December 5, 1867.

Dr. WILLIAM ALLEN MILLER, Treasurer and Vice-President, in the Chair.

It was announced from the Chair that the President had appointed the following Members of Council to be Vice-Presidents:—

The Treasurer,
Dr. Carpenter,
Mr. Gassiot.

In accordance with the notice given at the last Meeting, the question of Col. Le Couteur's readmission into the Society was put to the ballot, and, the ballot having been taken, Col. Le Couteur was declared to be re-admitted.

The following communications were read:—

I. "On some Alterations in the Composition of Carbonate-of-Lime Waters, depending on the influence of Vegetation, Animal Life, and Season." By ROBERT WARINGTON, F.R.S., F.C.S. Received October 19, 1867.

In carrying out through a series of years the principles of the aquarium for sustaining animal life in a confined and limited portion of water through the medium of growing vegetation *, I had observed that, during the summer months of the year, a considerable deposit made its appearance on the leaves of the plants and the glass front of the containing vessel, which was found to consist of carbonate of lime in a crystalline condition. This deposit formed a nidus for the growth of confervoid vegetation, which, at certain seasons of the year, increased very rapidly. These observations were alluded to at one of the Friday-evening meetings of the Royal Institution, March 27, 1857, when portions of the deposit were exhibited, and its composition demonstrated by experiment.

The formation of this deposit was then explained as arising from the fact that, as the summer season advances, and we have a longer continuance and also a greater intensity of the light of the sun, the absorption and consequent decomposition of carbonic acid by the plants is carried to a much greater extent, while the quantity of carbonic acid produced by the fish remains unchanged. The solvent of the carbonate of lime contained in the water being thus withdrawn, a deposit slowly takes place, incrusting the sides of the tank, particularly towards the light, where the confervoid growth, consequent upon it, accumulates in large quantities.

In continuing these observations, my attention was particularly arrested by the steady increase of deposition, attendant upon the renewed activity of the leaves, during the spring; and this determined me to ascertain by experiment the quantity of carbonate of lime existent in the water at fixed

* Quarterly Journal of the Chemical Society, vol. iii. p. 52.

intervals during a long period of time. And inasmuch as the degrees of hardness, indicated by the measures of Clark's soap-test, presented a very ready, accurate, and simple means of arriving at this result, that mode of estimation was adopted, care being taken to displace any uncombined carbonic acid by agitating the sample with atmospheric air prior to the addition of the test, as directed by Dr. Clark, the indications or degrees thus obtained representing the quantity of lime-salts contained in an imperial gallon of the sample (70·000 grains of distilled water) in terms of carbonate of lime.

In order that the nature of the experiment may be more clearly understood, it will perhaps be better for me, before stating the results thus obtained, to describe briefly the construction and arrangement of the aquarium, its position, and its contents. The tank consisted of a rectangular zinc framing, twenty inches long by thirteen broad, and twenty-one in depth, having slate cemented into it at the bottom and sides, and being glazed at the back and front. It was filled with water to the height of twelve inches, or a volume equal to ten gallons, and on the slate sides were cemented, at the water-line, ledges of rockwork composed of sandstone and tufaceous limestone from Matlock, on which were planted a few ferns, chiefly Trichomanes, for ornament. The bottom of the tank was covered, for about two inches, with a mixture of sandy loam and gravel, into which several plants of the *Vallisneria spiralis*, the vegetable member of the arrangement, were inserted. Some large fragments of rough rockwork, principally limestone, were also placed upright on the bottom to break up the stiff outline of the square framing, and give a pleasing effect to the eye. The animal branch of the circle consisted of four small crucian carp with a gold carp. Several freshwater mollusks, principally *Planorbis corneus* and *Limneus palustris*, were also introduced to act as scavengers and consume the decaying vegetation. The tank was loosely covered with a plate of glass, so as to allow of a free admission of the external air, and at the same time keep out a great deal of the soot and dust of the London atmosphere and impede the too rapid evaporation of the water. As the Trichomanes were stated to delight in shade, a thin muslin blind was placed over the covering glass.

