On boiling the dibromide with zinc dust and alcohol the bromine is eliminated and the unsaturated ketone can then be readily separated by distillation in a current of steam. After purification via the semicarbazone it is obtained as a colourless liquid which melts at —7° [1]) and boils at 235° $SG_{11,5}$ 0,848. MR = 52,47 (calculated for $C_{10}H_{20}O$ =,52,51).

The alcohols from the trawas oil obtained in the treatment with semicarbazide may be isolated in a similar manner. In this case a solution of bromine in carbon tetrachloride may be used.

The saturated alcohol proved to be methyl-n.-nonylcarbinol. It has a left handed rotation[2]) $a = - 5°.40'$ ($l = 1$ dM.). On oxidation with chromic acid in sulphuric acid solution methyl-n.-nonylketone is formed which was identified by the semicarbazone melting at 124°.

The unsaturated alcohol also has a left handed rotation ($a = - 5°$ 10° $l = 1$ dM.). The boiling point was situated at 233°; $Sp.Gr_{10} = 0,835$. On oxidation with chromic and sulphuric acids a ketone was obtained the semicarbazone of which melted at 113° whereas by oxidation with potassium permanganate 2-ketodecanic acid was formed. This alcohol therefore, consists of undecene (1) ol (10).

The results of this research will be communicated more fully elsewhere.

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Botany. — *"Investigation of the transmission of light stimuli in the seedlings of Avena"*. By P. C. VAN DER WOLK. (Communicated by Prof. F. A. F. C. WENT.)

(Communicated in the meeting of September 30, 1911).

§ 1.

The investigations, which are recorded in this preliminary communication were carried on in the Botanical Laboratory at Utrecht, in a phototropic room which, in order to eliminate the harmful constituents of the air, is isolated from the laboratory building and forms part of the group of hothouses in the Botanic Garden. Accordingly these experiments have in general been carried out at higher

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[1]) This melting point must be given with some reservation as the unsaturated ketone may possibly contain traces of the saturated compound formed during the action of the zinc dust. These cannot affect to any extent the other properties.

[2]) POWER and LEES (Soc. 81, 1593 [1902]) found in Algerian essential oil of Rue an active methyl. n. nonylcarbinol $\alpha = - 1°18'$ ($l = 0.25$ dm.).

temperatures and with greater degree of moisture than is usually the case, but all this with favourable results to the experimental material. A further great advantage as regards technique was due to the quicker course of separate experiments, a point to which in this paper further reference will be made.

By means of a ventilator fresh air is introduced directly from outside, so that the atmosphere in the phototropic room always remains pure; at the same time the temperature can be maintained more or less constant, for without ventilation the temperature would be raised as a result of the burning of red lights. The lighting is done electrically so that, briefly, this phototropic room is entirely arranged in accordance with the requirements of modern investigation on the physiology of stimulation.

In this section I must at the outset call attention to an important phenomenon that has not yet been observed by investigators of stimulation-phenomena and that can give rise and doubtless has given rise to faulty or at least to unreliable results. I refer here to the great sensitiveness of the coleoptile of Avena to contact-stimulation, an observation which may perhaps in the future be extended to other seedlings. This sensitiveness to contact-stimulation was first noticed when it was found that phototropic curvatures can be inhibited by rubbing with the finger on the non-illuminated side. Since I was fully occupied with other experiments, a further investigation of this newly-discovered phenomenon was postponed, and I limited myself to a few very preliminary experiments, with the intention of obtaining a rough idea of the nature and degree of this sensitiveness to contact-stimulation. With some objects of widely differing degrees of hardness the coleoptile was rubbed on one side, in red light, while light stimulation was excluded. The following table shows the results obtained.

Object.	Number of times rubbed up and down.	Beginning of Experiment.	Curvature first noted by naked eye.	Hence a curvature arose after:
wood.	10 $\times$	2^h 25.	2^h 53.	28 minutes.
wood.	20 $\times$	2^h 30.	2^h 46.	16 minutes.
wood.	50 $\times$	2^h 36.	2^h 45.	9 minutes.
Camel's hair brush.	75 $\times$	2^h 15.	2^h 43.	28 minutes.
soft gelatine.	.. 200 $\times$	3^h 11.	3^h 48.	37 minutes.

