corpus geniculatum mediale, the more remarkable because therein many cells are lost, only there, were the bracchium conjunctivum from the ganglion quadrigeminum posticum enters in the corpus mediale. At the same time the atrophy in the left bracchium conjunctivum is more important than that on the right side. The preponderance of the atrophy in the left bracchium, in accordance with the atrophy of the lateral lemniscus described before, is considered by the speaker as being occasioned by the encephalitic process. This focus was not situated (or only to a very small extent) in the temporal radiation of the corona radiata. It is not followed by an intense atrophy in the homolateral corpus geniculatum mediale, and therefore, cannot in itself be held answerable for the auditory defect of the animal.

This deaf-born white cat with the blue eyes consequently may not be considered to be a deaf variety of the genus cat. It is a pathological product. An encephalitis, probably during the intra-uterine life, has destroyed a part of the left hemisphere (not the so-called auditory radiation) and occasioned a hydrocephalus internus. Its pression became a danger to all the systems at the surface of the ventricles. More especially those systems were endangered that were threatened from both sides by compression according to their position on the border of the recessus lateralis. The stria acustica was destroyed in that way.

Botany. — "*On the investigations of* Mr. A. H. BLAAUW *on the relation between the intensity of light and the length of illumination in the phototropic curvatures in seedlings of Avena sativa.*" By Prof. F. A. F. C. WENT.

Some years ago WIESNER[1]) attempted to ascertain, what is the minimum intensity of light to which various plants still react phototropically. He found, for instance, that with the epicotyl of *Pisum sativum* and the hypocotyl of *Lepidium sativum* the limit of sensitiveness is not yet reached at 0.054 normal candle power. (WIESNER expresses it in a unit which is equal to 6.5 Spermaceti candles). For the epicotyl of *Phaseolus multiflorus* the limit is exactly at 0.054 normal candle power. While in this case, the author does not mention the duration of the experiments, he states for the epicotyl of

1) J. WIESNER. Die heliotropischen Erscheinungen im Pflanzenreiche. Wien 1878. p. 178—180.

Vicia sativa, that, at an intensity of 0.054 N.C., the curvature began to appear after 3 hours and 45 minutes, whereas the same organ in *Vicia Faba*, with light of the same strength, did not show any curvature even after 48 hours. In none of these cases, therefore, has an attempt been made to find the minimum period, during which light of a given intensity must act on a plant in order to produce a phototropic curvature. Later FIGDOR [1]) carried out similar experiments; here only his conclusion can be mentioned, that the inferior limit of phototropic sensitiveness is below 0.0003262 normal candle power for seedlings of *Lepidium sativum*, *Amarantus melancholicus ruber*, *Papaver paeoniflorum* and *Lunaria biennis*.

CZAPEK [2]) on the other hand has been engaged on a determination of the presentation-time; by this he means the minimum period of unilateral illumination, required for the subsequent production of a phototropic curvature. For seedlings of *Phalaris* and of *Avena* this period is stated by him to be about 7 minutes, although he furnishes no data as to the intensity of the light employed. Presumably the author did not perceive the necessity of such data, because his investigation was almost wholly concerned with geotropism, where the idea of presentation-time, without further specification, has a pretty definite meaning, because we are concerned with the constant force of gravity.

The question, whether there is a connexion between this presentation-time and the intensity of the light, was however close at hand. In his further investigation, on the perception of phototropic stimuli, Mr. A. H. BLAAUW has also taken up this question in my laboratory; he has arrived at some very striking results, about which I wish to make this brief preliminary communication.

The experiments were performed with etiolated seedlings of *Avena sativa*, the coleoptile of which is extremely sensitive to light stimuli, as is well known since the investigations of DARWIN and of ROTHERT.

For the weaker intensities an Auer von Welsbach burner (incandescent gas light) was used; it was kept very constant by means of a gas-pressure regulator. By placing the objects at varying distances from the lamp, and, where necessary, by screening the light through smoked glass, and further, by letting the light fall on a plate of opalescent glass with a diaphragm, which in its turn acted as source

[1]) W. FIGDOR. Versuche über heliotropische Empfindlichkeit der Pflanzen. Sitz ber. d. Math Naturw. Classe d. K. Akademie der Wissensch Wien. Bd. CII. Abth. I 1893, p. 45.

[2]) F. CZAPEK. Weitere Beiträge zur Kenntniss der geotropischen Reizbewegungen, Jahrbücher für wissenschaftliche Botanik. Bd. XXXII. 1898. p. 185.

of light, all possible intensities were obtainable, from 100 Hefner candles downwards. The intensity was measured by means of a WEBER photometer. The gaslamp was outside the room containing the experimental plants, so that the latter were protected against any harmful effect of coal-gas.

For greater light intensities the electric arc-lamp of a lecture lantern was used, and by concentrating its light through lenses, strengths up to 48000 Hefner candles were obtainable.

The period of illumination varied from 13 hours to 0.001 second; the very short periods were obtained by means of a photographic instantaneous shutter with slit.

