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become very much the same and the curvature — and that is the definitive phototropic curvature of *Phycomyces* — only appears after the maximum of the acceleration of growth, because the growth-reaction of the less illuminated anterior wall diminishes somewhat more rapidly than that of the posterior wall.

To be on the safe side I will not extend the scope of these facts further than to the positive phototropism of *Phycomyces*, but of this phenomenon I think, that proof has now been furnished, that *the appearance of these curvatures is the result of an asymmetrical modification of the growth of different sides of the cell, caused by the asymmetrical illumination of these sides; that for this case therefore DE CANDOLLE's simple and ancient theory — more particularly in contradiction to the later conception of SACHS — is reestablished and with this a theory of a perception of the light-direction itself is superfluous.*

In the meantime I do not wish to generalize, but only to await the results of further investigations, which are being continued in various directions, on *Phycomyces* and on the root and stem of higher plants. Only, in my opinion, for no single one of these cases can any decisive proof in the literature be found against DE CANDOLLE's theory.

Finally I desire to express my great indebtedness for the facilities afforded me in the Laboratory of the TEYLER Foundation, for carrying out these experiments — and it is no mere formality, that I tender my thanks especially to the conservator, Jhr. Dr. G. ELIAS, for his assistance and interest in the arrangements for this investigation.

Haarlem, Dec. 1013.

Physics. — “*Magnetic researches. X. Apparatus for the general cryomagnetic investigation of substances of small susceptibility.*”

By H. KAMERLINGH ONNES and ALBERT PERRIER. Communication N°. 139a from the Physical Laboratory at Leiden. (Continued).
(Communicated by Prof. H. KAMERLINGH ONNES.)

§ 7. *Sources of error. Sensibility. Accuracy. Disturbing magnetic influences.* The action of the magnet upon the carrier without the experimental tube appeared to be negligible, even when the lower end of the carrier was reduced to the temperature of liquid hydrogen. The action upon the coil of the carrier was also imperceptible even when a much stronger current i_m was passed through this coil than

was used in our experiments¹⁾. Moreover, even if it should be of any importance, it would be eliminated by the above indicated method of observation. The influence of the stationary coil upon the higher conducting spring is probably not negligible, but it cannot cause any errors, as neither in the calibration nor in the observations is anything changed in this spring.

It may also be mentioned that by the manner in which the conductors are arranged, in connection with the order in which readings are taken, any influence of the electro-magnet or the rheostats upon the ammeters or of these upon each other, are eliminated. These influences are moreover very small.

Capillary action. At first we were rather uneasy about the capillary action between the rods of the floats and the mercury surface, and between the carriers of the experimental tube and the surface of the liquid in the bath. The regular return of the carriers to the same zero, proved that no disturbances from these causes occurred in our experiments. We had always given great care to keeping the mercury surface as pure as possible.

Vibrations. Vibrations of the ground have a very injurious effect upon the observations, as they are reproduced in the apparatus, greatly magnified, and are likely to cause troublesome swinging of the floating carrier. Vibrations in the microscope caused by the vibration of the ground, which troubled us at first, could be avoided by fixing the microscope more firmly.

The carrier is moved by every change of the forces that act upon it, which causes vertical oscillations of great amplitude. To damp these, glass wings are attached to the floats, so that after 2 or 3 swings they come to rest. Finally, the vapour bubbles that constantly rise in the bath, cause small vertical movements of the carrier, which are more marked, the greater the density of the liquid gas is. Against these vibrations the comparatively large inert mass — about 200 grams — of the carrier combined with the damping just mentioned, proved to be the best expedient. The damping could as a matter of fact have been made much greater, without any difficulty. But it was better not to go any further, as it would have made the movements of the apparatus aperiodic, and a few swings were very useful to bring the influence of the capillary action upon the carriers each time to the same value.

¹⁾ When the axis of the coil falls exactly in the plane of symmetry of the poles and goes through the middle of the interferrum this force is strictly zero.

Sources of error in the experimental objects themselves.

For the calculation of the specific magnetisation, we need to know the *mass per unit of length* of the substance with which the experimental tube is filled. The total mass which the tube contains can be ascertained as accurately as we wish, but the length over which it is spread in the tube, owing to the irregularity of the extremities cannot be determined more accurately than within 0.2 to 0.3 m.m.

Further, it is assumed in the calculation that it is evenly distributed over the whole tube which cannot be strictly accurate, owing to slight differences in diameter and slight differences in the degree of closeness which is attained in filling to different heights, but this error is certainly small, and only influences the *absolute* value of the *calculated susceptibility*; if the same experimental tube is used in the same position at the various temperatures, this error has no effect upon the *relative* results, which are the principle object of our research.

The relative results may however become inaccurate, if between two experiments at different temperatures, some anisotropic grains, which together form an isotropic mass, each take a different direction, e.g. so that the line of greatest susceptibility in them approaches the direction of the lines of force, since the mean susceptibility of the group will thereby be changed. We can avoid that this happens unnoticed, by taking the observations at low temperature between two observations at ordinary temperature. To answer the more general question in how far an apparent isotropy can be obtained with substances which are in reality anisotropic, by pressing them in a more or less finely granulated condition into tubes of 5 to 8 m.m. we can, without changing the conditions in any other respect, repeat the experiments after having brought the experimental tube into another direction relatively to the lines of force, by turning it on its axis. In doubtful cases we applied this method.

Numerical data: The coils described, can carry currents of 6 amp. (i_f) and 1.5 amp. (i_m) respectively, for a quarter of an hour; the force which they then exert upon each other is about 25 grams. In the given arrangement this may therefore be regarded as the limit of the force which can be measured with the apparatus. Under favourable circumstances (little vibration) a change of 0.001 gram in the force acting upon the carrier can be observed. Generally speaking, the para-magnetic substances examined caused attractions of a few grams, sometimes even more. The accuracy of the results

is therefore more limited by the accuracy of the ammeters, than by that of the apparatus itself. With two of the ammeters, in each of which we constantly adjusted on one of the scale divisions, it was possible to bring the relative sensibility to within a thousandth. The third was almost equally accurate. In the relative measurements of the susceptibility calculated, we can thus rely in general upon an accuracy of 0,2 to 0,3 %. The absolute accuracy suffers somewhat from the fact that we are not certain of the homogeneity of the experimental object (see above); but it is principally limited by the accuracy of the determination of the magnetic field, the square of which occurs in the formula for the susceptibility, and not by that of the apparatus.

There is one more important factor to be considered, viz. the constancy of the temperature of the bath. Disturbances in this will have a different effect with different substances, as the change in the susceptibility with the temperature is very unequal for different substances, especially when we approach the absolute zero.

In our experiments in general we did not observe any disturbances from irregularity of temperature. Only in the case of gadolinium sulphate, the susceptibility of which changes most with the temperature (1 % for 0,2 degrees at 20° K.) the measurements in different fields (at different moments therefore) did not agree so well with each other as might have been expected if we only considered the accuracy of the magnetic determinations.

(February 26, 1914).