Naturally the first thing that strikes one is the great rapidity with which, to the naked eye, the reaction sets in; the next thing worthy of attention is the strongly marked parallelism between the amount of energy applied and the time of curvature, which hitherto has not really shown itself in the physiology of any stimulation effect at one and the same temperature of 18° C. Further we see that the softer the object is the longer must it be rubbed in order to obtain corresponding times of curvature.

It is also certainly worthy of note that one can quite well obtain a contact curvature with soft gelatine, although after rubbing longer and waiting longer; we here recall the studies of PFEFFER on tendrils. In short, although these facts give only a cursory and very imperfect representation of the sensitiveness to contact-stimulation of the coleoptiles of Avena, they are doubtless remarkable enough to be worked out in a further investigation.

Now this sensitiveness to contact-stimulation plays a very important part in experiments with the coleoptiles of Avena and when it is neglected may lead to all kinds of erroneous and unexpected results.

A knowledge of the sensitiveness to contact-stimulation and of the typical contact curvatures was of the greatest importance in those of my experiments where it was necessary that the coleoptiles should be touched in various ways, either by cutting them, or by placing on them little caps or by covering them with closely fitting little cylinders; every investigator in this field must above all make the necessary preliminary studies of this point. For a few striking cases this paper may be referred to.

At the same time the investigation of the susceptibility of the coleoptiles of Avena to stimuli has been enriched by a new field of work, which in certain respects raised the importance of this plant for the physiology of stimulation, yet, on the other hand, experimentation with so extremely sensitive an object thus becomes extraordinarily difficult.

In the second place a few words must be said in this introductory section with regard to the determination of phototropic sensitiveness, as it has been carried out in the present investigation and as it might perhaps be carried out with advantage in all future phototropic experiments. The earlier view adopts as measure of sensitiveness, the quantity of energy which is necessary for the crossing of the threshold of stimulation; the smaller the amount of energy required for this, the greater the sensitiveness of the plant. But the recent investigations

of ARISZ[1]) have made us somewhat sceptical with regard to the existence of a threshold of stimulation; fairly conclusive experiments have rendered its existence very doubtful. On the other hand there certainly exists a definite maximal curvature which appears after a definite time and at any definite temperature corresponds to a definite quantity of energy.

The more sensitive a plant is, the less light is necessary to produce one and the same definite maximal curvature. Now in order to be able to compare plants of different sensitiveness with one another it is necessary to have a standard to indicate that the different quantities of energy all correspond to one and the same definite maximal curvature.

For practical considerations the angle of curvature cannot be taken as this standard, seeing that its determination presents great difficulties and would demand much time. Further, just as little can we accept the maximal curvature which is still just visible to the naked eye, because we can observe exceedingly small curvatures with the naked eye; and this would be a source of individual errors; but this method is moreover especially objectionable, because these curvatures only arise after a long time and the longer an experiment lasts, the more unfavourable it is for the object and for the result, especially in the case of seedlings which are operated upon by one or another method.

We must indeed above all use a method in which the duration of the experiment shall be as short as possible. And seeing that the above described maximal curvature occurs after a definite time and it being so remarkable that, when two seedlings of different sensitiveness get such a quantity of light, that they produce the same maximal curvature, this maximal curvature is attained in the same time, this is also an indication, to express the measure of maximal curvature in terms of the time in which it arises. We are then able to make this time as small as possible, in which endeavour we are helped by carrying out the experiments at higher temperatures.

In this investigation I have worked with maximal curvatures which occur at 25—27° C. after half an hour, an interval which might even be somewhat shortened in the favourable condition of high temperatures. In order to obtain this maximal curvature after half an hour, a definite quantity of energy is necessary. If now a plant is more sensitive than the object with which it is being compared

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[1]) W. H. ARISZ. On the connection between stimulus and effect in the phototropic curvatures of seedlings of Avena sativa. (Proceedings Kon. Akad. v. Wetensch. March 1911.

we seek for the quantity of energy which is again necessary in order to give a maximal curvature, after half an hour. These two maximal curvatures will then be of the same magnitude, but the quantity of energy necessary, will be less in the case of the more sensitive plant. Further, whenever the sensitiveness is mentioned, the temperature should always be given, as this is of very great influence on the sensitiveness.

