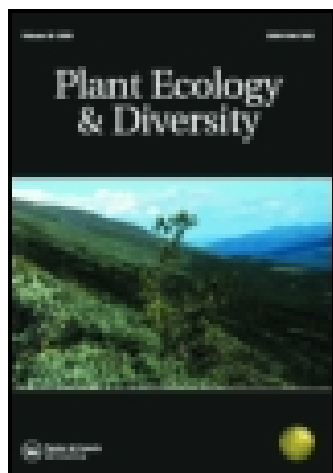


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Publisher: Taylor & Francis

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Transactions of the Botanical Society of Edinburgh

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/tped18>

Preliminary Note on the Evolution of Oxygen by Sea-Weeds

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Published online: 01 Dec 2010.

To cite this article: John Rattray M.A. B.Sc. F.R.S.E. (1886) Preliminary Note on the Evolution of Oxygen by Sea-Weeds, Transactions of the Botanical Society of Edinburgh, 16:1-4, 244-258, DOI: [10.1080/03746608609468269](https://doi.org/10.1080/03746608609468269)

To link to this article: <http://dx.doi.org/10.1080/03746608609468269>

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of *A. germanicum* growing from the same root with *A. septentrionale*, but there were unfortunately no intermediate forms proving their common origin, and I was unable to bring the roots home in a sufficiently good state to enable me to keep them alive.

In 1882 I was more fortunate in finding, near the same locality, several other specimens bearing on the same root every intermediate form betwixt *A. germanicum* and *A. septentrionale*. A few which are here figured (p. 243) will, I venture to think, help to decide the question. The roots which were brought home are still flourishing, and have put up a goodly crop of fronds, which are all typical forms of *A. germanicum*. This fact is especially interesting when viewed side by side with the instance noted by Mr Boyd, who informs me that his specimen, varying betwixt the two forms, finally developed into *A. septentrionale*.

In the figures which I have given it will be observed that only the intermediate forms are figured, but there were on the same root other fronds, having the distinctive characters of each species. I need scarcely add that extreme care was taken to satisfy myself that there was only a single root, all the fronds being observed to issue from the same point.

Preliminary Note on the Evolution of Oxygen by Sea-Weeds.

By JOHN RATTRAY, M.A., B.Sc., F.R.S.E., Scottish Marine Station, Granton, Edinburgh.

(Read May 14, 1885.)

Soon after commencing my work on the Algæ of the basin of the Firth of Forth in the summer of last year, I observed that living specimens of different species when kept in vessels of water in the floating laboratory, and exposed to the influence of sunlight, emitted a very variable number of bubbles of gas, though placed as far as possible under similar external conditions. Not being able to discover any data bearing on the proportion of oxygen to the entire quantity of gaseous matter accumulating under such circumstances, I determined to make a series of experiments, with the view of finding out whether any variations

could be shown to occur in this connection among the different species, and also consequently for the purpose of arriving at some approximate data on the efficiency of the several species in aiding the waves and other movements of the sea in oxygenating the ocean waters.

The method of work adopted was as follows:—A small number of cylindrical glass jars of moderate dimensions was procured, these selected measuring about $4\frac{1}{2}$ inches in diameter and $9\frac{1}{2}$ inches in height. Their lower extremities were left permanently open, while the upper end of each, which was gradually attenuated to form a neck, was closed by an india-rubber perforated stopper, through which a collecting tube, graduated to cubic centimeters, was passed. The diameter of the neck of each jar measured $1\frac{1}{2}$ inches, and the height of the collecting tube, though not always constant, averaged about 7 inches, its diameter being half an inch. The large size of the jars was found to be essential, in order that weeds of considerable magnitude might be selected for experiment and kept in their normal conditions.

