NOTES.

RESPIRATION AND ASSIMILATION IN CELLS CONTAINING CHLOROPHYLL.—It is a matter of common knowledge that free oxygen is essential to the continuance of active movement on the part of the protoplasm of the higher plants. An apparent—but only apparent—contradiction to this generalization is, however, furnished by the behaviour of the rotating protoplasm of an *Elodea* leaf when surrounded by an atmosphere of hydrogen gas. The experiment about to be described is a well-known one, but the conclusions which can be drawn from it would appear not to be so generally appreciated as they seem to deserve.

If a healthy leaf of *Elodea* be placed in one of those extremely convenient tubes designed by Professor Marshall Ward¹, the movement of the protoplasm can be studied under favourable circumstances. Indeed it is possible to keep the same leaf, with its moving protoplasm, under observation for several days. If a current of hydrogen be passed through such an apparatus containing a vigorous *Elodea* leaf, and the precaution be taken to dip the end of the tube through which the gas is escaping under mercury or water (to prevent the possibility of diffusion of air), it is clear that in a short time the pressure of oxygen within the chamber must speedily be reduced to what is practically zero. But if the experiment be conducted in the day-time, it is found that no arrest of the protoplasmic movement takes place. Indeed, in an experiment (which has been several times repeated in my laboratory), exposure to hydrogen from 10 a.m. to 5 p.m. produced no effect whatever on the rapidity of the rotation within the plant-cells.

¹ See Phil. Trans. Vol. clxxxiii (1892), B, pp. 131, 132, where a description and figures of the apparatus here referred to are given.

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But it is obvious that since the protoplasm was thus manifesting active vitality, respiration must have been also going on, and the only possible explanation of the process seemed to be that as fast as the carbon dioxide was produced, as the result of respiration, it was split up and the oxygen liberated by the chlorophyll-granules under the influence of the daylight. The oxygen thus would be again rendered available for purposes of continued respiration. Blackman's¹ researches have shown that it is highly probable that during active assimilation, no carbon dioxide passes out from the leaves, but that it is decomposed and utilized as fast as it is produced. The observation just recorded seems to confirm his conclusions on this point in a striking manner. Of course it is quite possible that a certain small amount of the gases may pass out along with the hydrogen-stream, but enough oxygen remains to allow of respiration being maintained. Clark's investigations² have, moreover, shown that a very low pressure of oxygen (about 1.3 mm. of mercury) is sufficient to enable protoplasmic movement to go on.

If the apparatus be covered over by a dark box, so as to exclude the light whilst the experiment is still proceeding, the movement of the protoplasm entirely ceases in a time varying in different experiments from two to five minutes, but it recommences on the light being once more admitted. This interference—the result of withdrawal of light—can be repeated many times, and recovery takes place as often afterwards. This seems to furnish a strong argument in support of the explanation of the phenomena here put forward, for it can be easily proved (in a control-experiment) that the mere exclusion of light from the leaf, the protoplasm of which is in a state of movement, produces no obvious effect so long as ordinary air is circulating through the apparatus.

Again, in the case of hairs which do not contain chlorophyll, the presence or absence of light makes no difference as regards their behaviour when exposed to an atmosphere of hydrogen. All movement is arrested, usually in a period varying from two to five minutes. I may add that the hairs present in the throat of the corolla of the White Dead-Nettle (*Lamium album*) are very suitable objects on which

¹ Experimental Researches on Vegetable Assimilation and Respiration, Phil. Trans. Vol. clxxxvi (1895), B.

² James Clark, Ueb. d. Einfluss niederer Sauerstoffpressungen auf d. Bewegung d. Protoplasmas. Ber. d. deutschen bot. Gesellsch., vi (1888).

to experiment on protoplasmic movement. They are easily prepared by cutting rather thick transverse sections of the corolla, and mounting in water. They react quickly to various stimuli, and they possess the additional advantage of being readily accessible during the greater part of the year.

I also tried the effect of exposure to an atmosphere of hydrogen on *Ophrydium versatile*, a colonial protozoan consisting of a large number of green Vorticella-like animals imbedded in a common gelatinous matrix. An exposure to hydrogen for half an hour in bright daylight produced no apparent effect, but after continuing the treatment for a further quarter of an hour, the large cilia had become sluggish in their movement. The experiment was then discontinued. In another series, a group of *Ophrydia* which had been for twenty minutes in an atmosphere of hydrogen, but seemed to be still perfectly healthy, were covered over with a dark box. After the light had been excluded for three minutes, a number of the organisms were found to have been killed, and a further exposure to the gas in the dark for three minutes resulted in the death of them all. They contracted, and quite suddenly burst, the green matter streaming out as globules into the water from the glairy mass of the disintegrating body of the animal.

This experiment shows that the utilization of some oxygen-containing substance (probably the carbon dioxide evolved during respiration) takes place under suitable conditions of illumination, and it may probably be concluded that the evolution of oxygen available for the continuance of the respiratory process is connected with the presence of the green colouring-matter already referred to. But it would seem that the balance between the two processes of assimilation and respiration, between the evolution and utilization of oxygen, is not so accurately maintained in this instance as in that of *Elodea*; since after three quarters of an hour's exposure to the atmosphere of hydrogen, the activity of the animal was clearly waning, although the conditions of illumination appeared to be in all respects favourable.