Observation of the maximal curvature takes place by means of a glass plate provided with a millimetre scale on which an image of the coleoptile is projected by means of a lens. Nevertheless, with some experience it is possible to observe with the naked eye the maximal curvature by repeatedly looking at and comparing the experimental objects. Of course red light is always used.

It so happens that BLAAUW and FRÖSCHEL have always worked with the quantity of energy, which is necessary to produce a maximal curvature after $1^1/_2$—2 hours, just visible to the naked eye. But as they did not pay special attention to the maximum of curvature, the values they obtained for the quantity of energy are somewhat divergent.

Finally, it must be specially remembered that the coleoptiles execute their strongest nutation in the median plane, i.e. the plane passing through the longitudinal axis of the grain [1]), so that stimulation should always take place in a direction perpendicular to this, in the transverse plane therefore.

§ 2.

It is fairly intelligible that, now when the physiology of stimulation has developed more and more in every direction, renewed interest is taken in investigating the problem of transmission of stimulus, at the same time with some hope that from this side also a step might be taken towards the solution of the problem of stimulus, a problem obviously beset with great difficulties.

Various investigators have already had the study of the transmission of stimuli in plants on their programme of work, but for all that it has remained in many aspects an obscure question and unfortunately the points at issue have quite recently again increased in number.

Thus in this section I wish to criticise the recent investigation of BOYSEN JENSEN [2]), which, by its remarkable and somewhat unexpected

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[1]) A. A. L. RUTGERS. De invloed der temperatuur op den praesentatietijd bij geotropie. (Diss. Utrecht 1910)

[2]) P. BOYSEN JENSEN. La transmission de l'irritation phototropique dans l'Avena. (Acad. roy. d. Sc. et des lett. de Danemark, 1911. N⁰. 1.

23

results as well as by its violent conflict with the results of FITTING[1]) offers ample inducement to subject this alleged localisation of the transmission of phototropic stimuli to a new inquiry.

So far as concerns experiments in the atmosphere of a room of usual humidity and temperature, my experiments were carried out in just the same conditions as those of BOYSEN JENSEN; they took place in the phototropic room of the laboratory building, at a temperature of 17° C. and a humidity of 70 %. The illumination was always with the very suitable amount of energy of 400 candle-meter seconds.

The phototropic curvature effect which was produced by unilateral illumination of the apex, transmits itself in the course of a certain time to the base, a phenomenon that since DARWIN is interpreted as the transmission of the phototropic stimulus.

Now if BOYSEN JENSEN makes a transverse incision on the illuminated side, which I will always speak of as the front or anterior side of the coleoptile, then he sees that a basal curvature nevertheless, arises in unilateral illumination of the apex. If on the other hand, an incision is made on the posterior side he observes that in the atmosphere of the room, only the apex curves phototropically, while the base remains erect; in a space saturated with water vapour the base indeed curves phototropically in the latter case, but the curvature remains absent, when a mica plate is introduced into the incision. These results cause BOYSEN JENSEN to conclude that the stimulus is only transmitted along the posterior side. Even in my very first experiments I found that the influence of the incision is much greater than might be concluded from BOYSEN JENSEN's paper. When a unilateral incision is made I perceived a really considerable curvature directed to the side of the wound; this curvature must probably be in part put down to some traumatic stimulus, seeing that a curvature also takes place in air saturated with water vapour; since in that case, however the curvature occurs in much less degree, this is an indication that in the ordinary room air the curvature is in the first place due to the great amount of evaporation from the wound. This view is still further confirmed by the following experiment. If we make a unilateral incision and leave the coleoptile thus operated upon for about half a day in a space saturated with water-vapour, it will gradually recover from the curvature which had arisen; various coleoptiles then resume their normal erect position; not that the wound itself closes through the apposition of the parts separated

[1]) H. FITTING. Die Leitung tropistischer Reize in parallelotropen Pflanzenteilen. (Jhrb. f. wiss. Bot. Bd. 44. 1907).

by the cut; this never happens; the cut under all circumstances becomes speedily a gaping wound. If we now bring a coleoptile which has once more become erect, into the ordinary air of a room which by continuous ventilation is kept as pure as possible, then we again see a strong curvature take place towards the wound.