In all cases the specimens chosen were left attached to the substratum upon which they grew, so that their rhizoids as well as their more expanded thalli were invariably intact. Where the attachment was, as sometimes happened (*e.g.*, in the case of *Fucus canaliculatus*), upon rocks, the part of the rock upon which any given plant was fixed was removed at a distance of a few inches round the specimen by means of a chisel, and no specimens were used in which the sandstone was fractured in the immediate vicinity of the point of attachment of the plant. The exclusion of other Algae except members of the species in question was in most instances attained by selecting from what might be called *exclusive* areas; that is, from places upon which one species grew to the exclusion of all others of the same or of different genera; but in a few cases in which it was found impossible to secure such conditions, and in which rounded stones of small size, but bearing a good growth of a given species were made use of, these stones were carefully examined by a lens and rejected when a mixture of organisms occurred.

The specimen once selected, was now washed carefully

in sea-water, so as to remove all loose muddy or sandy materials; it was then completely submerged, and allowed to remain at rest for some time, in order to get rid of all bubbles of air that might be entangled among the more minute ramuli before being finally placed inside the jar. This last process was effected in the usual manner. The jar was filled very slowly with sea-water, so as to prevent small bubbles of air from being included, and so accumulating at the top of the collecting tube when the jar was reversed. The specimen was now slipped under and inside this, without being allowed to reach the surface of the water, and a second cylindrical vessel with a flat bottom, and having a diameter a few inches greater than that of the jar, its height being equal to about one-third of the latter, was slowly filled with sea-water, and passed under the vessel which now contained the plant or plants. The whole apparatus was then raised out of the water, and exposed to the direct action of the rays of the sun.

The time of this exposure was not always the same, because in many cases, in which small specimens had to be dealt with, a longer period had to be allowed, in order that a sufficient amount of gas might be collected to enable further observations to be made; but in all instances the periods of exposure have been carefully recorded, and the conditions of the weather during those periods given.

The changes of the temperature of the water in the apparatus now introduced a disturbing element of great importance, inasmuch as with its variations the amount of oxygen, and of the other accumulated gaseous substances, absorbed by it would also vary. To counteract as far as possible these changes, or, in other words, to maintain the uniformity of the temperature of the water in the vessels, a current was established. This was readily effected by pumping water at frequent intervals from the sea into a tank at a higher level, from which it was again drained off into the apparatus by means of a small india-rubber tube provided with a small glass nozzle or a wooden clip, to prevent the passage of a current of too great strength. By this means the temperature of the water in the apparatus was found to vary within very small limits; but I have been unable to maintain an absolute constancy,

partly because of the variability in the intensity of the heat of the sun, which induced a more or less rapid increase or diminution of the temperature in the upper part of the apparatus, which the convection currents could not perfectly antagonise, and partly because the experiments had to be continued during the night, when the apparatus could not be attended to.

The significance of this factor I endeavoured to determine by erecting a second apparatus prepared like the first, but without any plants, and exposed in every way to similar external conditions. A similar current of sea-water was passed through the apparatus from the tank, and in it the gaseous molecules given off by the water itself in virtue of changes of temperature accumulated. In this manner the part played by the water as such was determined, and in any case, where even a very small accumulation of gases took place the experiment was repeated. When a hardly appreciable quantity of gas had accumulated in the second apparatus, the influence of the changes of temperature on the water was regarded as insufficient to modify the reading in the apparatus in which the experimental plant or plants were exposed, and this reading was accordingly accepted.

It need hardly be noted that, in admitting a current of sea-water into the vessels through the india-rubber tubing, great care was taken so to regulate the conditions that bubbles of air were not passed in along with the water, nor were swift surface eddies set up, as these might have caused an abnormal amount of air to pass into the circulating water.