The aquarium was located in a window-way having an eastern aspect, but, being surrounded within a few yards by the high walls of adjoining houses, the direct rays of the sun only reached it for about three hours in the morning during the months of June and July. It was established in January 1851, and has not since been disturbed, except by occasional supplies of distilled or rain-water, to replace the loss in volume arising from evaporation. It had been my custom to weed out the excessive growth of the Vallisneria during the summer, and also to remove some of the flaky deposit of calcareous matter from the surface of the glass nearest the light; but as I considered that such disturbances might interfere with the course of the investigation, these operations were discontinued.

The results that have been obtained from this investigation during the years 1861 and 1862 are as follows :—

1861.	March 13	26°·2	degrees of hardness, or grains of lime-salts, per imperial gallon, in terms of carbonate of lime.
	May 1	19·5	,, ,,
	July 3	12·5	,, ,,
	August 1	13·6	,, ,,
	Sept. 17	15·0	,, ,,
	Oct. 8	15·5	,, ,,
	Nov. 12	18·0	,, ,,
	Dec. 9	20·5	,, ,,
1862.	Jan. 8	23·5	,, ,,
	Feb. 8	25·0	,, ,,
	March 3	23·0	,, ,,
	April 3	21·0	,, ,,
	May 2	19·0	,, ,,
	June 4	16·5	,, ,,
	July 4	14·0	,, ,,
	August 5	12·0	,, ,,
	Sept. 2	12·5	,, ,,

The amount of calcareous matter dissolved will be seen to have steadily decreased during the spring and summer months, from its maximum in March 1861 and February 1862 to its minimum in July 1861 and August 1862, and then to have increased as steadily during the autumn and winter months.

Part of this hardness, however, unquestionably arose from the presence in the water of other salts of lime besides the carbonate. To determine how much was the next point for investigation. Portions of the water were taken on several occasions and boiled for a considerable time, filtered, and the volume restored to its original bulk with distilled water. On examining these portions with the soap-test, it was found that the hardness was lowered to 5·6 degrees, equivalent to 5·6 grains of carbonate of lime. But inasmuch as carbonate of lime is soluble in water to the extent of 2·4 grains in the imperial gallon*, this will be reduced to 3·2 grains, which amount will therefore have to be deducted from each of the above results, in order to arrive at the true quantity of carbonate present in solution.

The maximum and minimum results will then stand thus :—

		CaO, CO_2 in the imperial gallon.			CaO, CO_2 in the imperial gallon.
1861.	Maximum	23·0	1862.	Maximum	21·8
	Minimum	9·3		Minimum	8·8

* Chemical Report on the Supply of Water to the Metropolis, June 17, 1851, by Messrs. Graham, Miller, and Hofmann; and Quarterly Journal of the Chemical Society, vol. iv. p. 381.

The data thus obtained will help to elucidate several very important and interesting phenomena in respect to all the three elements of the arrangement—the water, the fish, and the vegetation.

1. *The Water.*

The importance of growing submerged vegetation in maintaining waters, rich in carbonate of lime, in a meliorated state by diminishing their hardness has been clearly demonstrated by the foregoing data; and how necessary, therefore, it is that this association should be kept in view whenever a soft and healthful water is required for domestic purposes. Unfortunately this appears hitherto not to have been well understood, or at all events has been little attended to, since the very agent which has been provided naturally for effecting these beneficial results has been most commonly regarded as an evil, and studiously eradicated in all directions. These data will also explain the cause of the rapid growth of vegetation in well-waters rich in carbonic acid, when pumped into tanks or reservoirs and exposed to the full light of day. The plant-germs, naturally contained in the water or absorbed from the atmosphere, being supplied with an abundance of appropriate nourishment, rapidly vegetate, and the containing vessels, particularly during the summer months, soon become thickly coated with a dense confervoid growth.

It will also follow that all fish, as generators of carbonic acid, should be excluded from waters flowing over carbonate-of-lime strata, and intended for the supply of towns &c., as tending to increase their hardness. Of course the absence of calcareous matter would prevent such an effect taking place—a fact borne out by the well-known softness of springs and rivers flowing out of or over granite or sandstone rocks, even when thickly inhabited by the scaly tribe.

