CHROMOTROPISM AND PHOTOTROPISM.

Because of the obvious importance of the facts which MINKIEWICZ claims to have discovered and of the stimulating value of his statements it has seemed worth while to print in this *Journal* a translation of the two brief notes on responses to chromatic stimulation which he has recently published.[1] The whole of the first note appears below; in the case of the second note the introductory paragraph is omitted in the translation.—THE EDITORS.

Because of striking contradictions in the generally accepted theory of SACHS and LOEB, to the effect that the most refrangible rays of the spectrum are alone active in the phototropism of animals and plants and that their action is the same as that of white light, and certain facts well established by P. BERT and LUBBOCK for Daphnia, which is attracted especially by the yellow-green, and by WIESNER for plants, which present two extremes of tropic action (first to the blue-violet, second to the infra-red, the action of the yellow being nil), I have given special attention in the course of my researches upon the tropisms and instinct to the tropic action of the chromatic rays. Some of my results follow:

1. The larvæ of Maia squinado (zoea) recently hatched present, as is well known, a strongly marked positive photo- and heliotropism. I have shown that they are at the same time very sensitive to chromatic rays, that they are directed constantly toward the rays of the shortest wave length, that is toward the violet, and in its absence toward the blue. They distinguish thus all the visible rays. The reaction is almost instantaneous; all the larvæ dash like a flock of birds toward the most refrangible rays as soon as they are placed under their influence.

This phenomenon has taken place not only in horizontal glass tubes but also in vertical ones no matter what the distance of the most tropic region from the surface of the water.

2. Nemerteans of the specias Lineus ruber behave in an entirely different manner. They are strongly negative in the presence of diffuse white light and at the same time they all direct themselves toward the rays of the greatest wave light, that is, toward the red, and in its absence, toward the yellow, etc.

Thus far everything seems to agree with the theory of LOEB. The positive phototropism of the larvæ coincides with the strongest positive action (attractive) of the violet part of the spectrum; the negative phototropism of Lineus with the strongest negative action (repellent) of the violet part. And yet these phenomena are not necessarily bound together.

[1] MINKIEWICZ, ROMAULD. Sur le chromotropisme et son inversion artificielle. *Comptes rendus de l'académie des sciences, Paris.* Nov. 19, 1906. Le rôle des phénomènes chromotropiques dans l'étude des problemes biologiques et psycho-physiologiques. *Comptes rendus de l'académie des sciences, Paris.* Dec. 3, 1906.

3. One may bring about artificially with the nemerteans the inversion of the tropisms in the presence of chromatic rays while preserving the negative sense of their phototropism with reference to white light.

a. Placing Lineus in a solution composed of from 25 to 80 cc. of distilled water to 100 cc. of sea water, I obtained on the following day this inversion with absolute certainty. Lineus while remaining negative with reference to white light now directs itself toward the most refrangible rays of the spectrum, just as it had previously directed itself away from them.

The result of the inversion is that the phototropism, which remains negative, is here absolutely separated from the chromotropism, of which the sense is changed. Every chromatic ray has a specific action and at the same time the action of white light is not a simple resultant of a mechanical fusion of the actions of all the possible rays of the spectrum.

I must remark further, that I have not as yet found, in spite of long continued researches, a single means of transforming the negative phototropism of Lineus into positive phototropism by agents either chemical, osmotic or thermic. Thus, for example, the animal remains negative until its death in the presence of white light whatever the concentration of the sea water.

b. The inversion of the chromotropism of the nemerteans appears the second day, continues in general two days and disappears the fourth, the animal becoming again normally erythrotropic. This seems to me to prove that the nature of chromotropism is not an absolute function of such or such vital medium but a function of the physiological state of the organism, a fact which agrees with the observations of LOEB concerning the changes in heliotropism at different periods of life.

c. There is one fact which confirms further this point of view, namely, that my Lineus after having lived for two or three weeks in my solutions and presenting consequently their normal chromotropism (erythrotropism) change anew when one transfers them into pure sea water and become purpurotropic (direct themselves toward the violet).