Evaporation doubtless plays a predominant part or, generally speaking, the influence of the wound is very great in the ordinary atmosphere of the room. Is it therefore to be wondered at, that with a cut on the posterior side and with unilateral illumination of the apex in front, the base does not curve phototropically in the ordinary atmosphere of the room?

As will follow from further experiments, the only right interpretation is that through evaporation from the wound the base has an inclination to curve backwards, so that its phototropic curvature is annulled. That the apex itself under these circumstances indeed curves photo-tropically, is one proof the more of its extraordinary sensitiveness to light.

These experiments emphatically show that any experiments in which incisions are made must per se take place in a space saturated with water-vapour: this requirement has not always been fulfilled, so that we have data in plant physiology on so-called traumatic stimuli and their transmission, which probably must be ascribed more to an evaporation-effect than to the effect of a stimulus; this applies for instance to the transmission of traumatic stimuli by dead elements.

When Boysen Jensen finds that the base, in a space saturated with water-vapour, and with a posterior cut, curves phototropically when the apex is illuminated (I call the illuminated side the anterior), then this is caused by the fact that on account of the great decrease of evaporation, the force directed backwards is also much smaller and therefore the phototropical effect is hardly counteracted at all. But we must at once add, that in the latter case the extent of the basal phototropical curvature is dependent on the size of the wound but above all on the time, during which the incised coleoptiles remained in the atmosphere of the room before being brought into the space saturated with water-vapour. A few minutes, exposure to the air of the room can indeed be sufficient to prevent the phototropic curvature of the base in the atmosphere saturated with water vapour. Alike in the experiments of Boysen Jensen and in my own the incision was always made in the ordinary air of the room, because of the very considerable difficulties that attend the performing of the various operations and preparations directly within a space saturated with water vapour.

23*

Therefore it is again easily understood why Boysen Jensen obtained no phototropic curvature of the base in air saturated with water vapour when he introduced a mica plate into the posterior incision. It always takes some time to introduce a mica plate into the very fine incision, when working in a weak red light with an average of 8—10 seedlings, and taking care not to handle the objects more than is necessary; above all great care is necessary in placing the little cylinders round the bases. The result of this is, that the seedlings have already been exposed too long to the air of the room to give a phototropical curvature of the base, because the influence of the evaporation from the wound has already become much too great. This is my reason for repeating Boysen Jensen's experiments in such a way, that special precautions were taken to avoid making the cut needlessly large and that the seedlings operated on were only exposed to the influence of the air of the room for a minimal time.

For this purpose each seedling is treated separately and finished completely; the cut on the posterior side is only made in the coleoptile and in particular does not extend to the leaves since these by an evaporation curvature counteract any curvature which might occur in the base of the coleoptile. Hence a semi-circular cut is made, into which a crescent-shaped piece of tin-foil is introduced, so that the wound is really completely shut off. Next the base is covered with a little cylinder of black paper and the coleoptile so treated is *at once* covered by a bell-jar saturated with water vapour. Thus, from a box of seedlings, each coleoptile is separately worked through; specimens, in which the operation does not succeed readily, are definitely excluded. When all the seedlings have been thus treated, unilateral illumination is admitted.

The result of this experiment was according to expectation, but nevertheless equally surprising and convincing: for in these conditions the base actually executed a clear phototropic curvature. With this not only is the interpretation of Boysen Jensen disproved, but it is moreover shown that his results must really be ascribed to some influence of the evaporation from the wound.

