Citation:

W.H. Arisz, Adjustment to light in oats, in:
KNAW, Proceedings, 16 II, 1913-1914, Amsterdam, 1914, pp. 615-628

a mucous one, it becomes evident what destruction the turpentine has caused there.

We investigated therefore whether the chemotaxis could not likewise be stimulated by injecting subcutaneously a solution of turpentine in NaCl 0.9 % in a concentraton of 1 : 10.000, instead of pure turpentine.

Provisional experiments have indeed shown that this has a favourable effect on chemotaxis. It was not considerable however.

Probably this must be attributed to the ineffective manner in which the experiments were carried out. In the first place too little was injected viz. only 5 times 5 cc. of a turpentine solution of 1 : 10.000, which means only a total amount of 0.0025 cc. of turpentine. But especially too much time elapsed between the injections so that the turpentine injected, had ample opportunity to be secreted in large quantities by the kidneys, whilst the method of injection adopted by FOCHIER creates a reserve of turpentine, from whence turpentine is continually yielded to the circulation.

In subsequent experiments, which, owing to lack of time, could not be carried out as yet, the above-mentioned consideration will be taken into account.

As the technical difficulties attending turpentine-injections are being removed, it will be possible to make use of these injections much more frequently in human pathology; meanwhile it may now be concluded already from the foregoing experiments that turpentine also stimulates chemotaxis in remote places. Further we may infer from the greater mobility of the phagocytes, which is indeed also the foundation of an increased chemotaxis, that in those places the phagocytosis will be stimulated likewise.

Groningen, November 1913. *Physiological Laboratory.*

Botany. — *"Adjustment to light in oats"* By W. H. ARISZ. (Communicated by Prof. WENT).

(Communicated in the meeting of November 29, 1913).

§ 1. *Introduction.*

In this preliminary communication there will be considered a number of phenomena which are generally grouped as adjustment phenomena (German: "Stimmung"). By functional adjustment is usually meant the state of an organ which determines the effect with which the latter reacts to a stimulus of a certain strength.

A change in adjustment is therefore made evident by a change in the reaction to a stimulus of the same intensity. Thus it has been known for a long time that plants grown in the light do not show the same sensitiveness to unilateral illumination as etiolated ones. PRINGSHEIM [1]), in a series of investigations, has attempted to obtain a more detailed knowledge of these processes and quite recently there appeared a paper by CLARK [2]) which, as an extension of PRINGSHEIM's work, possesses in many ways points of contact with the results about to be described. CLARK's conclusions and my own differ on a fundamental point, namely the validity of the energy law for negative reactions.

There are also striking differences with regard to our observations on the influence of omnilateral preliminary and after-illumination. Since CLARK's paper fortunately appeared before the close of the present investigation, I have been able to test his results by control experiments, which, at least with regard to the influence of omnilateral after-illumination, have sufficiently explained the divergence in our results. For a further explanation and for theoretical considerations I must, however, refer to the detailed account of my investigations, about to be published elsewhere.

§ 2. *Method.*

My method is in principle the same as that of PRINGSHEIM and of CLARK. These investigators obtained the omnilateral illumination by causing pots with seedlings to rotate on a clinostat round a vertical axis in front of the source of light. The objections to this method are that owing to the excentric position of most of the plants, the latter do not receive equal quantities of light on all sides, while moreover, on account of the large numbers of plants in each pot, they are continually getting into each other's shadow. Owing to the kindness of Prof. WENT I was able to use an apparatus specially built for these experiments. It is a kind of multiclinostat, in which 20 pots can rotate simultaneously each on its own axis. The arrangement is such, that when the source of light is one metre from the instrument, the possibility is excluded of the plants getting into each other's shadow. The time for a revolution varies from 4 seconds to 4 minutes, whilst a brake with an electrical contact makes it possible to illuminate during an integral number of revolutions. Since the plants rotate round their own axis, it is possible to use fairly large velocities

1) COHN's Beitrage Bd. 9. 1909. Bd. 10. 1910

2) Zeitschr. f. Bot. Bd. 5. H. 10. 1913.

without fear of centrifugal force. In the series of experiments now published, the rotation velocity was always 5 sec. The source of light was a NERNST projectionlamp fed by a current maintained constant. The light from the lamp, which was placed outside the dark room, passed through a cooling apparatus with running water and then through a diaphragm into the dark room. By interposing plates of frosted and of milk glass the intensity of the light could be changed in a few seconds. A greater intensity than 450 candles-metre was not obtainable with this lamp at the distance at which the multiclinostat was placed. The experiments described below, with unilateral illumination at greater intensities were carried out with the aid of a projection arc lamp which gave at 1 metre an intensity of 4600 candle-metre power. The numbers referring to the latter illuminations have no claim to great accuracy.