But this is not all.

d. The inversion of the chromotropism is not produced immediately and it also does not disappear all at once. There are stages when the animal still erythrotropic (normal) ceases to distinguish green from yellow. There are others when though indifferent to green and yellow it is already purpurotropic. These stages of tropic blindness with reference to the middle parts of the spectrum last several hours and thus one can easily observe them on the second and the fourth day. There should exist still two stages in the passage from erythrotropism to purpurotropism and inversely, during which the animal is completely indifferent in the presence of colored rays, that is, is achromotropic—either because it is equally influenced by all the chromatic rays or because it is entirely insensitive. This I have not yet been able to observe, for these stages are of very short duration.

In a second note the author points out the following bearings of his discovery upon the problems of general biology and of the psycho-physiology of vision.

A. GENERAL BIOLOGY.

1. One may find animals chromotropic with reference to the middle rays of the spectrum, each ray having its own specific action. Indeed Daphnia, according to PAUL BERT and J. LUBBOCK, is xantho-chlorotropic, a fact which is absolutely incompatible with the theory of LOEB ('90).

2. Purpurotropism is not necessarily connected with positive phototropism nor erythrotropism with negative phototropism. One may find animals which behave in the reverse manner. This is proved by the excellent experiments of ENGELMANN upon unicellular organisms (1882 and 1883). According to him Paramecium bursaria, which is positively phototropic, avoided the green and the blue and directed itself toward the red. Likewise Navicula (a diatom) ceased movement in darkness and in the green.

3. Organisms should exist which, while being positively or negatively phototropic are not at all chromotropic (total tropic blindness; that is achromotropy), as Lineus is during the transitory stages of inversion.

4. There are organisms like the plants studied by J. WIESNER ('79) which are insensitive to certain rays of the spectrum (partial tropic blindness; that is, the axanthotropy of Vicia sativa).

5. It follows from the vertical tube experiments upon the zoea larvæ that the chromatic rays may have a certain influence upon the vertical distribution of aquatic animals, granting the unequal absorption of the different rays of the spectrum, the greatest for the red, the least for the blue (W. SPRING, H. FOL, E. SARASIN, FOREL).

B. PSYCHO-PHYSIOLOGY.

The experiments which I described in my preceding note lead me to believe that in studying the biology of the lower animals one should seek the indices which may point the way to an explanation of the complex and difficult phenomena of vision.

1. Chromotropism being independent of phototropism, it seems to me that the perception of white light may be a primitive phenomenon, much more simple than it is generally believed to be and independent of chromatic perception (this is corroborated by the well known experiments of A. CHARPENTIER, and also by the historic fact that in the best theory of vision, HERING was forced to admit the existence of a special white-black substance).

2. It seems superfluous and futile to seek for the solution of the problems of chromatic vision in the hypothetical creation of different nerve fibers (YOUNG-HELMHOLTZ), of various pigment granules (A. PIZON), or of different chemical substances (HERING), endowed with specific sensitiveness for different rays of the spectrum. One should rather ask whether there are not different physiological states in the same living substance which give rise to these complex phenomena of chromatic vision, as in Lineus the different states artificially induced bring about all the successive and transitory stages of chromotropism. [Experiments of PERGENS and further of LODATO ('00) upon the chemical phenomena in the retina, the intensity of which varies according to the action of different rays of the spectrum.]

3. Thus is it not possible and profitable to compare color-blindness (Daltonism), in general, and the different cases of achromotropy, partial or total, of the xanthotropic blindness of plants (WIESNER) and of the indifference $\frac{\text{chloro-}}{\text{xantho-}}$ tropic of Lineus in certain stages of the artificial inversion of its chromotropism? [Personal experiments of W. NAGEL ('01) upon the artificial transitory blindness for red induced by santonin.]

4. Finally, is it not in this direction that one should look for the explanation of the consecutive colored images (six according to C. HESS ('00) or even more) after a short chromatic stimulation, if one bears in mind the succession of stages in the artificial inversion of chromotropism in my Lineus?