But also in a quite different way, I have succeeded in showing the inaccuracy of Boysen Jensen's interpretation. As has already been mentioned, when a cut is made on the posterior side. the base shows a strong curvature towards the wound. Yet if the apex is illuminated on its anterior side then the base remains erect, and does *not* curve towards the wound as indeed Boysen Jensen found. The question which at once presents itself is *why*, in this last case, the base does not curve towards the wound, for if Boysen Jensen's

localisation hypothesis is correct, if by the cut on the posterior side, provided with a mica plate, the phototropic connection between the base and the apex is indeed broken, then it must still be a matter of indifference to the base, whether the coleoptile is illuminated or not. Now, however, since we see that on illuminating the apex, the base does not curve towards the side of the wound, the suspicion arises that there is still, along the front side of the coleoptile, a transmission of the phototropic effect. This suspicion was confirmed when in addition to that on the posterior side, an anterior cut was made and was provided with a mica plate, so that the alleged transmission in front would be inhibited. I have carried out the experiment in such a way that I made first a cut on the anterior side, after which I let the plant recover from the operation as described above, for about three-quarters of a day in a space saturated with water-vapour, so that it again became erect. Then on the posterior side a cut was made and provided with a mica-plate; immediately afterwards the apex was illuminated, while for the rest I allowed the plant to remain in the ordinary air of the room. This is therefore really the fundamental experiment of BOYSEN JENSEN, only with the difference, that by taking special precautions, transmission on the front side is also prevented. The result of this experiment was again completely convincing; the base now curved indeed towards the side of the wound in spite of the illumination at the apex. The cut on the anterior side indeed exerts an influence, but the fresh cut on the posterior side preponderates and over-rules also the transmission of stimulus which possibly might have taken place from both incisions. This result furnishes proof that by the cut on the front side "something" is really held back which before prevented the base from curving towards the side of the wound. What can this "something" be other than a phototropic curvature effect? Therefore here also on the anterior side transmission of stimulus takes place.

The following experiment furnishes direct proof that the transmission of stimulus can take place anywhere. In contrast with the foregoing experiment a cut with the arrangement of mica-plate was made both in front and behind, whilst the seedlings during the whole experiment remain in the ordinary air of the room, this again being an experiment, similar to BOYSEN JENSEN's initial experiment, with the difference that the unilateral influence of the cut on the posterior side is inhibited by a cut on the anterior side. Control experiments indeed show that in such an experiment, without further illumination, the base remains erect. Suppose we now

illumine the apex on the anterior side, then we see unequivocally that the base executes a phototropic curvature, although it is sometimes necessary to wait longer. This therefore is again proof that Boysen Jensen's hypothesis cannot be accepted, but also, that the stimulus can transmit itself past the two wounds which often overlap, that is to say, it does not necessarily take a straight course.

In short, all these experiments sufficiently show that Boysen Jensen has not interpreted his results correctly. There is no question of localisation of the transmission of phototropic stimulus. The stimulus is transmitted, from the apex to the base, along any arbitrary line, so that the results of Fitting are thus upheld once more.

§ 3.

A second problem of the phototropic transmission of stimulus, with which I have occupied myself, and shall deal in this section, is the polarity of phototropic stimulus transmission and some newly discovered facts in connection with it.

The polarity of phototropic transmission of stimulus was first of all discussed by Rothert, but as he himself truly says, was not demonstrated by him with complete certainty. Since then no one has further concerned himself with it.

When the coleoptiles of Avena are illuminated at the apex unilaterally, then the plant executes a phototropic curvature effect towards the base. If we now wish to investigate the polarity of this transmission of stimulus, we have only to illuminate the base in order further to trace to what extent any basal curvature is transmitted towards the apex. It should be clearly understood that henceforth the base and apex refer to the basal *half* and the apical *half* of the coleoptile. Accordingly before I adjusted the necessary little cylinders or caps, a very fine line of ink was made at the middle of the coleoptile, which might thus always serve as a guide. In order to be able to observe clearly the curvature of the apex, I fastened the basal part after illuminating it, by means of a closely fitting, unbendable cylinder of tin-foil, made by rolling the foil several times round a little glass-tube, of the same width as the coleoptile. During the illumination of the base the apical portion was always covered by an accurately fitting cap of tin-foil. A really great experimental difficulty arises from the sensitiveness of the coleoptile to contact stimulus. We must proceed very carefully, and a knowledge of contact-curvatures as such is of first

importance. Thus, for instance, we must take special care that the little cylinder or cap does not, by being placed obliquely, rest with its edge unilaterally against the coleoptile, as may so easily happen; this causes very troublesome contact-curvatures, which might lead to error. We may probably conclude that the reason for ROTHERT's failure in his experiments on polarity, must be ascribed to these contact-curvatures, which were unknown to him.

If we now set to work to discover whether any basal phototropic curvature effect can be transmitted to the apex then in any case we must first apply to the base such a quantity of light that it really curves, in order to be sure that the light has been perceived there. One is at once struck by the fact, *that the base is very much less sensitive than the apex*, in spite of the former not being inferior in rate of growth to the latter, especially at the higher temperatures at which these experiments were made. I made a determination of sensitiveness as described in the first section and so found that the quantity of light which is necessary to cause a just observable maximal curvature at 25—27° C., after $1^1/_2$ hours is for the base about 20000 candle meter seconds, whilst that for the apex, at the high temperature employed reaches a value of only 13 candle meter seconds. A very distinct basal curvature was only obtained with 50000 candle meter seconds, a quantity of energy with which my first experiments were performed.

The result of this first series of experiments was to show that after an illumination of the base in this way a phototropic curvature of the apex can never be observed. Now since for a possible apical curvature it might not be indifferent, with what quantity of light the base was illuminated, a large series of experiments were arranged, in which the base was illuminated with very different quantities of light, starting from 100 candle meter seconds and gradually mounting to several thousand candle meter seconds. But not in a single one of these cases could curvature of the apex be observed. *This is therefore a clear proof of the existence of a polarity, of an irreversibility, in the transmission of a phototropic stimulus.*

In order now to trace how far this polarity was dependent on the influence of any external conditions, especially having in mind gravitation, we made two new series of experiments, in which first of all suitable coleoptiles were kept in an inverted position during the whole experiment, and in addition experiments in which the coleoptiles were fastened to a clinostat with horizontal axis.

But in *neither* of these two series of experiments could any transmission from the base to the apex be traced.

Bearing in mind the great difference in sensitiveness between the apex and the base, I considered to what extent the greater sensitiveness of the apex might be caused by its being in general more transparent to light than the base, since the leaves which are found within the coleoptile, frequently do not completely fill the apex and since they are also narrower and thinner than those in the base; hence at the apex more cells of the coleoptile receive direct unilateral illumination than at the base, where the leaves are much thicker and broader and, in addition to being more opaque, offer a greater resistance to any curvatures. In order further to decide this question the leaves when very young were removed from the coleoptile, so that the base was then as transparent as the apex. However the great trouble which this gave was not rewarded by a positive result: the leafless coleoptiles behaved in exactly the same way as the normal ones.

We will now pass on to the description of some experiments, of which the results may be able to throw new light on the physiology of stimulus.This paper has always been concerned with the polarity of the transmission of phototropic stimuli; but it must be specially borne in mind, that our terminology is only based on the outward visible effect, which we shall speak of as the phototropic curvature effect; and it is the polarity or rather the irreversibility of the phototropic curvature effect which has been demonstrated in the course of this investigation. The question will now be answered as to how far the apex, even though it does not curve when the base is illuminated, is nevertheless influenced by the illuminated basal portion. Here we obtain the result that the darkened apex is indeed influenced by the illuminated base, namely in the sense that the base renders the *apex more sensitive*. For this experiment the apex is shut off by means of a closely fitting cap of tin-foil, and subsequently the base is illuminated; immediately afterwards the apex is freed and the base made immoveable by means of a closely fitting cylinder of tin-foil; then the apex is illuminated in order to determine the quantity of light which is necessary in order to establish after half an hour a maximal curvature and at the same time control plants are started in which the base had not been illuminated before, but which, for the sake of more accurate comparison, had been fitted with little caps and cylinders just as the actual plants of the experiment. The result now was that the quantity of light necessary to give a maximal apex curvature after half an hour at 25°—27° C., amounts to about 85 candle meter seconds for the control-plants, whilst for the seedlings in which the base

had been previously illuminated, the amount was only about 12 candle meter seconds. *Through illumination of the base the apex therefore became more sensitive.*