The experiments were carried out in a small dark room in the experimental hothouse of the laboratory. This small space could be maintained at 23° C. by means of an electric heating apparatus and regulator.

§ 3. *Omnilateral fore-illumination followed by unilateral after-illumination*

In order to determine the state of sensitiveness of a plant at a given moment, the plant must be exposed to unilateral illumination at this moment and the resultant reaction must be observed. In the course of the investigation it was found desirable to make a rule of following the process of curvature, for the first two hours. A longer period was not required for after two hours no further phototropic phenomena became visible. The investigation aimed at observing how a plant behaves towards unilateral illumination of various intensities, after previous exposures of varying duration and intensity. In order to determine the state of sensitiveness exactly at the end of the preliminary illumination it is necessary to supply the quantity of energy of the unilateral after-illumination in as short a time as possible. How desirable this is will be seen especially from a consideration of the processes discussed below, affecting the return of sensitiveness. In contradistinction to PRINGSHEIM and to CLARK, I did therefore not always use the same intensity for the unilateral after-illumination as had been employed when the plants were rotating.

On the contrary, an attempt was made to supply the plants in as short a time as possible with a definite amount of energy, which attempt was only limited at the higher amounts by the available supply of light. I have investigated the influence of omnilateral fore-illumination by allowing the plants to rotate for various periods of time at 5 different intensities, of 5.5, 12.1, 25, 100 and 450 candle metre power. The results of the first four series are summarized in tables. Without going into points of agreement and difference, which would require detailed discussion, I here only wish to remark, that Table I is comparable with the investigation of PRINGSHEIM (second paper IV) and that my table III shows agreement with CLARK's figure 2.

It is especially by a consideration of table I, where the preliminary illumination is weakest, namely 5.5 candle metre power, that we can most readily obtain some idea of the influence of omnilateral fore-illumination. A survey of the first six vertical columns of this table, in which the unilateral after-illumination was 22—1000 C.M.S., reveals that a fore-illumination of 100 seconds already requires an after-illumination of 60 C. M. S. to bring about a curvature, whereas after 10 seconds 22 C. M. S. were able to do this. After still longer preliminary illumination not much more energy need be supplied and 120 C. M. S. always gives a definite positive curvature. We may therefore conclude that the sensitiveness has been diminished by the fore-illumination.

A second phenomenon is observed when the amount of the energy of the after-illumination is increased (the last three columns of table I). As I have previously [1]) shown these large amounts of energy (more than 4000 C. M. S.) bring about negative curvatures. Even after brief fore-illumination these negative curvatures occur after large amounts of energy, but now the phenomenon is observed, that after preliminary exposures of 5 minutes or longer, these negative curvatures become feebler, and already after 20 minutes they are no longer obtainable. Then positive curvatures occur, which are extremely feeble at 27000 C. M. S. and become more clearly visible at 13500 and 4500 C. M. S. After 1 hour's fore-illumination the positive curvature is even very marked at 4500 C. M. S.

This second phenomenon, which, as will be explained more fully at the end of this paper, I wish to consider as the typical "adjustment phenomenon" must therefore be formulated as the fact, that after a certain duration of the preliminary exposure, it is no longer possible to obtain negative curvatures at a certain intensity of unilateral after-illumination.

If we compare with this the other tables we find that also at

[1]) Proc. Kon. Akad. v. Wetensch. Amsterdam Sept. 1913.

Explanation of signs.

+ all plants show definite positive curvature.
++ all plants show strong positive curvature.
0 no plants curved.
— all plants show definite negative curvature.
+? a few plants show slight positive curvature.
—? a few plants show slight negative curvature.

Two different signs placed in the same space e.g. ± means that the reaction after about 1 hour was according to the first of these, after about 2 hours according to the second.

No previous illumination.

No previous illumination	Energy of the unilateral illumination in C. M. S.								
	22	44	60	120	500	1000	4500	13.500	27.000
	+	++	++	++	++	++	±	—	—

TABLE I.

