped space which is much wider at the top than at the bottom. In the coenocytes next above, the contents assume the shape of an hour-glass, reminding one of the bones in an x-ray picture of the fingers. In those near the tip the contents of the coenocyte occupies a space which gradually increases from a less diameter at the base to a slightly greater diameter at the upper end. In the apical coenocyte the reverse is true and the contents are rounded off at the apex. The chloroplasts in the coenocytes are somewhat spherical and measure 5 - 8.4 mic.in diameter.

From the basal coenocyte two or more large rhizoids depart. These branch and branch again until some of the smallest branches are no more than 20 mic. in diameter. Throughout their length the rhizoids are filled with protoplasm and large regular and irregular bright green chloroplasts. Often the contents can not be clearly made out because of the roughness of the surface of the wall.

Buds arising from the rhizoids are first noticed as a widening in a small branch (Plate V. fig. 3 a, b. and 6). At that place the chloroplasts seem to increase in numbers and the rhizoid enlarges.

There soon occurs a separation of the contents of a bud from that of the rhizoid, often on one or the other side first (Plate V. fig. 2 c and 3 d). The connection between the new filament and the rhizoid becomes narrower and the first coenocyte then has the position shown in Plate V. fig. 9. Sometimes the first coenocyte rises perpendicularly from the rhizoid and the contents separate off at about the same time on both sides. The contents later assume a more triangular shape and become much elongated. New coenocytes

develop at the upper end. A young filament containing but two or three coenocytes is broadened at the tip, but gradually changes to a more uniform diameter as it grows older.

The most rapidly growing parts of a filament are above the two or three basal cells and below the apical cell. The basal cell or coenocyte seems to have merely the function of support and attachment.

The material studied contains no fruiting stages. No gonidangia or zoogonida were found.

Several very closely allied forms have been described. The characteristics of these have been tabulated and are given below: (When ready for printing these will be given on a separate plate or folder).

Insert extension folders

It would seem from the descriptions of these forms that all are much alike, except in the diameters of the filaments and the length of the basal coenocytes. According to measurements of the latter, Chaetomorphopsis pacifica comes at one end of the series while the Australian form is at the other end. Measurements in this group vary through such wide limits in each species that perhaps they may all be varieties of one species.

Explanation of Plates

Plate V

Fig. 1. Chaetomorpha (?). Habit sketch.

Fig. 2. Basal portion of a colony showing rhizoids, buds etc.

Fig. 3. Branching of rhizoids and formation of buds.

Fig. 4. Branching of rhizoids.

Fig. 5. Tip of rhizoid.

Fig. 6, 7, 8, 9. Steps in formation of buds.

Fig. 10. Two-celled stage of young plant. a, an epiphyte.

Fig. 11. Three-celled stage of young plant. Portion of an epiphytic plant at base.

Fig. 12. Four-celled stage of young plant, with rhizoids.

Plate VI.

Fig. 14 - 16. Apical coenocytes of older plants.

Fig. 17 - 19. Coenocytes in middle portions of different filaments.

Fig. 20. Basal portion of a filament.

I wish to offer my best thanks to Miss Tilden for advice and assistance in the preparation of this paper.