This fact is very remarkable; for let us at once lay emphasis on the fact that the adequacy of a small amount of light necessary to make the apex curve, when the base is illuminated, is not at all a question of summation; for an effective summation only occurs in unilateral stimulation, whilst in the present case the increase of sensitiveness is on every side; summation does not therefore come into consideration.

This diffuse enrichment with light energy might to some extent be compared with an all-round direct illumination of the apex, but, *and here I wish to lay special emphasis,* we know from phototropic attunement, that on the contrary an all-round illumination diminishes the sensitiveness; *the conception of sensitiveness in the present investigation is therefore completely opposed to the notion of attuning and may in no way be identified with it.*

What has been established with regard to the influence of the illuminated base on the apex was also found to be true of the influence of the illuminated apex on the darkened base.

Since in the latter case we have the difficulty of the phototropic curvature effect being transmitted to the base, the top half of the coleoptile was cut off, three minutes after the illumination of the base. Three minutes, and most probably even less, were sufficient for the base to show already the influence of the illuminated apex, again in the sense *that the base becomes more sensitive.* Control experiments prove that by means of the current of sensitiveness alone, hence without the direct illumination following upon it, a curvature of the base never occurred. All that we know of the transmission of the curvature effect from the apex makes it improbable, that in the three minutes (a time which in all probability might be further diminished), the curvature effect would have already reached the base. We can confidently say that there is also here, as in the case of increased apical sensitiveness, a current of sensitiveness which as it were travels like a shock through the plant at the moment of illumination.

§ 4.

As a result of the experiments described above, we can say that it is here very clearly found that perception and reaction are two wholly different processes. We have seen how on illumination a current of sensitiveness travels almost immediately through the

coleoptile and in it we therefore see the perception reflected. But this current of sensitiveness in itself never gives rise to curvature effect; for that, direct illumination is necessary, a second physiological principle, as it were of light which calls into existence a distinct process, namely the curvature effect, which thus manifests itself to some extent as independent of the perception process. When we seek to explain the facts described above we are thus justified in expressing in our hypothesis, the independent course of these two photo-physiological processes, and so the results of the present investigation have perhaps brought us a step nearer to the solution of the process of phototropic stimulation. I shall now attempt to construct with the facts mentioned a hypothesis which may perhaps lead to further investigations in the field of the physiology of stimulus.

Let us first of all take the really striking fact that the base is so very much less sensitive than the apex. We must duly consider that we are dealing with the following phenomenon: in one and the same small organ two parts are in proximity, only separated from each other by about 1 cm. and differing in age only by about one day, and these parts show a difference of sensitiveness to light to the extent of the apex being 1500 times more sensitive than the base. The question is whether such a difference of sensitiveness corresponds to a normal condition; can it be regarded as true under all circumstances? is it a predisposition, independent of any illumination, a difference in the constitution of the protoplasm existing apart from any effect of light?

Is it probable that the plasma of one and the same young tissue growing vigorously and healthily in every part, can in the course of one day decrease so enormously in sensitiveness that the apex possesses an almost proverbial sensitiveness, while with respect to the base there has even been a time (I am thinking of DARWIN) when the latter was regarded as insensitive to light?

Such a phenomenon must be based on something else than a decrease of sensitiveness in the ordinary sense of the word. It points to a certain definite influence which the *illumination as such* exercises on the coleoptile, and suggests a certain change which the plant undergoes by means of the illumination. If in this polarity of the sensitiveness of apex and base, we were inclined to see a suggestion of the polarity of the transmission of stimulus, the admission of a change which is brought about by the *light itself* corresponds with the fact that the polarity of phototropic transmission of stimulus is also not influenced by external circumstances which lie outside the actual illumination.