Intensity of the *omnilateral fore-illumination* **5.5 C.M.**

Duration of omnilateral fore-illumination	Energy of the unilateral after-illumination in C. M. S.								
	4×5.5 22	8×5.5 44	5×12 60	10×12 120	5×100 500	10×100 1000	10×450 4500	30×450 13.500	60×450 27.000
10 sec.	+	++	++	++	++	++	±	—	—
100 sec.		0	+?	+	++	++	±	—	—
3 min.			+?	+	++	++	±	—	—
5 min.		0	0	+	++	++	+	—?	—?
20 min.				+	++	++	+	+ 0	+? 0
1 hour			0	+	++	++	++	+	0

TABLE II

Intensity of the *omnilateral fore-illumination* **12.1 C. M.**

Duration of omnilateral fore-illumination.	Energy of the unilateral after-illumination in C. M. S.								
	22	44	60	120	500	1000	4500	13.500	27.000
10 sec.	+	+	++	++	++	++	±	±?	—
36 sec.	0	+?	+	+	++	++	—	±?	—
100 sec.	0	0	0	+?	++	++	±?	—	—
3 min.			0	?	+?	±??	±?	—?	—?
5 min.			0	0	0	+	±?	±?	—?
20 min.				0	+	++	++	++	++
1 hour.				+?	++	++	++	++	++

TABLE III.

Intensity of the *omnilateral fore-illumination* **25 C. M.**

Duration of omnilateral fore-illumination	Energy of the unilateral after-illumination in C. M.*S.								
	22	44	60	120	500	1000	4500	13.500	27.000
10 sec.	0	+?		+	+	+	±	—	—
36 sec.				0	+?	+?	—	—	—
100 sec.				0	?	?	—?	—?	—
3 min.				0	0	0	—?	—	—
5 min.					0	0	+?	+	+
20 min.					+	++	++	++	++
1 hour.				0	+	++	++	++	++

TABLE IV.

Intensity of the *omnilateral fore-illumination* **100 C. M.**

Duration of omnilateral fore-illumination	Energy of the unilateral after-illumination in C. M. S.								
	22	44	60	120	500	1000	4500	13.500	27.000
10 sec.	0	0	0	+?	+	++	—	—	—
36 sec.			0	0	0	0	—	—	—
100 sec.			0	0	0	0	—?	-?	—?
5 min.				0	0	0	0	+?	++
20 min.						0	+	+	++
1 hour.						+	++	++	++

these intensities of fore-illumination the sensitiveness to the positive reaction diminishes at first. Whereas at 12.1 C. M. (table II) it was always possible to obtain a positive effect, this is not so at stronger intensities. At 25 C. M. and 100 C. M. (tables III and IV) it is no longer possible to bring about a positive curvature after a fore-illumination of 100 seconds.

Just as in table I the possibility of obtaining negative curvatures disappears with increased duration of the preliminary exposure, we see also from tables II, III, and IV, after a certain period of fore-illumination, that the strongest unilateral after-illuminations no longer bring about negative curvatures. While at 5.5 C. M. the positive curvatures only occur after a fore-illumination of 20 minutes, we see that with more intense fore-illumination strong positive curvatures already occur in plants which had only 5 minutes fore-illumination.

Tables II and III show a further feature to this extent, that with more prolonged fore-illumination smaller quantities of energy suffice to give again a positive reaction, i. e. the plants become as it were more sensitive. The four tables show gradual transition and present a concordant picture. All tables demonstrate the existence side by side of at least two different processes.

In the first place after any preliminary illumination a larger amount of energy is required to bring about a positive reaction. Secondly after a certain duration of the preliminary illumination the capacity of giving negative curvatures is lost more or less completely; after more prolonged fore-illuminations only positive curvatures occur. This second process, the adjustment phenomenon, recalls the phenomena which are known to occur with unilateral illumination of greater duration. In that case also the capacity of giving negative curvatures is lost and after prolonged illumination only positive curvatures appear. Let us therefore first consider unilateral illuminations of great duration.

§ 4. *Unilateral illuminations of great duration.*

A preliminary idea may be obtained from the following table of intensities from 1.4 to about 20000 candle metre power.

TABLE V.

Unilateral illumination.

	Intensity in candle metre power.							
	1,4	5,5	12	100	450	1800	4600	20000
Negative curvature begins at	Always positive	± 4000 C. M. S					limit not determined, at about ± 10.000 M. C. S. neg.	
Negative curvature no more visible second positive curvature at		9900	18000	90000	135000	72000	± 18000	± 20000
Duration of stimulus for sec. positive curvature		30min.	25min.	15 min.	5 min.	40 sec.	4 sec.	1 sec.

