AN INTERPRETATION: THE "NONBLACKBODY EFFECT" IN PHOTOSYNTHESIS

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Abstract: The nonblackbody is a possible energy-catching apparatus which can be easily formed by a matching process in the complementary behaviour of light and pigment to absorb the light quanta maximally throughout the visible spectrum in photosynthesis.

Evidence of the existence of the two photopigment systems is derived when the photosythetic behavior in the photometric measurement is considered, namely, the chromatic transient (Blinks, 1964), the "red drop" phenomen (Emerson & Rabinowitch, 1960), the photosynthetic deficiency at the wavelength above 680 nm in farred light and other characteristics. The photoactive pigment is chlorophyll-a which has been found in all photosynthetic plants. The other pigments even chlorophyll-b, serve only as accessory pigments, whose function is that of absorbing the light and transferring energy to chlorophyll-a (Emerson, 1958). The photosynthetic behavior of other pigments in red algae (e.g. phycoerythrine) and in blue-green algae (e.g. phycocyanine) has already proved that it is mainly light other than red light which is absorbed, therefore, they are important as chlorophylls (Haxo & Blinks, 1950). Judging by the complementary behaviour of light and pigment as far as their respective colour changes are concerned, the first stage in the energy-catching process would appear to be a "nonblackbody effect".

Photometric studies show that in general, the pigments, which are present in different ratios in the cells, are connected to one another throughout the visible spectrum by the overlapping of their absorption bands, and show an almost stable quantum yield below 680 nm. A quantum deficiency can be observed only in the green region, and is caused, as illustrated in green plants, by strong diffusion and low absorption (Gandillere & Costes, 1971). The large diffusion and transmittance would account for the photosynthetic deficiency in green cells. The colourless cells diffuse the shorter waves, while the coloured cells diffuse the longer waves (Latimer & Rabinowitch, 1957). When absorption by chlorophylls, for example, takes place at 680 nm and 450 nm the blue and yellow-green components mix to give green plants their colour. The yellow-green component absorbs the light energy not only below 440 nm but also above 700 nm (Fig. 1), namely through photosystem I in the "Z-scheme". If the green cells were illuminated only with above 690 nm light (the photoreaction I) or only with below 690 nm light (the photoreaction II), naturally only one part of the chlorophylls has been photoactivated: the yellow-green or the blue one. Both together could complementarily cause the well known "Emerson's enhancement" (cf. Clayton, 1971). The photoreaction II by the blue component might relate to the photosynthetic production of oxygen, while the photoreaction I by the yellow-green component relates to the thermo-catalyzing CO_2-reduction.

A blackbody absorbs all kinds of colour light and changes the light energy into the warmness or into the remitting light, or into both of these. As the

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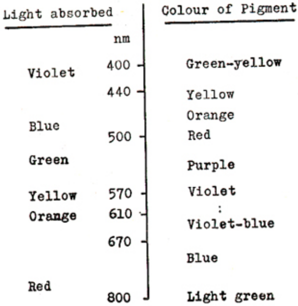

Fig. 1.

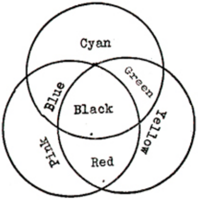

Fig. 2.

Fig. 1. The "blackbody effect" brought about by the process in which the colour of light and pigment complement each other. (after Patterson, 1967).

A scale shows the way in which lights and pigments match one another. The left side represents the visible spectrum, whose light, when absorbed, is responsible for the colour of pigments, a table of which can be seen on the right side.

Fig. 2. The filter phenomena. The white light passes through the filters. The colours shown above can be detected by the "human eye". The "blackbody effect" is formed by the overlapping of the filters. (after CCOSA, 1953).