The specific change which the plant undergoes under the influence of illumination, we will call *phototonus*. The phototonus is then seen to bring about the difference in sensitiveness between the apex and base and by reason of this in the last resort, the polarity of the transmission of stimulus also.

In the foregoing section emphasis has been laid on the fact that this phototonus can absolutely not be compared to the "attuning phenomenon". This phototonus expresses itself as a wave of sensitiveness which in a short time runs through the plant organ and must, on the ground of experiment, be regarded as distinct from the phototropic curvature effect. From the experiments on the sensitisation of the base when the apex is illuminated, it is clear that the process of sensitisation is primary, and the curvature effect secondary. The rapidity with which the phototonus spreads through the coleoptile, taken in connection with the very remarkable polarity in sensitiveness of apex and base, gives rise to the surmise that we have here to deal with a polar displacement followed by a polar massing of ions; in the apex an accumulation of ions specially sensitive to light, in the base of those less sensitive to light, and it is this process which first shows itself on illumination; this phototonus would therefore be the actual process of perception; experiments prove that this process is an independent one. We then get as a secondary process the specific influence of direct light on the two accumulations of ions; this also is an independent process and is very probably of a chemical nature, a photochemical process therefore [1]. This photochemical process causes the curvature effect; to what extent the actual curvature is directly caused by any change of permeability which might be set up photochemically is left undecided. The ions in the apex which are very sensitive to light cause there also a very intense photochemical process, which in its turn brings about an equally powerful transmission towards the basal portion, while in the base the ions which are slightly sensitive to light cause a weak basal photochemical process with a correspondingly weak transmission of negligible magnitude; it is thus that the phenomenon of irreversibility of the transmission of phototropic stimulus arises.

If we take the general standpoint of the physiology of stimulus, that where there is absence of or little sensitiveness, absence of or slight transmission of stimulus is to be expected, then the well-known slowness of transmission of vegetable phototropic stimuli is explained by the fact that the base is so slightly sensitive.

1) A. H. Blaauw. Die Perzeption des Lichtes. (Recueil des Travaux Botaniques Néerlandais. Vol. 5).

To sum up, we have been able to analyse the process of phototropic stimulation into the primary electro-physiological perception process which causes the remarkable polar division of sensitiveness between the apex and the base and by this means has become the actual cause of the irreversibility of the phototropic curvature effect and in addition, secondarily, the photochemical process which brings about the curvature. Possibly we may be able to refer the decrease of the phototropic curvature effect by means of greater quantities of energy, as also rectipetality, to the origin of polarisation currents, to which the polar accumulations of ions in their turn give rise.

Utrecht, September 1911.

Chemistry. — "*The photochemical transformations of Ferri-trichloro-acetate solutions*". By Prof. F. M. JAEGER. (Communicated by Prof. v. ROMBURGH).

(Communicated in the meeting of September 30, 1911).

§ 1. When carrying out some few years ago a series of investigations relating to the photochemical transformations of certain iron-salts by exposure to the light, I noticed that the almost colourless solution, which forms, if freshly precipitated ferric hydroxide is shaken for some days, in the dark, with an excess of an aqueous solution of trichloroacetic acid, — rapidly deposits, when exposed to the light, a white crystalline substance; while, simultaneously, a colourless gas collects in the closed limb of the U-tube employed. Although a more fully detailed article on the many questions which present themselves, will appear shortly, a few preliminary communications are already following here, regarding this remarkable photo-chemical reaction.

§ 2. Originally the solutions were prepared by shaking freshly precipitated ferric hydroxide, after prolonged and complete washing, in stoppered bottles with an aqueous solution of thrichloroacetic acid for some days in the dark. The *colourless* solution may be kept unaltered in the dark for an indefinite time; but when exposed to daylight, it splits off, after some time, a white crystalline substance with a peculiar odour. If an *excess* of Fe_2O_3 is taken, the solution obtained is *orange-yellow*; it is then *not* sensitive to light, but it regains this property as soon as the solution is again rendered colourless by addition of an excess of trichloroacetic acid.