After a sufficient amount of gas had accumulated in the collecting tube, the entire apparatus was removed and immersed in a tubful of sea-water which had been prepared for some time so as to settle and acquire a temperature equal to that of the water in the apparatus. The depth of water in the tub was such that the lower end of the collecting tube of the experimental apparatus could be removed from the jar without coming above its surface. The accumulated gas was now decanted into a clean eudiometer which was carefully transferred, its open end being closed by the thumb, to a chemical stand, and on this it was clamped

with its lower extremity under the surface of the mercury in the mercurial trough. A reading of the amount of gas present was now taken, the temperature of the room and the height of the barometer at the time being at the same time recorded. Potash and pyrogallic acid were then added in turn, and after allowing adequate time for absorption of the oxygen to take place a second reading of the remaining volume was made, the temperature and pressure being noted as previously. In all cases this direct method was employed in analysing the gases.

In reading the volumes of these gases, the level of the centre or summit the downwardly convex meniscus has been taken, and the observations were always made in the outer room of the floating laboratory, at a distance from all artificial heat, and in a place secluded from the action of sunlight. The mercury in the trough, after becoming unsuitable for work, owing to the presence of pyrogallate and water, was cleaned by being passed through filter paper.

It is important to note that the presence of micro-organisms of a vegetable or animal nature in the sea water inside the apparatus exercises another disturbing influence on the gaseous products; but, as already stated, this factor has not been found to cause an accumulation of gas in the empty apparatus, and its influence, though real, is not included in the annexed calculations.

The corrections of the volumes of the gases for temperature and pressure have been calculated from the following formula:—

$$V' = \frac{V \times (B - b - T)}{760 \times (1 + 0.003665 t)},$$

where V' =corrected volume, V =observed volume, B =height of barometer at time of reading, b =difference between height of mercury in trough and in eudiometer, t =temperature in degrees centigrade, T =tension of aqueous vapour in mm. of mercury at temperature t . With regard to the value of b in the above equation, it is to be noted that the watery substance in the eudiometer have been reduced to mm. of mercury by regarding $\frac{1}{13}$ of the volume of these substances as giving their mercurial equivalent. This factor is of importance, as the height of the column of

mercury in the eudiometer has to be deducted from the reading of the barometer in making the calculations.

A. Enteromorpha compressa (L.) Grev.

In this case the results of seven experiments are given, different plants being employed on each occasion. Good specimens were procured in the immediate vicinity of this station, all being in full vigour of growth. The first experiment gave the following statistics:—

Time of Exposure.	Vol. of Gas collected.	Temp. of Room.	Height of Barom.	Height of Water in Eudio.	Vol. after Potash.	Vol. after Pyro. Acid.	Temp. of Room.	Height of Barom.	Height of Hg in Eudio.	Height of Watery Substances in Eudio.
hrs.	c.c.	Cent.	mm.	in mm. of Hg.	c.c.	c.c.	Cent.	mm.	mm.	in mm. of Hg.
22½	12·6	16°·2	755	4·8	12·6	6	16°·4	756	31·5	6·8

Correcting according to the formula,

$$\begin{aligned}
 V_1 &= \frac{12\cdot6 \times (755 - \frac{1}{3} \text{ of } 4\cdot8 - 13\cdot710)}{760 \times (1 + 0\cdot003665 \times 16\cdot2)}. \\
 &= \log A - \log B. \\
 &= x - y. \\
 &= z.
 \end{aligned}$$

Hence the number whose log. is z is the number required. In this instance it is found to be 11·5 approx.

The variations in the percentages of oxygen shown by the following table are indeed considerable, but perhaps cannot be looked upon as abnormal. The maximum, 61·2, was obtained in the second experiment, the minimum in the third, namely, 51·7. On comparing the condition of the plants in these two cases, a very remarkable difference was recorded. Both were in an exceedingly perfect condition of health, and had not been injured in any part by impact of foreign bodies, but on examining the former under the microscope, the spores were found to be just moving out of the cells. That a plant at the acme of its vigour was thus observed is of interest, as proving that in such a condition its efficacy as an oxygenator is very great—higher indeed than in any previous, and, of necessity, than in any subsequent period of its existence. In the second instance referred to, the stage for emission of spores had not yet arrived, nor did this occur during the week following, while

Similarly, by substituting the required figures, the volume remaining, after removal of the oxygen by the pyrogallie acid, will be found to be 5.2 c.c. Hence $11.5 - 5.2 = 6.3$ = amount of oxygen that was present, *thus representing 54.8 p.c. of the whole volume collected.*

The following table gives the results of the remaining experiments that were made on this species. The figures having reference to the experiment just discussed have been inserted to make the table complete.