2. *The Fish.*

It is well known that water has the property of absorbing air from the surrounding atmosphere, and holding it in solution to the extent of from one-fortieth to one-thirtieth of its volume, not, however, without somewhat changing the proportion of its constituents; for when the absorbed air is abstracted from water it usually contains about thirty-two per cent. of oxygen gas, instead of twenty-one. This oxygen is converted by the respiration of the fish into carbonic acid, which is held dissolved by a still stronger affinity, the water being capable of retaining as much as its own volume of this gas in solution at the ordinary temperature and pressure of the atmosphere.

In the above-described arrangement the carbonic acid thus produced is absorbed by the submerged vegetation under the influence of the sun's light; the carbon is appropriated for its growth, while the oxygen is again liberated and held in solution by the water, provided the evolution is not too rapid, an effect produced by too great an exposure to the sun's light. When this is the case, much of the oxygen necessarily escapes into the air

in a gaseous state and is lost. During the winter season, however, when the active functions of vegetation are to a great extent dormant, from the diminished quantity and intensity of the sun's light, the amount of carbonic acid produced by the respiration of the fish is greater than the plants are capable of consuming, and the excess must necessarily accumulate in the water. Were the production of carbonic acid confined to a short period, the water would doubtless right itself after a time, the poisonous gas passing away and fresh atmospheric air being absorbed. As, however, the production of carbonic acid is constant, this ameliorating action can have little effect; the water must remain always highly charged with carbonic acid. Here, then, its solvent action on the carbonate of lime, present in the rockwork and gravel, comes into play, and the hardness of the water is gradually increased in proportion as the light diminishes. Now, supposing for an instant that no carbonate of lime had been present in the arrangement, the question arises, what must then have ensued? The fish would have continued to respire, and would produce carbonic acid as before, which, remaining in a free state dissolved in the water, would unquestionably have had a most detrimental effect upon their health. Every one must have noticed the manner in which the golden carp confined in a globe of water, in which there is no growing vegetation to decompose the carbonic acid generated, or no limestone to combine with it, rise to the surface and continually gulp in the air required for their vital functions. Nothing whatever of this kind has ever been noticed in the aquarium under consideration, although the quantity of carbonic acid dissolved in the water has been at times very large.

From the experiments of Bischof*, we glean that the carbonic acid contained in a saturated aqueous solution is entirely displaced by a current of atmospheric air passed through it for five minutes; and also † that, by the same means, a solution of carbonate of lime, in water previously saturated with carbonic acid, will have all the excess of gas displaced in fifteen minutes, leaving the water with *bicarbonate of lime* in solution. It is in this form of combination that MM. Peligot ‡ and Poggiale § consider the carbonate of lime to exist in the water of the Seine, and M. Bineau ‖ in that of the Rhone, in which rivers they state there is no free carbonic acid. In the present investigation we shall therefore assume it to be in the same state of combination. We have, in the series of experiments detailed above, an increase in the quantity of carbonate of lime held in solution, amounting to 14·2 grains in the imperial gallon, which would require nearly $6\frac{1}{4}$ grains of carbonic acid gas to dissolve it. Besides this there is also the quantity already present in the water at its minimum, which amounts to nearly four grains more, or in all to about ten grains, equal to nearly

* Bischof's 'Elements of Chemical Geology,' Cavendish Society's edition, vol. iii. p. 5.

† *Op. cit.* vol. iii. p. 7.

‡ Comptes Rendus, vol. xl. p. 1121, and Bischof's 'Elements,' vol. iii. p. 117.

§ Journal de Pharmacie, vol. xxviii. p. 321, and *op. cit.* vol. iii. p. 118.

‖ Comptes Rendus, vol. xli. p. 511, and *op. cit.* vol. iii. p. 118.

215 cubic inches of that gas in the ten gallons of water, or more than $\frac{1}{13}$th its volume. The exact numbers will be seen in the following Table:—

		CaO, CO_2 in the gallon.		CO_2.	
1861	Maximum	23·0 grains,	requiring	10·120	grains to form CaO,$2CO_2$.
	Minimum	9·3 ,,	,,	4·092	,, ,, ,,
1862	Maximum	21·8 ,,	,,	9·592	,, ,, ,,
	Minimum	8·8 ,,	,,	3·872	,, ,, ,,

Carbonic acid required to dissolve the increase	6·248 grains	=	13·269 cub. in.
,, ,, minimum	3·872 ,,		8·228 ,,
	10·120 ,,		21·497 ,,

Yet, although the quantity of poisonous gas had been thus increased, we find no deleterious action on the health of the fish, no disturbance in the ordinary respiration, no gulping at the surface of the water for fresh air. It is quite evident, therefore, that the carbonic acid, by entering into combination with carbonate of lime, however weak that combination may be, is thereby rendered perfectly innocuous, and a wonderful provision is thus afforded for preventing this poisonous agent from becoming fatal to animal life.