In 1887 Pringsheim published a series of researches on the behaviour of *Chara* in an atmosphere of hydrogen to which a small amount of carbon dioxide had been added¹. He states that the

¹ Pringsheim, Ueb. d. Abhängigkeit der Assimilation grüner Zellen von ihrer Sauerstoffathmung, &c. Sitzungsber. d. k. Preuss. Akad. d. Wiss. z. Berlin,

moving protoplasm is brought to rest in a period varying from two to twelve hours, and that it seemed to make no difference whether light were excluded or not. I repeated the experiment on *Nitella*, but used pure hydrogen instead of the mixture of gases employed by Professor Pringsheim. Possibly the discrepancies existing between our observations may be partly due to this fact. *Nitella* and also *Chara* are somewhat difficult plants to work with; and often, for no apparent reason, fail to give conclusive results unless one is very careful to select thoroughly healthy cells in which the rotation is very active. I find that under these circumstances one can keep the cell in an active condition, in an atmosphere of hydrogen, for a whole day when exposed to light. If light be at any time excluded, by means of the darkened box already mentioned, the movement becomes slow in about twenty minutes, and in half an hour usually, though not always, ceases. On re-exposure to light, rotation rapidly begins again, and in most cases completely recovers its old rate in about one or two minutes. If the cell be now darkened once more, a slowing down, or even complete arrest, of the protoplasmic rotation is effected in *five to seven minutes*. This experiment I have repeated a large number of times, and it may be safely shown as a class-demonstration. A longer re-exposure to light necessitates a more prolonged continuance of darkness in order to reproduce the quiescent condition.

The experiments with *Nitella* were further checked by similar ones, carried on simultaneously with *Elodea*, as detailed above, and the differences are, I think, susceptible of an easy explanation.

The cell of *Nitella* is a very large one, and consequently the volume of its cell-sap is *relatively* (as well as absolutely) greater than that in *Elodea* as compared with the amount of protoplasmic substance. Hence, supposing the cell-contents to be saturated to an equal extent with oxygen, it is clear that *Nitella* would be in a more favourable position when the further supply of oxygen was cut off than is *Elodea*. We might expect then, assuming the cells to be similar in other respects, that the movement of the protoplasm in *Nitella* would continue after that in the other plant had come to rest, and this is found to be the case. But, on the whole, the experiments seem also to show that *Nitella* can do with *less* oxygen than *Elodea*, for the difference in relative bulk in the two cases is hardly sufficient to

xxxviii. 1887. A critical abstract of this paper is given by Professor Vines in *Annals of Botany*, Vol. i, p. 371 et seq.

account for all the diversity in their respective reactions. These results and considerations support Professor Vines' criticisms passed on Pringsheim's conclusions as to the seat of origin of the oxygen evolved during assimilation. Further discussion of the many points here raised would, however, be out of place within the limits of a note, but I hope to return to the subject at length on a future occasion.

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A NEW CASE OF POLYSTELY IN DICOTYLEDONS.—The stems of Angiosperms and the roots of vascular plants in general may be considered as exhibiting almost universally a monostelic structure. As regards the former, the only exceptions hitherto described are the Gunneras, and the Primulas of the section *Auricula*, which are polystelic, and the Nymphaeaceae with a few others, chiefly water-plants, which are astelic. In the case of roots, no exception was known until polystely was recently discovered in the adventitious roots of certain Palms, *Areca*, *Verschaffeltia*, &c., by Cormack¹.

While making a comparative examination of certain Nymphaeaceae, the results of which I hope to publish fully at a later time, I have found that in addition to astely, this remarkable order also presents cases of polystely.

In certain tropical and sub-tropical species of *Nymphaea*, the plants, at the end of each vegetative period, form numerous tubers as a means of surviving through the approaching dry season. Some, as *Nymphaea rubra*, *N. stellata*, &c., according to Raciborski², convert the whole of the lower part of the rhizome into a tuberous starch-laden structure coated with periderm. Others, as *N. flava* and *N. tuberosa*, examined by me, bear their tubers on lateral stalks of greater or less length. In *N. flava* they form very long stolons or runners (30–40 c. m. long), which are but slightly thickened at their terminations, where they bear below a large number of swollen starch-laden sausage-shaped roots, and above a number of buds protected by scale-leaves. These runners exhibit a truly polystelic arrangement of their vascular tissues, four to five groups of which are found running in the lacunar ground-tissue, each consisting of three to four vascular bundles grouped around a common centre where their xylems are confluent.

¹ In a paper read before the Linnean Society early this year.

² Raciborski, *Flora*, Band lxxviii, p. 262, 1894.

Farmer, J. B. 1896. "Respiration and assimilation in cells containing chlorophyll." *Annals of botany* 10, 285–289.

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