Physiology of Plants. — Professor BEIJERINCK presents a paper on: *„Photobacteria as a Reactive in the Investigation of the Chlorophyll-function."*

If in a mortar leaves of some neutrally reacting plant, e. g. of white clover are crushed, diluted with destilled water, and filtered, a green filtrate is obtained, in which are found that portion of the living protoplasm which is soluble in water, and many chlorophyll-granules which give the filtrate a green colour.

If this green liquid is mixed with a culture of phosphorescent bacteria in fish-broth with 3 pCt common salt, or with sea-water[1]) rendered phosphorescent by a „luminous bouillon", and if this mixture is filled into a test-tube or stoppered bottle, the liquid becomes dark as soon as the oxygen has been used by the physiological processes of the phosphorescent bacteria and of the living protoplasm of the clover-leaves in the filtrate.

If the dark liquid is exposed to light, it is evident that the chlorophyll and the living protoplasm have not become inactive by the said treatment, for, by production of oxygen, they again cause the luminosity of the bacteria. If the plant-juice is fresh and the bottle is placed for a minute or longer in the full sun, then so much oxygen is formed, that the bacteria, transferred to the dark can continue phosphorescing for some minutes.

This experiment is of an extreme sensibility, for even the lighting of a match is sufficient, after part of a second already, to produce a distinct phosphorescence which, of course, can only be observed when by remaining long enough in the dark, the eye has become sensible to feeble light.

If the liquid is left to stand for some hours, either as such or after mixing with the phosphorescent culture, the power of decomposing carbonic acid gets quite lost. Evidently the presence of living protoplasm is necessary for it. Concequently, FRIEDEL's[2]) experiment, wherein clear, filtered juice of squeezed spinage-leaves, mixed with powdered leaves of the plant, dried at 100° C., causes decomposition of carbonic acid, does not prove, as FRIEDEL thinks, that the function of chlorophyll reposes on the action of enzymes, but on the fact, that the portion of the protoplasm concerned in the

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[1]) By „sea-water" is meant tap-water with 3 pCt. ClNa.

[2]) J. FRIEDEL, l'Assimilation chlorophyllienne réalisée en dehors de l'organisme vivant. Comptes rendus T. 132, pag. 1138, 6 Mai 1901.

process, occurs in the liquid state and is not solid, — hence, a new argument for the more and more prevailing opinion, that the living protoplasm is, if not quite, at least partly liquid. That the juice can be precipitated with alcohol, without the precipitate becoming inactive, proves nothing for the enzyme-hypothesis, as in many other cases the living protoplasm is proof against the action of alcohol.

If it be thought desirable to use the name of „protoplasm" only for the mixture of the living matter such as it occurs in the cell, and to connect with that term the idea of a special structure, I can quite well share this view, and will allow that, in this case, the decomposition of the carbonic acid is brought about by something else but "the protoplasm", namely by a portion of it. To this portion, or rather, to this particular constituent of the protoplasm, the name of "oxybiophores" or "oxy-pangens" might be given, in accordance with the theory of biophores or pangenesis. With what has always been understood by enzymes, the properties of the biophores do not coincide but, of course, they do with those of the protoplasm itself [1]).

With crushed algae I could also perform the above experiment, but the secretion of oxygen was much slighter than with the sap of the examined land-plants.

On the other hand, algae which have not been crushed, whether enclosed in a mixture of culture-gelatin and luminous bacteria, or simply in sea-water rendered luminous by phosphorescent bouillon, are very well fit to study the secretion of oxygen in the light and its relation to the colour of the light.

Some years hence, Prof. KAMERLINGH ONNES, at Leiden, had the kindness to enable me to make an investigation thereabout in his laboratory. Our experiment was conducted as follows.

Between two glass-plates was enclosed fish-bouillon-gelatin diluted with sea-water, and thus containing 3 pCt. Cl Na, which by a great number of phosphorescent bacteria (*Photobacter phosphorescens*), mixed with it, was highly luminous at sufficient access of oxygen. In the middle of the gelatin I had placed, before the solidification, a broad stripe of a sea-*Ulva*.

In the dark the gelatin quickly loses its luminosity, the glass-plates rendering access of air impossible. When exposed to the light, the *Ulva* produces oxygen through the decomposition of

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[1]) This observation holds also good with regard to BUCHNER's„ alcohol-enzyme", of which the active agent consists in „alcohol-biophores"

carbonic acid, and a local spot of light appears, which may be caused to come and to vanish at will as often as desired.

This apparatus was set up in a simple camera and could be locally illumined by withdrawing a slide. When the slide was closed the camera was quite dark, by which the eye of the observer became sensible to the light. Prof. ONNES himself supplied spectral colours of known refrangebility, taken from the spectrum of an electric arc-light, and projected them on the *Ulva* in the gelatin. By me was then observed what coloured lights were well, and what were not able to cause the decomposition of carbonic acid. The result was the following: Only red light decomposes carbonic acid, for only in it the phosphorescent bacteria emit a strong light; the maximum of decomposition was found near the chief absorption-band of the chlorophyll-pigment, situated between B and C, and this maximum coincides about with C itself, certainly it was somewhat out of the middle of B—C. Decomposition of carbonic acid in other coloured lights could not be detected.

If the Chlorophycee was replaced by a Rhodophycee, which I determined as *Porphyra vulgaris*, and which, like the *Ulva*, is common on the stone piers at Scheveningen, the process was nearly the same, but with this difference that the maximum of decomposition does not coincide with C but lies quite in the orange.