No. of Expt.	Time of Expt.	Vol. of Gas collected.	Temp. of Room.	Height of Barom.	Height of Water in Endio.	Vol. of Gas collected after correction.	Vol. of Gas after Potash.	Vol. of Gas after Pyro. Acid.	Temp. of Room.	Height of Barom.	Height of Hg in Endio.	Height of Watery Substances in Endio.	Vol. of Gas after correction.	Per cent. of Oxygen collected.	Remarks.
	Hrs.	c.c.	Cent.	mm.	mm.	c.c.	c.c.	c.c.	Cent.	mm.	mm.	mm.	c.c.		
I.	22½	12.6	16°2	775	4.8	11.5	12.6	6	16°4	756	31.5	6.8	5.2	54.8	Sky in part overcast, subsequently bright sunshine and a little cloud.
II.	25½	16.4	15°9	759	2	16.2	16.4	7	15°9	759	65	4	5.9	61.2	Sky mostly clear with bright sunshine, a grand breeze.
III.	29½	15.9	16°6	755	2.7	14.5	15.9	8.1	16°1	757	38	4.9	7	51.7	Sky sometimes overcast, intermittent sunshine.
IV.	25½	15	15°9	759	3	13.8	15.9	6.8	15°3	760	60	5	5.8	58	Sky cloudy, bright sunshine at times, and generally calm.
V.	25½	15.8	15°3	760	2	14.8	15.8	7.2	17°2	762	60	4	6.1	58.8	Sunshine intermittent, cloud and a little rain.
VI.	22	14.8	17°6	770	2.9	13.7	14.8	7.3	17°2	770	38	4.7	6.4	53.3	Sultry, with cloud and intermittent sunshine.
VII.	22	16.3	17°4	770	2.9	15.3	14.2	7.8	16°9	770	44	4.9	6.7	52.8	Sultry, with cloud and intermittent sunshine.

By adding the above percentages and dividing by 7, the number of experiments, average percentages of 57.2 is obtained for the oxygen factor.

It is noteworthy that in the above experiments, as in all the succeeding ones, the addition of potash, which would readily have absorbed any carbonic acid gas present, produced no appreciable change in the volumes of the collected gases, *it accordingly follows, and this is a very significant deduction, that among the gases no trace of carbonic acid existed.* As bearing on this inference, however, it must be stated that the analyses have never been made during the earlier part of the day.

B. ULVA LATISSIMA, Kütz. MONOSTROMA LATISSIMUM (Kütz.). Wittr.

Excellent specimens of this plant were procured on small round stones on the gently sloping somewhat shingly beach leading down into the estuary from the entrance to Granton Quarry. In the first series about a dozen of experiments were performed, and from these the following eight have been selected as representative.

SERIES 1.

