Preliminary Notes

Periodic phenomena in photosynthesis as reflected by oxygen exchange of blue-green algae

Periodic phenomena with a more or less pronounced character of damped oscillations have been observed in the time course of CO_2 uptake and fluorescence during the transitory phases of photosynthesis[1,2]. Recently, periodic fluctuations in reservoir sizes of photosynthetic intermediates have been detected with isotope techniques; they occur as a reaction to a sudden change in CO_2 concentration[3]. Unfortunately, light-dark and dark-light transitions do not seem to induce changes of such strikingly periodic character so far as photosynthetic intermediates are concerned[4]. Nevertheless, it is tempting to speculate that any periodic phenomena in the time course of photosynthesis should be referred to, and can be best explained by, the cyclic and autocatalytic character of the CO_2 fixation-reduction cycle proposed by CALVIN *et al.*[5].

The purpose of this communication is to show that periodic phenomena are encountered also in the photosynthetic exchange of oxygen.

The records of oxygen exchange presented in Fig. 1 were obtained during an investigation

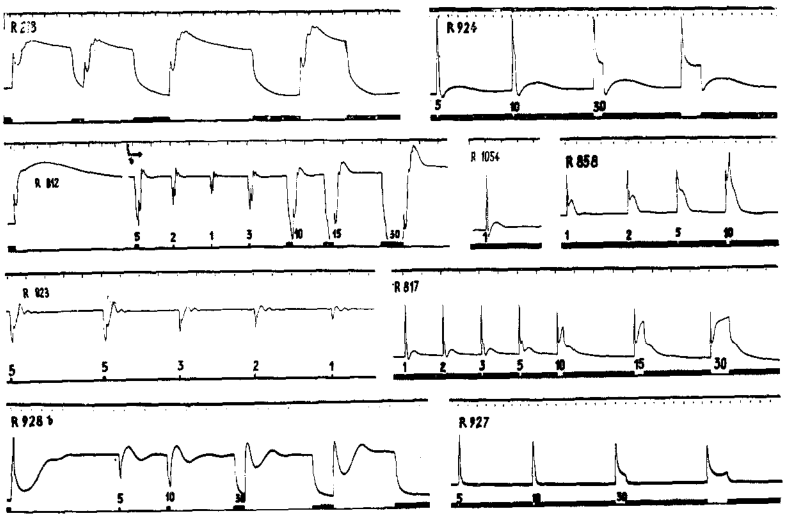

Fig. 1. Records of oxygen exchange obtained by the method of BLINKS AND SKOW. A 20 × 20 mm platinum electrode was covered by a very thin layer of the respective alga. "Sensitivity" given below for individual records means that rate of O_2 exchange in μl/min which would correspond to the full scale deflection of the galvanometer. This value was adjusted by variation of galvanometer sensitivity. On the lower margin of the records dark strips are found representing the intervals of darkness; with short light and dark intervals their length is given in seconds by the figures on the records. The time marks on the upper margin are 30 sec apart. On aerobic records, the basic line in the dark is the respiration line, *i.e.* zero of gas exchange minus respiration. The compensation point cannot be established by this method. R 218 – *Oscillatoria*, 25° C, pH 5, air + 1 % CO_2, $2 \cdot 10^4$ lux, sensitivity $9.5 \cdot 10^{-2}$; R 812 – *Oscillatoria*, 40°C, pH 7, air, $2 \cdot 10^4$ lux, sensitivity $5.4 \cdot 10^{-1}$ at point b denoted by the arrow sensitivity changed to $2.7 \cdot 10^{-1}$; R 823 – *Oscillatoria*, 30° C, pH 7, air, $2 \cdot 10^4$ lux, sensitivity $1.35 \cdot 10^{-1}$; R 928b – *Oscillatoria*, 10° C, pH 7, nitrogen + 1 % CO_2, $2 \cdot 10^3$ lux, sensitivity $4.05 \cdot 10^{-2}$; R 1054 – *Oscillatoria*, 25° C, pH 7, air + 1 % CO_2, $2 \cdot 10^3$ lux, sensitivity $1.35 \cdot 10^{-1}$; R 924 – *Oscillatoria*, 15° C, pH 7, air, $2 \cdot 10^3$ lux, sensitivity $4.05 \cdot 10^{-2}$; R 858 – *Oscillatoria*, 35° C, pH 7, air + 1 % CO_2, $2 \cdot 10^3$ lux, sensitivity $4.05 \cdot 10^{-1}$; R 817 – *Oscillatoria*, 40° C, pH 7, air, $2 \cdot 10^3$ lux, sensitivity $5.4 \cdot 10^{-1}$; R 927 – *Oscillatoria*, 10° C, pH 7, nitrogen + 1 % CO_2, sensitivity $4.5 \cdot 10^{-2}$.

of the photosynthesis time course with blue-green (thermal) algae. The method, originally proposed by BLINKS AND SKOW[6], was used with modifications described earlier[7]. Here it must suffice to state that the method works with minimum hysteresis, so that it is especially suitable for the study of rapid processes in oxygen exchange.

Periodic oscillations in oxygen production were observed both under aerobic and anaerobic conditions, provided relatively high intensities of illumination are applied. They may be found at the beginning of many dark-light transition curves (Fig. 1, record 218). Very often, however, they can be provoked only by short dark intervals and are not seen on the corresponding induction curves following longer periods of darkness (*e.g.* record 812).

The oscillations are, as a rule, superimposed on other induction phenomena (records 218, 812, 928) and it is only after very short intervals of darkness that the axis around which the oscillations occur becomes almost horizontal (R 823). Then the character of damped oscillations stands out most clearly.

The period of the oscillations is an exponential function of the temperature (Fig. 2). With constant temperature, the amplitude of the oscillations increases with light intensity.

The first peak in oxygen production, which is characteristic of induction curves under higher light intensities, bears an ambiguous relationship to the remaining oscillations on induction curves. It may be observed that after longer intervals of darkness the process reflected by the first peak is certainly not perfectly identical with the process reflected by later oscillations.

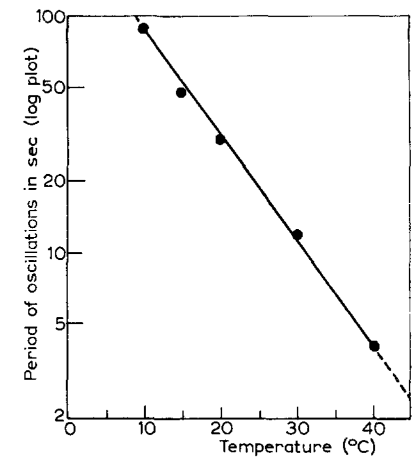

Fig. 2. The exponential temperature dependence of the oscillation period in oxygen production for one sample of *Oscillatòria*. The oscillations were provoked by short dark intervals at approximately ten times the saturating light intensity for the respective temperature.

Nevertheless, with the shortening of the dark interval a sort of fusion of the first peak with the following oscillation is observed (records 823, 928).

Phenomena which might bear some relation to those just described are also observed after very short intervals of intense illumination under aerobic conditions (records 1054, 924, 817, 858). The dark oxygen exchange following such flashes reveals a definite periodic character. Whether these are oscillations of oxygen production or uptake cannot be settled on the basis of the incomplete information available. Participation of respiratory or at least oxidative processes in these phenomena is rendered probable by the fact that no after-effects are observed under anaerobic conditions. Connection between these phenomena and some characteristic features of aerobic light-dark transition curves is clearly demonstrated on records, where in successive exposures the light interval was gradually lengthened.

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