The cyan (green plus blue) pigment complements the red light to form a "blackbody". Similarly, pink pigment complements green light and yellow pigmen complements blue light. Should, however, the green component in the cyan pigment be greater than the blue component, or should some yellow pigment be present, then the complementary light colour will be violet, or farred (red plus pink). If, on the other hand, the blue component constitutes the predominant part of the cyan pigment, giving deep green, then the complementary light will be orange or light red (red and yellow). The processes in which the complementary lights are violet and orange are secondary processes during which a "nonblackbody" is formed.

temperature of a blackbody increases, so is a large proportion of the total light energy emitted within the visible spectrum. A blackbody could be presenting in a biological system because of the complementary composition of different pigments (Fig. 2). Beside the chlorophylls for example the pink pigment-group, the "Krasnovski's pink (cf. Latimer & Rabinowitch, 1957), cytochromes, flavoproteins and carotenoides to the yellow pigment-group, are needed to build a blackbody (Figs. 1 & 2). Because of the unequal composition of the 3 blackbody-forming pigment-groups, only a "nonblackbody" could be really formed in a biological system. A nonblackbody has a blackbody effect in order to absorb light at a different level. However, a nonblackbody emits less light during a wavelength interval than a blackbody at the same temperature (Seliger & McElroy, 1965). In a biological system the intensity of emitted light is very weak compared with the intensity of incident light.

The nonblackbody formation can be regarded as the first response to the light by the pigmented membrane, and its effect is the first process in the energy transfer of photosynthesis. The formation level of nonblackbody can determine its nonblackbody effect which results from the matching activity of colour. The "quenching" in the photoreaction II may be a phenomenon of red-blue matching in the nonblackbody forming process (Figs. 1, 2).

If the different energy states in pigment molecules have been light-induced, then the energy can be either absorbed or radiated. In this case a nonblackbody likes a blackbody to absorb a certain light and then emits its complementary colour light at a certain wavelength. At first, the emitted light increases in intensity and then decreases very rapidly to infinity or to zero (Seliger & McElroy, 1965), reverting the non-and blackbody once more to its black state.

The nonblackbody effect can be increased by a structural comformation of the pigmented membranes or by making the cell suspension denser. If the density of cell suspension is too great, some cells probably respire in the weak light instead of photosynthesizing behind the forming nonblackbody.

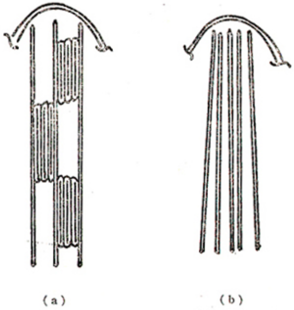

Fig. 3. Schematic membrane systems in the photosynthetic organisms (e. g. in chloroplasts or in thylakoids), (a) The granaform which is illustrated mainly in Calvin cycle plants, and, (b) the parallel form in the C-4 dicarboxylic acid cycle plants.

The multilayer arrangement appears in the chloroplast or thylakoide system to reinforce the nonblackbody effect (Fig. 3). A parallel membrane system in C-4 dicarboxylic acid cycle plants (Fig. 3b) could still transmit mainly green light, then red, then blue, comparing with the absorption measurements (cf. Moss & Loomis, 1952; Latimer & Rabinowitch, 1957) and with the layering of filters (cf. Gaudillere

& Costes, 1971). But the Calvin cycle plants have grana-structures (Fig. 3a) and so absorb not only the red and the blue but also the green light (Gaudillere & Costes, 1971; McElroy & Glass, 1961). The membrane layering for the photosynthetic process is perhaps related to the local light conditions and to plant ecology.

The formation of a nonblackbody is independent of any change in temperature. For example, if phytochromes (cf. Clayton, 1971) are frozen at a liquid nitrogen temperature, then illuminated, then warmed up again, then their photochemical characteristics are revealed. The essential influence of temperature on the photosynthetic process is that of denaturising the enzyme proteins contigent of the pigments.

Oxygen is the first quencher because its basic state is triplet. If oxygen is employed in the chemical reaction, an oxidation is catalyzed by the biological system to release radiation for the thermal degradation (McElroy & Glass, 1961). This emitting system is beyond nonblackbody control because the formation of nonblackbody occurs only in the light. In the dark, light emittance is brought about by respiratory oxidation, and is part of the enzymatic process. The oxidation in the dark and the the nonblackbody effect in the light both conserve energy finally into biological compounds, for example ATP.

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