Unilateral illumination according to CLARK.

	1,25	5	16	100	400	2500
Negative curvature begins at	500—900	± 900	± 2000—2500			
Second positive curv. begins at	2300	7500	18000	34000	480000	4500000

At 1.4 metre-candlepower only positive curvatures are found, but at each greater intensity there is a larger or smaller range of energy in which negative curvatures occur. Although the accuracy of the determination of the strongest light intensities was not very great, we may nevertheless say that, at all intensities from 5.5 C.M. onwards, there is a range over which negative curvatures are present. At 5.5 C.M. this range is very small, the curvatures which occur are very feeble and a positive one always precedes them. This range first increases at greater intensities and then diminishes again, but even at the greatest intensity employed, namely 20000 C.M., it was possible to obtain a negative curvature after stimulation for about half a second. If we, however, compare with this the values published by CLARK for the appearance of a negative curvature, there is a very striking difference. For the first positive reaction the energy law is valid according to CLARK, but not for the negative one. The great discrepancy between our figures depends on the phenomena at small intensities. For larger ones CLARK agrees in finding the negative reaction at a constant amount of energy, but for feebler intensities he considers that a negative curvature occurs after much smaller amounts of energy. The cause of the discrepancy is CLARK's method of working, as I have been able to show by control experiments. A plant which executes a positive phototropic curvature assumes a position in which its apex is stimulated by gravity. When the reaction caused by the last stimulus is stronger than the phototropic one, the plant assumes an upright position, which greatly resembles that due to a negative phototropic curvature succeeding a positive one. For an amount of energy from 500—2000 C. M. S. CLARK has mistaken this geotropic erection for negative phototropic curvatures.[1]) Had he made his plants, after illumination, rotate on a clinostat round a horizontal axis he would have seen no trace of a negative curvature. I desire to emphasize here, that in all my experiments control observations were made on a clinostat; by this means alone it is possible to obtain

[1]) Prof. JOST was so kind as to inform me by letter, that CLARK never rotated his plants round a horizontal axis on a clinostat.

certainty with regard to the occurrence of a negative phototropic curvature. We have thus to consider the fact that at small intensities no negative curvatures were observed, whereas at greater intensities, as indeed CLARK also found, after stimulation with a definite amount of energy the plants curve negatively. CLARK's observations were entirely at variance with the energy law. The question now arises, whether the facts, as above set forth, necessitate a limitation of the energy law to smaller amounts of energy. It seems to me that from the data obtained for negative curvatures we may not draw the conclusion that the energy law is invalid for small intensities and a long duration of the stimulus. There are so many facts in favour of the general validity of this law that it is safer to assume that the occurrence of negative curvature is *not* entirely dependent on a definite quantity of energy. It is necessary that this quantity should be supplied within a certain time, for otherwise, owing to processes to be discussed below, the effect is so much diminished, that the excitation, which is required for the negative curvature, is no longer reached.

In place of the negative curvature there arises again at all intensities employed a positive one, when the illumination is continued for a longer period. For this second positive curvature also there is a striking discrepancy between CLARK's figures and my own. My figures (as indeed those of CLARK) show convincingly that the occurrence of the second positive curvature is not dependent on a definite quantity of energy.

If we take into consideration the well-known fact, that it is not even necessary to supply this energy unilaterally, but that the latter as PRINGSHEIM has shown, may be partially replaced by an illumination from the opposite side, then the hypothesis presents itself to us that this second positive curvature arises through a process which is independent of the direction of illumination. *This process* results in a *lowering of the excitation.* In this train of thought there is therefore *no essential difference between the first and the second positive curvature.* On further consideration of the tables an additional conclusion may be drawn. We see that the duration of stimulus, i.e. the time during which illumination was necessary to induce the second positive curvature, decreases continuously at greater intensities, that is to say, that *the intensity of the process, through which the excitation diminishes is greater* according as the *quantity of energy supplied per unit of time increases.* We see therefore in unilateral illumination the same process which we have studied as *adjustment phenomenon* with omnilateral fore-illumination. In that case also the action of this process became evident after a certain period of preliminary illumination by the disappearance of the possibility of inducing negative curvatures and the exclusive appearance of positive ones.

§ 5. *The fading phenomenon ("Abklingen").*

Omnilateral preliminary illuminations render possible the closer study of a phenomenon, which is generally called fading of an excitation. By omnilateral stimulation of a plant for a longer or shorter time we obtain as response a certain insensitiveness. We

TABLE VI.