No. of Expt.	Time of Expt. sure.	Vol. of Gas collected.	Temp. of Room.	Height of Water in Eudio.	Vol. of Gas collected after correction.	Vol. of Gas after Potash.	Vols. of Gas after Tyro. Acid.	Temp. of Room.	Height of Barom.	Height of Hg in Eudio.	Height of Watery Substances in Eudio.	Vol. of Gas after correction.	Per cent. of Oxygen collected.	Remarks.
	Hrs.	c.c.	Cent.	mm.	c.c.	c.c.	c.c.	Cent.	mm.	mm.	mm.	c.c.		
I.	4	15.4	16° 2	772	14.4	15.4	7.8	14° 1	778	44	4.4	7	51.4	Sunshine generally, sultry, but cooler towards the close.
II.	46	14.7	16°	778	13.9	14.7	8	12° 8	778	28	3.9	7.4	46.8	Sky sometimes overcast and cloudy, sultry and bright sunshine.
III.	22	10.3	11° 7	775	10.3	10.8	5.3	13° 2	775	19	7.4	4.9	52.5	Misty, sunshine less than in above cases, but clear later on.
IV.	24	8.2	13° 3	775	7.8	8.2	4.1	13° 1	775	3	9.5	3.8	50.7	Misty, sunshine less than in above cases, but clear later on.
V.	26	10.6	13°	775	10.1	10.6	5.1	12° 8	775	25	7.8	4.6	54.5	Sunshine general, a little fog.
VI.	26	10.2	12° 3	774	9.7	10.2	4.9	12° 5	774	7	8.9	4.6	52.6	Intermittent sunshine, cloudy, on the whole mild.
VII.	27	9	12° 5	774	8.5	9	4.3	12° 4	774	6	9.5	4	57.9	Mild, sunshine, cloud.
VIII.	27½	7.5	12° 4	774	7.1	7.5	4.2	15° 9	774	6	10.5	3.9	45.1	Mild, sunshine, cloud.

Average percentage of oxygen = 50.8.

SERIES 2.

IX.	50	2.6	7° 3	978	2.5	2.6	1.6	7° 8	778	0	13.9	1.5	40	Dry, a little frost at night, snatches of sunshine during day.
X.	50	1.4	8° 3	778	1.3	1.4	0.8	8° 4	778	0	14.8	0.78	40	Sunshine on whole general, a little frost at night.
XI.	50	1.5	8° 6	778	1.4	1.5	0.9	8° 8	778	0	14.2	0.86	38.6	Sunshine on whole general, a little frost at night.

Average percentage of oxygen = 35.9.

the plant was kept under daily observation. The clear green and fresh colour of all the cells, however, at once disproved all possibility of the presence of pathological conditions, nor is it unlikely that this number approximately represents the average normal percentage for an ordinary specimen of this alga.

In the case of the fourth and fifth experiments the specimens were also approaching the stage for extravasation of the spores, inasmuch these were shed on the fifth day after the experiments ceased; while in the case of the first plant, the results of which are recorded above, a similar emission of motile spores only occurred after eight days. *The general inference, therefore, that the maximum of oxygen evolution is reached at the time of sporulation seems to be clearly warrantable in this species*, and the deduction has been corroborated by some of the experiments recorded on p. 251.

The experiments in connection with this species, which is very abundantly represented in most localities of the estuary of the Forth, have been divided into two series, differing widely in the percentages of oxygen which they present. The first series was conducted during the month of September, and under very favourable conditions on the whole with regard to mildness and amount of sunshine. The latter, on the other hand, was undertaken in November, when the amount of sunshine was but small, and the night no longer mild. A comparison of the two series, therefore, shows that in the warmer autumn months there is a very pronounced excess of oxygen given out, as compared with what takes place at the approach of or during winter. It must also be noted, that although care was taken to procure sound specimens for all the experiments, greater difficulty was encountered in this respect in the latter series, and in one instance especially (Exp. XI.) the plant selected was somewhat injured along one of its margins. Owing to this difficulty, the second group of experiments were limited to five, but from a slight admission of air into the eudiometer tube during the process of analyses in two cases, the results so far obtained had to be abandoned.

Among the plants chosen for the first group of experiments, emission of spores was observed in none, yet all were

C. PORPHYRA LACINIATA (Lightf.), Ag.

Specimens procured from same locality and with same kind of attachment as in the case of *Monostroma latissima*. The time of exposure varied as in other instances with the size of the plant.

No. of Expt.	Time of Expo- sure.	Vol. of Gas col- lected.	Temp. Room.	Height of Water in Barom.	Height of Water in Eudio.	Vol. of Gas collected after correction.	Vol. of Gas after Potash.	Vol. of Gas after Pyro. Acid.	Temp. Room.	Height of Barom.	Height of Hg. in Eudio.	Height of Watery Substances in Eudio.	Vol. of Gas after correc- tion.	Per cent. of Oxygen col- lected.	Remarks.
	Hrs.	c.c.	Cent.	mm.	mm.	c.c.	c.c.	c.c.	Cent.	mm.	mm.	mm.	c.c.		
I.	47	20.2	15° 2	770	0	19.1	22.2	7.7	14° 3	767	42	55	6.8	64.4	Sunshine, a little fog and cloudy.
II.	47	20	15° 1	770	0	18.9	20	7.5	14° 4	767	43	58	6.6	65.1	Sunshine, a little fog and cloudy.
III.	62½	12.8	15° 8	765	45	11.9	12.8	5.2	15° 5	765	34	85	4.6	61.4	Sunshine general, mild and cloudy sometimes.
IV.	62½	17.5	15° 7	765	18	16.3	17.5	7.8	15° 7	765	55	40	6.7	58.9	Sunshine general, mild and cloudy sometimes.
V.	63	15	16° 1	765	2.1	13.9	15	6.6	16° 6	764	45	4.7	5.7	59	Nimbus cloud, no wind, sunshine.
VI.	63	16.3	16° 6	764	1.4	15.1	16.3	7.3	16° 7	764	52	3.9	6.2	58.9	Nimbus cloud, no wind, sunshine.
VII.	52	18.4	15° 5	756	0.7	17	18.4	8	14° 7	756	39	4.2	6.9	59.4	Intermittent sunshine, mild, gentle breeze.
VIII.	48	15.8	15° 4	756	2.4	14.5	15.8	7.1	15° 8	756	40	4.1	6.3	56.9	Intermittent sunshine, mild, gentle breeze.
IX.	48	9.4	15° 5	756	7.1	8.6	9.4	4.5	15° 8	756	10	9	4.0	53.5	Nimbus cloud at times, otherwise fine, sun- shine general.
X.	24	14.4	14°	765	3.2	13.5	14.4	6.4	14° 1	765	37	5.2	5.6	58.6	Slight showers, generally mild and fine.
XI.	14	14.5	13° 5	760	2.5	13.5	14.5	6.8	13° 6	760	45	4.7	5.9	56.3	Moderate wind, sunshine and cloud alter- nating.

Average percentage of oxygen = 59.3.

D. CONFERYA TORTUOSA, J. Ag. CHAETOMORPHA TORTUOSA, Kütz.

Excellent specimens of this were procured from Inchkeith, where it occurred in large masses in some of the tidal pools.

No. of Expt.	Time of Expt. sure.	Vol. of Gas expt. col. lected.		Temp. of Room. Barom.	Height of Water in Eudio.	Vol. of Gas collected after correction.		Vol. of Gas after Pyro. Foulsh.		Temp. of Room. Barom.	Height of Hg in Eudio.	Height of Watery Substances in Eudio.	Vol. of Gas after correc- tion.	Per cent. of Oxygen col- lected.	Remarks.
		Hrs.	c.c.	Cent.	mm.	c.c.	c.c.	c.c.	c.c.	Cent.	mm.	mm.	c.c.		
I.	144	10	73	17°-3	783	9.4	68.6	10	31.4	17°-1	783	20	3.9	58.5	Wind moderate, a little rain, sunshine general, sky sometimes overcast.
II.	144	83	12.6	16°-4	783	78	23.9	12.6	35.7	16°-3	783	32	32.4	57.8	Intermittent sunshine, fine to cloudy, gentle breeze.
III.	144	37.8	16.4	16°-6	783	35.8	62.0	16.4	15.9	15°-8	783	59	14.4	65.5	Calm, sunshine general, sometimes a little cloud.
IV.	163	81.6	16.2	10°-3	767	77.6	70.1	16.2	6.4	14°-9	768	72	26.8	65.2	Mild, cloudy, but generally clear and sunny.
V.	266	89.5	14.4	15°-1	768	85.6	76.9	14.5	6.6	15°-5	768	38	29.8	57.4	Slight wind, hazy and overcast, sunshine and clear.
VI.	64	95.9	19.4	11°-7	770	90.5	18.5	19.4	9.1	12°-2	770	60	28.6	57.3	Intermittent, but general sunshine or cloud, calm.
VII.	64	13.3	13.3	12°-3	770	12.6	12.6	13.3	8.9	12°-5	770	38	7.9	58	Intermittent, but general sunshine or cloud, calm.

