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[1] Alfvén, H., "Cosmical Electrodynamics", chapter 4 (Oxford University Press, 1950).
[2] Bailey, V. A., *Aust. J. Sci. Res.*, A, **1**, 351 (1948).
[3] Åström, E., *Nature*, **165**, 1019 (1950).
[4] Herlofson, N., *Nature*, **165**, 1020 (1950).

Photoreduction in Algæ

FOR several years it has been known that a number of green algæ are able to carry out reduction of carbon dioxide by molecular hydrogen at low light intensities[1]:

$$CO_2 + 2H_2 \xrightarrow{\text{light}} \text{product.}$$

We have attempted to find out if this process can be observed among other algæ besides the green algæ. Gaffron[2] had tested several algæ for their capacity to carry out photoreduction and found that several green algæ were active; however, *Chlorella pyrenoidosa*, one species of the blue-green alga *Oscillatoria*, and two strains of the diatom *Nitzschia*, proved to be inactive. In the meantime, it had been demonstrated that two species of blue-green algæ[3] and a pure culture of the green flagellate *Chlamydomonas mœwusii*[4] can also carry out photoreduction. We also have had the opportunity of studying a pure culture of the red alga *Porphyridium cruentum* (isolated by J. Garnic[5]), and thalli of the marine red alga *Porphyra umbilicalis*, both of which could carry out this process. Two other marine algæ, the green alga *Ulva lactuca*, and the brown alga *Ascophyllum nodosum*, were likewise able to carry out photoreduction.

It thus appears that the ability to reduce carbon dioxide anaerobically with hydrogen in light is not restricted to the photosynthetic bacteria and the green algæ, but can be found among various species of at least four phyla of the algæ.

ALGÆ WHICH HAVE BEEN TESTED FOR ABILITY TO CARRY OUT PHOTOREDUCTION

Phylum	Algæ successfully adapted	Author	Algæ not showing photoreduction	Author
Cyanophyta (blue-green algæ)	*Synechococcus elongatus* Näg.	Ref. 3	*Oscillatoria* sp.	Ref. 1, 2
	Synechocystis sp.	Ref. 3	*Nostoc muscorum* Kützing	Ref. 7
			Cylindrospermum sp.	Ref. 7
Chlorophyta (green algæ)	*Scenedesmus obliquus* (Turp.) Kützing	Ref. 1, 2	*Chlorella pyrenoidosa* Chick.	Ref. 1, 2
	Ankistrodesmus sp.	Ref. 1, 2		
	Raphidium sp.	Ref. 1, 2		
	Ulva lactuca L.			
Chrysophyta (yellow-brown algæ)			*Nitzschia* sp. (2 strains)	Ref. 1, 2
Phæophyta (brown algæ)	*Ascophyllum nodosum* (L.) Le Jolis			
Rhodophyta (red algæ)	*Porphyra umbilicalis* (L.) J. Agardh			
	Porphyridium cruentum (C. Ag.) Näg.			

In studies with *Scenedesmus*[2], it was demonstrated that the ability to carry out photoreduction was not immediately apparent under anaerobic conditions, but that a dark-adaptation period was necessary. It is not known if an adaptive enzyme is formed during this period, or if an existing enzyme is activated so that it can react with molecular hydrogen. It is of interest that not all the algæ which can carry out photoreduction behave in the same manner in regard to this period of adaptation. We have observed that *Chlamydomonas mœwusii* either requires no adaptation period at all, or that this period is shorter than ten minutes. On the other hand, the marine algæ which we have tested thus far all required long periods of dark adaptation. We have evidence that at least one of the algæ, *Porphyridium cruentum*, will increase in dry weight and pigmentation under anaerobic conditions. We have been able to follow photoreduction in one culture for two weeks, although it was necessary to give this alga several hours of darkness every day to avoid reversion to normal photosynthesis with the evolution of oxygen.

Chlamydomonas mœwusii exhibits another striking effect: at very low intensities of light, photofermentation will take place; the cells actively evolve carbon dioxide and hydrogen from an unknown endogenous substrate. This process had been observed previously in *Scenedesmus*[2], but the relative activities of *Scenedesmus* and *Chlamydomonas* differ by almost a factor of 10. The rate of photoproduction of hydrogen by *Chlamydomonas* is of the same order of magnitude as that demonstrated by Gest and Kamen[6] for the purple bacterium, *Rhodospirillum rubrum*.

It remains to be seen if the ability to carry out this special type of photosynthesis by certain freshwater and marine algæ is an evolutionary remnant or is of importance in the distribution of algæ and in the fixation of carbon dioxide under special environmental conditions.

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[1] Gaffron, H., *Nature*, **143**, 204 (1939).
[2] Gaffron, H., *Biol. Rev.*, **19**, 1 (1944). Rabinowitch, E., "Photosynthesis", 129 (Interscience Pub., New York, 1945).
[3] Frenkel, A., Gaffron, H., and Battley, E. H., *Biol. Bull.*, **99**, 157 (1950).
[4] Frenkel, A., *Biol. Bull.*, **97**, 261 (1949).
[5] Garnic, J., thesis, Northwestern University (1950).
[6] Gest, H., Kamen, M. D., and Bregoff, H. M., *J. Biol. Chem.*, **182**, 153 (1950).
[7] Frenkel, A. (unpublished).

Amino-Acids of Certain Algæ

Pearsall and Fogg[1] have discussed the possibility of using algæ, especially *Chlorella*, as a source of food. Though cultures having a very high protein content have been produced under suitable conditions of growth, little information is available regarding the amino-acid composition of such algal proteins. Eny[2], using the technique of paper chromatography, reported that seven of the 'essential' amino-acids were absent from the proteins of *Chlorella*. These results are open to criticism on two grounds. The protein subjected to acid hydrolysis was apparently limited