Fading of an omnilateral preliminary illumination.

Time between fore- and after-illumination	Energy of the unilateral after-illumination in C. M. S.								
	22	44	125	250	500	1000	4500	13.500	27.000
at once				0	0	0	—?	—	—
1 min.					+?	+? 0	—	—	—
5 min.			+	+	++	++	++	±?	—
20 min.		+	++	++	++	++	++	+feetle 0	—?
1 hour	+	++	++	++	++	++	+	0	—?
no fore-illumination	+	++	++	++	++	++	±	—	—

During 100 sec. omnilateral fore-illumination with an intensity of 25 C. M.

TABLE VII.

Fading of an omnilateral preliminary illumination.

Time between fore- and after illumination	Energy of the unilateral after-illumination in C. M. S.								
	22	44	125	250	500	1000	4500	13.500	27.000
at once				0	+	++	++	++	++
1 min.				+?	+	++	++	++	++
5 min.			+?	+	++	++	++	++	+
20 min.		+?	++	++	++	++	++	+	±?
1 hour	+?	+	++	++	++	++	++ +	±? 0	—?
no fore-illumination	+	++	++	++	++	++	±	—	—

During 20 minutes omnilateral fore-illumination with an intensity of 25 C. M.

can then see how this insensitiveness gradually disappears again; for this purpose the plant must be left in the dark for some time and the slight residual sensitiveness which remains at that moment must be determined by observing the magnitude of the reaction to a given stimulus. In tables VI and VII the values are given relating to a preliminary illumination of ·25 candle-meter power during 100 secs. and 20 mins. respectively (see also table III).

From table VI we see that the possibility of obtaining positive curvatures has returned after only one minute has elapsed between the end of the omnilateral illumination and the beginning of the after-illumination. After 1 hour the original sensitiveness for the positive reaction has returned more or less completely. It is however remarkable that at 4500 C. M. S. after an interval of 5 mins. between fore- and after-illumination no negative curvature occurs again, but instead a strong positive one. We see that here also through the omnilateral illumination during 100 secs. the adjustment process has been put into action, which process has continued *in the dark* and resulted in the large quantity of energy giving not a negative but a positive curvature. But the intensity of this process also diminishes in the long run, so that after 60 minutes the negative reaction again begins to be evident.

In table VII we see the return of the sensitiveness for positive curvature as well as the possibility of a negative reaction. In this case, however, neither the original sensitiveness for positive curvatures, nor that for negative ones is completely reestablished after 1 hour.

§ 6. *Omnilateral after-illumination.*

Following PRINGSHEIM, I investigated together with omnilateral fore-illumination, the influence of an omnilateral after-illumination. The simplest case imaginable, with two successive illuminations, is that of a brief illumination from one side followed by one of equal strength from the opposite side. Then the result is that the plant remains straight. If there is an interval between the two exposures even of only 2 minutes, the curvatures occur separately, so that there is first a curvature in the direction of the first exposure and then in that of the second.

TABLE VIII

105 C.M.S. (7×15) immediately afterwards in the opposite direction 105 CMS (7×15). No curvature.

1 min.	„	No curvature
2 min.	„	apex curves first one way, then the other way
4 min.	„	first one way, then slightly the other way
8 min.	„	first one way then strongly the other way

Clark also paid attention to bilateral illumination and since his results differ from my own, I made a series of observations, collected here in table IX, for special comparison with his figure 7. This table refers to successive illumination from two sides with an intensity of 16 candle metre power. After the first exposure the plants were turned through 180° and illuminated from the opposite side. It is found that as long as a certain interval elapses between the beginning of the two stimuli, each is expressed independently. If for instance

TABLE IX.

Successive illumination from two sides.

Duration of the first exposure.	Duration of the second exposure					
	10 sec.	30 sec.	60 sec.	90 sec.	180 sec.	600 sec.
30 sec.	+	0	—	—	—	—
60 sec.	+	+	±	±?	—	—
90 sec.	+	+	±	±?	—	—
180 sec.	+	±?	±	±	±	±
300 sec.	±	±	±	±	±	±
600 sec.	±	±	±	±	±	± +?

Intensity of both exposures 16 candle metre power.
\+ signifies curvature in the direction of the first illumination.
— signifies curvature in the direction of the second illumination.

the illumination is first for 60 sec. from one side, and is then followed at once by the same quantity of energy from the opposite

TABLE X.