Average percentage of oxygen = 59.9.

in a highly vigorous condition of vitality. It does not seem easy to account adequately for the somewhat low percentage shown in Experiments II. and VIII., but under ordinary normal circumstances probably the general average stated, viz., 50·8 per cent., may not be far from the truth.

The high percentages of oxygen obtained in the above experiments is very noteworthy, and demonstrate clearly that the presence of the pinkish red colouring matter present in the cells, and masking the green colour of the chlorophyll, does not diminish their physiological activity in this respect. As in the previous cases, all the specimens experimented with were subsequently examined microscopically, some being kept alive in vessels of water for several days. Spores were observed to be emitted only in three instances, viz., in the first, second, and sixth; the others did not show this even after being kept alive for upwards of two weeks. The general inference already stated is accordingly substantiated in this case also, the occurrence of a maximum period of vitality contemporaneous with a maximum of physiological function being recognisable. That this has a greater influence than the amount of sunshine occurring during the period of exposure is also indicated by comparing the percentages in Experiments I. and IX., since, on the whole, more favourable conditions in this respect existed in the latter case than in the former, yet the percentage of oxygen in the one is much greater than in the other.

Two points deserve notice in connection with this table—(1) in nine of the specimens examined were spores observed, notwithstanding the high percentage shown in the third and fourth experiments; and (2) the calculation of the percentage has been divided into parts on account of the large amount of gas collected. Thus in (Exp. I.) 83 c.c. in all were obtained, of which 10 c.c. were taken for determining the oxygen, its amount in the remaining 73 c.c. being calculated by proportion. Thus, by considering that 10 c.c. became 9·4 c.c. after correction, 73 c.c. under similar conditions would become 68·6 c.c.; and again, by observing that 9·4 c.c. was reduced to 4·3 c.c., after pyrogalllic acid was introduced, it follows that 68·6 c.c. would be reduced to 31·4 c.c. Thus, in the whole 83 c.c. (the original volume), is represented by 35·7 c.c. after the pyrogalllic test. Hence it

E. FUCUS CANALICULATUS, Linn.

Specimens of good growth to attached chips of Sandstone, and obtained in the estuarine face of the neck of land separating the old Granton Quarry from the Forth.

No. of Expt.	Time of Exposure.	Vol. of Gas collected.	Temp. of Room.	Height of Water in Eudio.	Vol. of Gas collected after correction.	Vol. of Gas after Pyro. Acid.	Temp. of Room.	Height of Barom.	Height of Hg in Eudio.	Height of Watery Substances in Eudio.	Vol. of Gas after correction.	Per cent. of Oxygen collected.	Remarks.	
	Hrs.	c.c.	Cent.	mm.	c.c.	c.c.	Cent.	mm.	mm.	mm.	c.c.			
I.	124	2.2	9°7	756	11.2	2.0	2.2	9°4	756	0	14.1	1.1	45	Sky overcast, sunshine moderate, settled, a little frost at night.
II.	124	1.9	9°4	756	11.6	1.7	1.9	9°8	756	0	14.7	1.0	41.2	Sky overcast, sunshine moderate, settled, a little frost at night.
III.	124	1.4	10°3	756	11.9	1.3	1.4	10°7	756	0	15.1	0.7	46.2	Sky overcast, sunshine moderate, settled, a little frost at night.
IV.	124	2.3	5°	756	11.3	2.2	2.3	5°1	756	0	14.1	1.3	40.9	Sky overcast, sunshine moderate, settled, a little frost at night.
V.	124	1.2	5°2	756	12.1	1.1	1.2	5°5	756	0	14.6	0.7	38.4	Sky overcast, sunshine moderate, settled, a little frost at night.