The plants were now placed at various distances from the source of light; they were illuminated for a given time and were then left in the dark and were examined for phototropic curvature after about 2 hours. When the distance and time had been properly chosen, a well-marked limit was found to occur, so that below a certain strength of light no curvature occurred, whereas above that strength all or nearly all the seedlings were bent towards the light. It may be said, therefore, that with a given exposure-time, a certain minimum intensity of light is required for perception, or, more correctly, for the production of a reaction, since of the actual perception of a light stimulus we know nothing.

It was already a striking result, that while, as stated above, the presentation time was assumed to be 7 minutes, Mr. BLAAUW in his experiments still obtained a reaction when the exposure was diminished to 0.001 second, provided the light was very strong.

The results become still more important if expressed numerically, as in the following table. The first column gives the length of the exposure, the second the corresponding intensity of the light (in Hefner candles) which just sufficed for a phototropic reaction; the third column gives the product of these two magnitudes, the time being expressed in seconds, so that the product might be called candles-seconds. In other words, the third column indicates in every case, how much light should have been allowed to fall on the plant during one second, in order to give the same amount of light as in the experiment.

I (Exposure).		II (Intensity of light).	III (Candles-seconds).
13	hours	0,000439 H.C.	20,6
10	,,	0,000609 ,,	21,9
6	,,	0,000855 ,,	18,6
3	,,	0,001769 ,,	19,1

I (Exposure).		II (Intensity of light).		III (Candles-seconds).
100	minutes	0,002706	H.C.	16,2
60	,,	0,004773	,,	17,2
30	,,	0,01018	,,	18,3
20	,,	0,01640	,,	19,7
15	,,	0,0249	,,	22,4
8	,,	0,0498	,,	23,9
4	,,	0,0898	,,	21,6
40	seconds	0,6156	,,	24,8
25	,,	1,0998	,,	27,5
8	,,	3,0281	,,	24,2
4	,,	5,456	,,	21,8
2	,,	8,453	,,	16,9
1	,,	18,94	,,	18,9
2/5	,,	45,05	,,	18,0
2/25	,,	308,7	,,	24,7
1/25	,,	511,4	,,	20,5
1/55	,,	1255	,,	22,8
1/100	,,	1902	,,	19,0
1/400	,,	7905	,,	19,8
1/800	,,	13094	,,	16,4
1/1000	,,	26520	,,	26,5

It follows at once from columns I and II that with a shorter exposure the strength of the light has to be increased, in order to obtain a curvature. The calculated values in column III show, in addition, that the intensity of light is inversely proportional to the length of exposure, or, in other words, that a definite quantity of light, independent of the exposure-time, is required to produce a reaction. It is true that the values in column III are not identical, but they clearly oscillate about a mean. Perfect identity cannot be expected in experiments of this nature, when it is remembered that the limit between curvature and non-curvature cannot always be determined exactly; moreover the oats seedlings are of course subject to individual variations, which could only be eliminated by making for each determination a long series of experiments; finally external conditions of humidity, temperature, etc. could not be kept perfectly constant in the various experiments.

There was not much point in choosing exposures of less than 0.001 second, nor of more than 13 hours, since the results obtained show clearly that the essential condition for the production of a phototropic curvature is the supply of a definite quantity of radiant

energy; whether this quantity be supplied in a very short time, or only extremely slowly, is a matter of indifference. This result is therefore in complete agreement with PFEFFER's view (at least as far as luminous stimuli are concerned) that the action of a stimulus is to be regarded as a phenomenon of "Auslösung".

A similar critical value for the stimulus has also been observed for the human eye. It is certainly very difficult to compare human observations with reactions of plants under the influence of light, but the observations of BLOCH and CHARPENTIER nevertheless indicate a close analogy between the two sets of phenomena. This is most readily shown by quoting a paragraph from the latter author[1]):

"Nous avons vu le minimum perceptible varier pour des durées de l'excitation allant de $^{3}/_{1000}$ à $^{125}/_{1000}$ sec. Dans ces conditions le minimum perceptible varie toujours sensiblement en raison inverse de la durée de l'excitation. Si la lumière est intense, elle produira cet effet en moins de temps, si elle est faible, elle devra, par contre, durer davantage. Pour que la sensation se produise il faut que, sur une zone rétinienne donnée et dans un certain temps, il arrive pour ainsi dire *une masse constante de lumière*, peu importe que cette masse se distribue sur un grand ou sur un petit espace et qu'elle arrive vite ou lentement sur la rétine. C'est là un fait important, dont il conviendra de rechercher les analogies sur d'autres territoires sensoriels."

From observations, published by BACH[2]) we may perhaps deduce, that something of the same nature holds good for geotropic curvatures as has been found by Mr. BLAAUW for phototropic ones. I hope that further investigations in my laboratory will bring certainty on this point.

Utrecht, September 1908.

ERRATUM.

p. 62 l. 12 from the top: for *uniform* read *uniformly*
p. 183 l. 14 „ „ „ after „*hydrogen line*" insert *C*

[1]) CHARPENTIER. Archives d'Ophthalmologie. X. 1890, p. 122—123.

[2]) H. BACH. Ueber die Abhängigkeit der geotropischen Praesentations- und Reaktionszeit von verschiedenen Aussenbedingungen. Jahrb. für wiss. Botanik. Bd. XLIV. 1907, p. 86.

(October 28, 1908).