Unilateral illumination followed by omnilateral after-illumination.

Duration of the unilateral fore-illumination	Duration of the omnilateral after illumination			
	35 sec.	100 sec.	300 sec.	600 sec.
30 sec	++	±	—	— 0
60 sec	++	±?	±??	—
180 sec.	+	++ top. —	±	—
300 sec.	±	±?	±?	—

Intensity of fore- and after-illumination 12 candle metre power.
\+ signifies curvature in the direction of the first (unilateral) illumination.
— signifies curvature in a direction opposite to that of the first illumination.

side, the two curvatures occur *separately one after the other.* CLARK makes no mention of the first occurrence of the curvature in the direction of the first illumination, and this deprives the phenomenon of its surprising feature.

Let us finally consider table X for an *omnilateral* after-illumination. Although carried out with a somewhat weaker intensity, it may very well be compared with CLARK's fig. 4. In this case also CLARK makes no mention of the positive curvature which occurs first and only gives the negative values. Had the after-illumination here not been omnilateral, no new result would have been obtained, but since all sides were afterwards exposed to an equal amount of energy, the phenomenon is somewhat more complicated. We must come to the very plausible conclusion, that after-illumination has not the same effect on all sides, but has a different effect on the side which had already been illuminated unilaterally. This results in a separate production of the curvatures, first in the direction of the first illumination and then in the opposite one. There is not the slightest reason to call a curvature, in a direction opposite to the first illumination, *negative.*

§ 7. *Summary.*

In conclusion a few results of this investigation may be considered in their mutual relationship.

The observations with *bilateral illumination* (table VIII) show, that when we apply to a plant two stimuli by illuminating first one side and then the opposite side, each stimulus results in a visible ipsilateral curvature, as long as a certain time intervenes between the two exposures. This is very marked when the interval between the two inductions is long and less so with progressively shorter intervals until, when the interval is very short, only very slight apical curvatures are seen. This suggests that also when the two sides are illuminated simultaneously, both stimuli would produce a tendency to curve, which tendencies are not expressed because they are simultaneous, equal and opposite, and therefore annul each other.

The phenomena of *omnilateral* illumination are in complete agreement with this. Here also, under certain conditions, there may occur a curvature towards that side, which has had no preliminary unilateral illumination. An *omnilateral illumination* must therefore be regarded as the *summation of unilateral* ones.

A series of experiments, which are not described here, has shown me, that when a plant is illuminated *simultaneously* from two opposite sides with the same intensity, and when the illumination is then continued on one side, results are obtained completely analogous to those with omnilateral instead of bilateral fore-illumination. It need cause no surprise, that with a *bilateral* illumination, the excess which must be given on one of the sides, to obtain an ipsilateral curvature, must be greater, in proportion as the tendency to curvature on the other side is stronger. This is the same phenomenon, which we have observed after an *omnilateral* fore-illumination. The quantity of energy, which had to be given in one direction, in order to obtain a positive curvature, was greater in proportion as the previous illumination was more intense.

There is no reason to regard this so-called smaller sensitiveness of a previously illuminated plant, which only depends on the necessity of overcoming a tendency to curve, as an adjustment phenomenon. Rather should this name be reserved for the process which we have here always called adjustment process. We have been able to observe how it is affected both by unilateral and by omnilateral illumination.

Bilateral illumination can also give some explanation of the fading phenomenon (§ 5).

We saw that, as the intervals between the two opposite illuminations become longer, the curvatures show better. This gives us a new point of view with regard to the fading process, which the omnilateral illumination enabled us to study.

Here, with the time which elapses between the first stimulation (omnilateral fore-illumination) and the second one (unilateral after-illumination), the power of the latter of becoming visible increases. This manifests itself in the phenomenon that, the longer the interval has lasted, the smaller is the amount of energy required to produce a visible curvature. We must therefore assume that the gradual return of the original sensitiveness is the result of the fact that a tendency to curvature can express itself more strongly when a longer period has elapsed since the last stimulation.

Utrecht, Botanical Laboratory.

Chemistry. — *"The Allotropy of Copper"* I. By Prof. ERNST COHEN and Mr. W. D. HELDERMAN.

1. In studying the earlier literature on copper we found certain indications which justified the presumption that this metal is capable of existing in different allotropic modifications. This presumption had been strengthened by the results of our investigations on tin, bismuth, cadmium and zinc.