Average percentage of oxygen = 41.9.

F. CHONDROS CRISPUS (L.), Stackh.

Specimens from tidal pools opposite Royston House, near Granton.

I.	336	1.4	2°1	773	11.7	1.3	1.4	1	7°	731	0	14.7	0.9	30.8	Cold, showery and sunny, a little frost at night.
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is clear that 58.5 per cent. of oxygen was originally present.

A similar method has been adopted in the case of the first five experiments on this table, the last two being calculated in the ordinary manner already described.

Seeing that no spores were observed in connection with the plants employed, the high percentages of oxygen are somewhat striking.

Good tufts of the closely allied *Chaetomorpa melagonium* were also procured from the same locality, but the difficulties connected with their manipulation precluded an extensive series of experiments from being made. So far as my observations went, an average percentage of about 54 was obtained.

The experiments made on *Fucus canaliculatus*, Linn., had unfortunately to be conducted somewhat late in the season, during the earlier part of November. They cannot accordingly be taken as indicative of the average summer or early autumn conditions of the plant, yet they demonstrate that the oxygen-emitting power is not eclipsed by the advent of a little frost during night, or by the presence of conditions which cannot be looked upon as so favourable as in the earlier parts of the year. That the part played by the various perennial algæ in the oxygenation of ocean water, even during winter, is a very important one, cannot longer be doubted, nor is it unlikely that it may yet be shown that in the cases of those which emit their spores in the cold season their maximum power as oxygenators may be attained at the same time.

The single experiment recorded in the case of *Chondrus crispus* (L.), Stackh., was also made in the early part of November, but a little later than those recorded for *Fucus canaliculatus*. That this is sufficient to account for the low percentage, as in the former cases, can hardly be doubted; but unfortunately I have as yet been unable to collect data bearing on the summer evolution of oxygen in this common but interesting species.

In conclusion, it must be pointed out that the figures given in the preceding lists cannot be regarded as of *absolute* but only of *relative* importance. That more exact methods of analysis would probably give results varying

from the above, is not unlikely; but since all the experiments have, so far as practicable, been carried out in the same manner, a comparison of the figures may prove of some interest. Thus by combining the averages in the case of *Enteromorpha*, *Ulva*, *Porphyra*, and *Conferva*, obtained above, a general average of 56.5 per cent. of oxygen is found—a figure which may accordingly be taken as fairly representing the summer and early autumn evolutions of these plants. By similarly combining the averages got for the second series of experiments with *Ulva*, and those with *Fucus* and *Chondrus*, a general average of 37.3 per cent. is obtained, which, as in the previous cases, may be taken as representative of the evolutions at the more inert stages of growth during the colder seasons of the year. A much more extensive series of observations must be made before an adequate conception of the oxygenating power of these comparatively lowly organised forms of life can be obtained, but that their capacities in this respect merit careful study is at once apparent from the foregoing tables. In the calculations no account has been taken of the volume of the seaweeds experimented with, the only problem being the determination of the amount of oxygen present in the entire volume of gases collected, it being clear that that this proportion will remain the same for the same species under the same circumstances, whether the volume of the algæ be large or small.

On the Development of Bifoliar Spurs into ordinary Buds in Pinus sylvestris. By Professor ALEXANDER DICKSON, M.D., LL.D.

(Read February 12, 1885.)

Many Coniferæ exhibit remarkable specialisation as regards branch development. In some, such as *Larix* and *Cedrus*, there is a marked tendency to a contracted development, or shortening of many of the shoots which appear as "spurs," with numerous leaves crowded together to form a fascicle. Here it is only certain of the shoots which are developed in this way, and of these it may happen that a spur of one season may next season become produced at its extremity in the ordinary elongated form with scattered