We turn now to the next member of our arrangement.

3. *The Vegetation.*

It will be seen from the foregoing numerical results that the maximum quantity of dissolved carbonate of lime, and consequently of carbonic acid, is found just before the period of the reviving energies of the plant's growth, namely, the spring time of the year, when the days are lengthening and the sun's light is continually increasing in strength; the minimum quantity when this growth has attained its greatest exuberance, namely, when the summer months are past and the light is beginning to decrease in its intensity and the days to shorten. So exactly, indeed, are the energies of the plants regulated by the amount of light to which they are exposed, that a constant arrangement, such as that here described, affords an excellent indication of the variation of the seasons in different years, or might even be made a rough measure of the total amount of light from month to month.

But while the demand for carbonic acid on the part of the plant varies in this manner with the seasons, the amount of that gas produced by the respiration of the fish is very nearly the same all through the year. Whence, then, does the plant obtain that additional quantity of food which its stimulated energies require during the spring and early summer months, and which its rapid and luxurious growth show to be readily supplied? After what has been stated, I think the source must be apparent to every one—it is from the carbonic acid which has been gradually accumulated, and rendered innocuous to animal life from its being held in combination with carbonate of lime, in so marvellous a manner during the winter

months. Stored up, yet held in feeble combination, a combination so weak that the vital forces of the fresh-growing vegetation can easily overcome it, and resolve once more into carbonate of lime, carbon, and oxygen the bicarbonate of lime contained in the water *.

Thus beautifully are the necessary irregularities in the purifying action of the plant compensated and provided for, that the balance of existence between the animal and vegetable organisms be not disturbed or overthrown, and thus additional proof is furnished, if such were needed, of the wisdom of that creative power that has ordered all things to work together for good, and by endowing certain bodies with such seemingly minute and insignificant affinities, maintains the glorious harmony of the whole.

II. "Results of Observations of Atmospheric Electricity at Kew Observatory, and at Windsor, Nova Scotia." By Joseph D. Everett, D.C.L., F.R.S.E., Assistant to the Professor of Mathematics in the University of Glasgow. Communicated by Sir William Thomson. Received October 14, 1867.

(Abstract.)

The paper commences with an account of the concluding observations taken by the author at Windsor, N.S., of which the previous portion has already been published in the 'Proceedings,' vols. xii. & xiv.

It then goes on to describe the self-recording apparatus employed at Kew Observatory for the observation of atmospheric electricity, and the method of procedure employed in measuring and reducing the curves thus obtained, this portion of the work having been performed in the Physical Laboratory of the University of Glasgow.

Tables are given showing the mean hourly values of the electrical potential for each month, and the mean monthly values are hence derived. These values for Kew are compared with the corresponding values for Windsor, N.S., and remarkable differences are shown to exist between the curves, both diurnal and annual, for the two places.

The hourly means at Kew for the mean of the year are represented by the following numbers :—

23^h	0^h	1^h	2^h	3^h	4^h	5^h	6^h	7^h
1·91	1·96	1·92	1·93	1·95	2·08	2·29	2·58	2·86
8^h	9^h	10^h	11^h	12^h	13^h	14^h	15^h	16^h
2·96	2·93	2·74	2·42	2·12	1·86	1·68	1·58	1·54
17^h	18^h	19^h	20^h	21^h	22^h			
1·52	1·64	1·96	2·26	2·28	2·13.			

These numbers indicate a principal maximum between 8^h and 9^h, and a

* The rapid growth of submerged vegetation in rivers and waters containing a considerable amount of carbonate of lime must have been observed by all interested in the subject, in some cases obliging the cleansing of such streams three or four times during the year.