As the chromatophores of *Porphyra*, besides the chlorophyll-pigment, contain a red pigment soluble in water, and of which two chief absorption-bands are situated in the yellow, it is obvious that the maximum of carbonic-acid decomposition is in this case determined by the co-operation of the coloured rays which both pigments by preference absorb.

Our results, accordingly, correspond in the main point with those obtained by Prof. ENGELMANN [1]), by his method based on the motion of bacteria, with this difference that the production of oxygen in two other absorption-bands, situated in the blue, as described by him, could not be observed by us.

In opposition to the sea-algae and likewise to the crushed leaves of landplants, whole leaves of the latter, immersed in luminous fish-bouillon, or in gelatin mixed with phosphorescent bacteria, do not distinctly, or only for a very short time, produce oxygen, when they are illumined after being freed from the air enclosed in their tissues.

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[1]) Botanische Zeitung. 1883 pag. 1, 1884 pag. 81.

In the following way, however, the experiments with them went very satisfactorily.

Instead of enclosing the leaf *in* the strongly phosphorescent gelatin it is simply laid *on* the surface, and firmly pressed to it by means of a solid glass-plate.

Kept in the dark, after some time all the oxygen originally enclosed in the tissues of the leaf is utilised by the phosphorescent bacteria and everything under the glass-plate grows dark. If now the leaf is illumined, oxygen is formed, and when transferred to the dark, the bacteria will be seen to continue emitting light for some time [1]).

These experiments confirm the results obtained by STAHL [2]), which demonstrate that the stomata are the ways by which the gases enter and leave the leaf. For when suitable leaves are selected with about an equal number of stomata on both surfaces, and examined after our method, it appears to be all the same, whether the leaf is pressed with its under or upper side against the gelatin, in both cases a luminous spot of the shape of the leaf appears, after illumination. If, on the other hand, the stomata are only, or for the greater part, at the under surface, and the leaf is pressed with its *upper* surface on the gelatin, thus with its underside against the glass-plate, then the oxygen accumulates between the latter and the leaf, and does not, or only partly pass through the lamina but, reaching the gelatin along the margin of the leaf, a luminous *line* following this margin is produced.

If such a leaf is illumined after being pressed with its *under* surface on the gelatin, the oxygen issuing from the stomata directly comes into contact with the gelatin, and a luminous *spot* appears shaped like the leaf.

In performing this experiment it is advisable to cut one and the same leave into two halves and press at once both parts on the gelatin, one with the upper- the other with the underside.

The process can, however, become very complicated by the closing of the stomata, which are extremely sensitive to the contact of the salt-containing culture-gelatin, and evidently also to the absence of oxygen in their surrounding, when kept in the dark.

The fact that nyctitropic leaves evaporate the most vigorously

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[1]) For the right performance of this experiment some practice is required as the layers of air, adhering to the leaves, and which are greatly different at the upper and under surface, influence largely on the course of the process.

[2]) Botan. Zeitung, 1894 pag. 117, 1897 pag. 71.

at that side, which is covered during the night, has been confirmed by the photobacteria-method respecting the secretion of oxygen. So, the clover-leaf closes at night by putting the upper surfaces of the leaflets against one another: hence these surfaces must exhibit a more energetic secretion of water-vapour, and in the light, of oxygen, then the under surfaces, which has been confirmed by the experiment.

For *Robinia pseud-acacia*, where at night the under surfaces cover each other, the most vigorous secretion of oxygen is to be expected in the light from the underside, which is likewise confirmed by the experiment. But with *Robinia* the difference is less considerable than with clover.

Physics. — Mr. FRED. SCHUH ON: "*Plane waves of light in an homogeneous, electrically and magnetically anisotropic dielectric.*" (First part).

1. If P, Q and R are the components of the electric force $\mathfrak{E}$, and f, g and h the components of the electric induction $\mathfrak{D}$ (4π times the dielectric displacement) both expressed in electric units, then we have, in the case of an electrically anisotropic medium, the relations:

$$P = k_{xx} f + k_{xy} g + k_{xz} h \ , \ . \ . \ . \ . \ . \ . \ . \ (1)$$

$$Q = k_{yx} f + k_{yy} g + k_{yz} h \ , \ . \ . \ . \ . \ . \ . \ . \ (2)$$

$$R = k_{zx} f + k_{zy} g + k_{zz} h \ , \ . \ . \ . \ . \ . \ . \ . \ (3)$$

in which $k_{xy} = k_{yx}$, $k_{xz} = k_{zx}$, $k_{yz} = k_{zy}$. The electric (potential) energy per unit volume is:

$$U_e = \frac{1}{8\pi}(Pf + Qg + Rh) \ . \ . \ . \ . \ . \ . \ (4)$$

The surface:

$$k_{xx} x^2 + k_{yy} y^2 + k_{zz} z^2 + 2 k_{yz} yz + 2 k_{zx} xz + 2 k_{xy} xy = 1$$

is an ellipsoid (with O as centre), because $U_e > 0$, if f, g and h are not all zero. I shall call this the electric ellipsoid. If $\mathfrak{D}$ is a radius vector of this ellipsoid, then $U_e = \frac{1}{8\pi}$; $\mathfrak{E}$ is then normal to the diametral plane conjugate to $\mathfrak{D}$, which we shall call the electrically conjugate diametral plane. The radius vector r_e of this ellipsoid has the following meaning: