

Anal. Calcd. for $C_{17}H_{20}O_6N_4$: C, 54.25; H, 5.32; N, 14.89. Found: C, 54.00; H, 5.36; N, 14.92.

Although the sodium and potassium salts of isoriboflavin are sparingly soluble in water, the lithium salt is freely soluble.

The optical rotation of a 0.50% solution in *N*/20 potassium hydroxide half saturated with borax gave $[\alpha]^{25D} +237 \pm 1.5^\circ$ whereas riboflavin under the same conditions showed $[\alpha]^{25D} +376 \pm 1.5^\circ$. In 0.5% solution in *N*/2 lithium hydroxide half saturated with borax: isoriboflavin, $[\alpha]^{25D} +220 \pm 2^\circ$; riboflavin, $[\alpha]^{25D} +386 \pm 2^\circ$.

The polarograms were made in 0.1 *M* lithium tetraborate at concentration equal to 0.130-0.190 mg./cc. Capillary constant $m^{2/3}t^{1/3} = 2.10 \text{ mg.}^{2/3} \text{ sec.}^{-1/3}$. As indicated in Table I, polarographic constants of isoriboflavin were nearly identical with those of riboflavin.

Isoriboflavin was also prepared from 1-(*D*-ribitylamino)-6-phenylazo-4,5-dimethylbenzene by reducing the azo compound to the corresponding diamine, and condensing the latter with alloxan in acetic acid containing boric acid. The product was isolated in 67% yield and found identical with the isoriboflavin described above.

Acknowledgment.—We are indebted to Drs. R. T. Major and J. R. Stevens²² for their interest

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Summary

1. A new synthesis of riboflavin has been described consisting of the reaction between 1-(*D*-ribitylamino)-2-arylozo-4,5-dimethylbenzene and barbituric acid.

2. The coupling of 1-(*D*-ribitylamino)-3,4-dimethylbenzene with a number of different aryl diazonium salts produced predominantly the 2-arylozo compounds contaminated with significant quantities of the isomeric 6-arylozo derivative. The latter did not react with barbituric acid to form an isoalloxazine.

3. The isomeric 6-arylozo derivative was catalytically reduced to an *o*-phenylenediamine derivative which was condensed with alloxan to isoriboflavin.

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[CONTRIBUTION FROM THE DIVISION OF PLANT BIOLOGY OF THE CARNEGIE INSTITUTION OF WASHINGTON]

Organic Compounds of Magnesium and Phosphorus in Relation to Chlorophyll Formation

BY JAMES H. C. SMITH

Introduction

When etiolated seedlings are placed in the light, one of the most conspicuous changes observed is the formation of chlorophyll. During the formation of chlorophyll some transformation of magnesium compounds must necessarily take place. Whether this is a transformation of preformed organic magnesium compounds closely related to chlorophyll or a utilization of magnesium from simpler sources is uncertain. A distinction between these two types of reaction in the formation of chlorophyll would contribute to our knowledge of this synthesis and possibly lead to a clearer understanding of the photosynthetic process itself. In this research, some progress has been made toward distinguishing between these two types of reaction by comparing the amounts of magnesium attributable to chlorophyll with the total amounts of ether-soluble magnesium present at different stages of greening.

Other syntheses also occur in etiolated leaves upon illumination. In the present experiments on the greening of etiolated barley leaves, two such syntheses have been followed: the formation of total ether-soluble material, and of ether-soluble phosphorus compounds.

Inasmuch as albino leaves are abnormal in regard to the formation of chlorophyll, albino corn leaves have been examined to determine whether they are deficient with respect to other ether-soluble compounds.

Methods

Leaf Material.—The barley leaf material was obtained from seedlings grown in darkness. For convenience, the seedlings were grown in small flats of soil—25 g. of seed sowed to the flat. This amount of seed yielded over 50 g. of leaf material. About nine days after planting, the flats of seedlings were removed from the dark cabinet and illuminated for various periods of time. A 100-watt Mazda lamp, hung 40 cm. above the flat, furnished the illumination. After greening for the desired period, the leaves were harvested, cut into short lengths, and 50 g. weighed out for analysis.

A series of experiments was also run on excised leaves. The leaves were cut from the roots and the cut ends placed in vials of tap water. After the leaves had been illuminated in the manner described and for the period desired, they were cut into short lengths and 50 g. taken for analysis.

In both series of experiments, additional samples were removed for dry-weight determinations.

Analytical Procedures.—Extraction of the cut leaves was carried out by grinding them with sand under a solvent in a large mortar. Six changes of solvent were used as follows: 200 ml. of 90% acetone, 100 ml. of diethyl ether, 100 ml. of 80% acetone, 100 ml. of ether, 100 ml. of 80% acetone and 100 ml. of ether. The combined extracts were filtered and washed four times with 200 ml. of water. The ether solution was filtered into a 200-ml. volumetric flask and diluted to volume with ether.

The absorption spectrum of the ether solution was measured spectrophotometrically¹ and the chlorophyll content of the solution was determined by use of the equation published by Comar and Zscheile²: Total chlorophyll (mg./liter) = $7.12 \log_{10}(I_0/I)_{6800} + 16.8 \log_{10}(I_0/I)_{8425}$. From the weight of chlorophyll determined spectrophotometrically the weight of magnesium attributable to the

(1) Smith, *THIS JOURNAL*, **58**, 247 (1936).

(2) Comar and Zscheile, *Plant Physiol.*, **17**, 198 (1942).

chlorophyll was calculated by use of the factor 0.0271. This factor is based on the percentage of magnesium in a mixture of chlorophylls in which the ratio of chlorophyll a to chlorophyll b is assumed to be 3 to 1. The amounts of chlorophyll calculated for the samples greened for only a short time, and especially for the etiolated seedlings, are relatively too high because of the absorption of non-chlorophyllous compounds in the extracts. For the purposes of this investigation, however, correction for such absorption is unnecessary.

The total ether-soluble material was also determined. A known fraction of the ether solution was taken to dryness in a platinum dish on the water-bath. The residue was dried for about an hour in an oven at 110°, and then was weighed.

This residue was ashed with sulfuric acid and the sulfuric acid removed by evaporation. The sulfate ash was dissolved in 0.25 ml. of 6 *N* sulfuric acid and about 25 ml. of water. This solution was concentrated to small volume on the water-bath. The concentrated solution was transferred quantitatively to a 25-ml. volumetric flask and diluted to the mark with water. Measured portions of this solution were used for the determination of ether-soluble magnesium and phosphorus.

The magnesium was determined spectrophotometrically by the Titan-yellow method. The procedure of Ludwig and Johnson³ in somewhat modified form, was used. One modification was measurement of the light absorption at 540 m μ instead of at 525 m μ as recommended. Greater sensitivity was obtained by this change.

The phosphorus content of the lipoidal fraction was also determined spectrophotometrically by the formation of molybdenum blue using 1,2,4-aminonaphtholsulfonic acid as reducing agent. The absorption was measured at 700 m μ and compared with samples containing known amounts of phosphorus. The procedure of Parks, *et al.*⁴ for preparing the solution was followed.

Dry-weight determinations were made by drying portions of the leaf samples for twenty-four hours in an oven at 110°. The ash in the dried samples was found by heating the samples in a muffle furnace at 625° to constant weight.

The magnesium and phosphorus contents of the dried leaves were determined by ashing the samples with sulfuric acid in the manner described and by analyzing proportionate parts of solutions of the ash by the methods already indicated.

In order to get values convenient for tabulation, the weights of the various substances obtained by analysis have been multiplied by appropriate factors. In the tables these factors are listed with the substances to which they apply. For example, the weights of chlorophyll have been multiplied by 10⁶ to give the values recorded in the tables.

Results and Discussion

The results of the analyses performed to determine whether the formation of chlorophyll bears any relation to obvious changes in other components of leaves during greening, particularly to ether-soluble magnesium and phosphorus, are tabulated in Tables IA and IB. Comparison of the results in the two tables shows that etiolated leaves which are excised and those which are attached to their roots behave similarly on illumination with respect to the properties examined. The effects induced by illumination in whole seedlings, therefore, are not due to translocation of materials from the roots but are effects localized in the leaves.

(3) Ludwig and Johnson, *Ind. Eng. Chem., Anal. Ed.*, **14**, 895 (1942).

(4) Parks, Hood, Hurwitz and Ellis, *Ind. Eng. Chem., Anal. Ed.*, **15**, 527 (1943).

TABLE I
THE CHANGE IN WEIGHT OF CONSTITUENTS OF ETIOLATED BARLEY LEAVES DURING GREENING

A. Leaves attached to the roots.						
Hours greened	0	2	24	47	71	0 ^a
Fresh weight, g.	50.0	50.0	50.0	50.0	50.0	50.0
Dry weight, g.	3.26	3.36	3.96	4.02	3.91	3.51
Weight per gram dry weight of leaves						
Chlorophyll, g. $\times 10^6$	4.20	127	4890	7140	6660	3.49
Chlorophyll Mg, g. $\times 10^7$	1.14	34.6	1330	1940	1800	0.95
Total ether-soluble Mg, g. $\times 10^7$	52.3	101	1410	1960	2000	59.7
Total ether-soluble P, g. $\times 10^7$	265	464	1230	1450	1490	2915
Total ether-soluble material, g. $\times 10^2$	3.89	3.99	5.09	6.05	5.59	3.87
Total ash, g. $\times 10$	1.46	1.46	1.85	1.95	2.16	1.96
Total magnesium, g. $\times 10^3$	1.56	1.51	1.82	2.10	2.17	1.91
Total phosphorus, g. $\times 10^2$	1.08	1.01	1.20	1.26	1.26	1.30
B. Leaves cut from the roots.						
Hours greened	0	2	24	46		
Fresh weight, g.	50.0	50.0	50.0	50.0		
Dry weight, g.	3.66	3.01	3.21	3.49		
Weight per gram dry weight of leaves						
Chlorophyll, g. $\times 10^6$	5.44	96.5	1990	4110		
Chlorophyll Mg, g. $\times 10^7$	1.48	26.2	540	1110		
Total ether-soluble Mg, g. $\times 10^7$	53.7	139	717	1180		
Total ether-soluble P, g. $\times 10^7$	186	361	766	625		
Total ether-soluble material, g. $\times 10^2$	4.02	4.27	4.46	5.43		
Total ash, g. $\times 10$	1.78	1.54	1.74	1.66		
Total magnesium, g. $\times 10^3$	1.90	1.72	2.05	2.16		
Total phosphorus, g. $\times 10^2$	1.11	1.01	1.08	1.12		

^a Remained in the dark cabinet for four days after the other plants had been removed for illumination and analysis.

Prior to illumination, the leaves contain small quantities of ether-soluble magnesium and phosphorus and at most only a trace of chlorophyll. On illumination, there is an increase in the chlorophyll and the magnesium attributable to it, the total ether-soluble magnesium, the total ether-soluble phosphorus, and total ether-soluble material. The increases in these leaf components are relatively large in the early periods of greening.

In general, the leaves increase in total ash, total magnesium, and total phosphorus during illumination. In leaves greened for two hours, however, the values for these constituents are mostly somewhat less than in etiolated leaves. The increases in these constituents may be due to increase in age since leaves left in the dark for a period longer than the longest period of illumination show considerable increases in these components (Table IA, last column).

Increase in Ether-Soluble Magnesium Compounds during Chlorophyll Formation.—The etiolated leaves, prior to illumination, contain an amount of total ether-soluble magnesium which is much greater than can be accounted for by the magnesium attributable to whatever chlorophyll is present (Tables IA and IB). On illumination both chlorophyll and total ether-soluble magnesium increase. When the leaves have become relatively rich in chlorophyll, the magne-

sium attributable to chlorophyll accounts for approximately all of the ether-soluble magnesium (Tables IA and IB, IIA and IIB). This fact sup-

TABLE II

INCREASE OF ETHER-SOLUBLE MAGNESIUM COMPOUNDS DURING GREENING OF ETIOLATED BARLEY LEAVES^a

A. Leaves attached to the roots.					
Hours greened	0	2	24	47	71
Chlorophyll Mg. + total ether-soluble Mg	0.022	0.341	0.938	0.987	0.901
Increase in chlorophyll Mg, g. $\times 10^7$	...	33.4	1320	1940	1800
Increase in total ether-soluble Mg, g. $\times 10^7$	...	49.1	1360	1910	1950
Δ Chlorophyll Mg + Δ total ether-soluble Mg	...	0.680	0.975	1.01	0.924
B. Leaves cut from the roots.					
Hours greened	0	2	24	46	
Chlorophyll Mg + total ether-soluble Mg	0.028	0.188	0.752	0.947	
Increase in chlorophyll Mg, g. $\times 10^7$	...	24.7	538	1110	
Increase in total ether-soluble Mg, g. $\times 10^7$	...	85.4	663	1120	
Δ Chlorophyll Mg + Δ total ether-soluble Mg	...	0.289	0.811	0.991	

^a All weights in this table are referred to 1 g. of dry weight of leaves.

ports the observation of Deleano and Dick⁵ that chlorophyll in foliage leaves may be estimated by determination of the magnesium soluble in chloroform. In the first two-hour period of greening, the increase in chlorophyll magnesium is considerably less than the increase in total ether-soluble magnesium (Tables IIA and IIB). The increases in these two quantities, however, nearly coincide in the later periods of greening. The amount of ether-soluble magnesium which is present in the leaves prior to illumination is much too small to account for all of the chlorophyll magnesium which is accumulated during greening (Tables IA and IB).

The experimental evidence supports the view that chlorophyll formation is more complex than a simple photochemical transformation of a preformed chlorophyll precursor present in sufficient amount to account for all the chlorophyll produced—a conclusion reached from other experimental evidence by Barrenscheen and his co-workers.⁶ If the formation of chlorophyll were a simple photochemical transformation—for example an oxidation or reduction—of magnesium compounds closely related to chlorophyll, there probably would be little change in the amount of ether-soluble magnesium during greening. In such a case, the magnesium-containing precursors of chlorophyll would most likely be ether-soluble and would be present in amounts sufficient to produce all of the chlorophyll formed.

Besides chlorophyll, other ether-soluble compounds containing magnesium are formed in the leaf during illumination. In the first two-hour period of illumination the increase in total ether-

soluble magnesium considerably exceeds the magnesium attributable to chlorophyll.

It is possible that these magnesium-containing compounds are transformed into chlorophyll. The evidence which supports this supposition is as follows: The increase in total ether-soluble magnesium is greater than the increase in chlorophyll magnesium when little chlorophyll has been formed (two-hour period), whereas the increases in these two fractions coincide when much chlorophyll has been formed. Under certain circumstances, if these two reactions were simultaneous side-by-side reactions, the ratio of the two would remain constant, but if these two reactions were simultaneous consecutive reactions in which the non-chlorophyll, ether-soluble magnesium compounds were transformed into chlorophyll at a relatively rapid rate, the ratio of the two would approach unity as the amount of chlorophyll increased. The facts fit the latter case and make it plausible to assume that the non-chlorophyll ether-soluble magnesium compounds formed by illumination are transformed into chlorophyll. The evidence is not sufficient, however, to establish this assumption as fact.

Light is effective in this formation of ether-soluble magnesium compounds because etiolated plants left in the dark for a period longer than the longest period of greening show no such increase in total ether-soluble magnesium compounds (Table IA, last column).

Previous work in this Laboratory⁷ and the more recent work of Bukatsch⁸ have demonstrated the participation of alkaline earths in the absorption of carbon dioxide by leaves. The experiments of Arens⁹ have shown how light can cause the migration of carbonates of these elements through aquatic leaves and at the same time rob them of carbon dioxide. And the present experiments have shown that by illumination magnesium is withdrawn from inorganic sources to form chlorophyll. Taken together, these processes suggest a possible path by which carbon dioxide can be brought into the photosynthetic apparatus.

Increase in Ether-soluble Phosphorus during Chlorophyll Formation.—In the unilluminated, etiolated barley seedlings, there is a considerable quantity of ether-soluble phosphorus (Tables IA and IB). This material increases in amount very rapidly on illumination and the increase occurs in leaves whether or not they are attached to the roots of the plants (Tables IIIA and IIIB). The most rapid increase occurs during the initial two-hour period of illumination. As the periods of illumination are lengthened the rate of increase gradually lessens.

Comparison shows that the increase in total ether-soluble phosphorus is greater in the first two-hour period than is the increase in chloro-

(7) Smith, *Plant Physiol.*, **15**, 183 (1940); Smith and Cowie *ibid.*, **16**, 237 (1941).

(8) Bukatsch, *Jahrb. wiss. Botan.*, **90**, 293 (1942).

(9) Arens, *ibid.*, **83**, 513 (1936).

(5) Deleano and Dick, *Biochem. Z.*, **268**, 317 (1934).

(6) Barrenscheen, Pany and Srb, *ibid.*, **310**, 333 (1941/1942).

TABLE III

INCREASE OF ETHER-SOLUBLE PHOSPHORUS COMPOUNDS DURING GREENING OF ETIOLATED BARLEY LEAVES^a

A. Leaves attached to the roots.				
Hours greened	2	24	47	71
Increase in total ether-soluble P, g. $\times 10^7$	199	976	1190	1220
Δ Total ether-sol. P \div Δ chlorophyll Mg	5.96	0.737	0.613	0.677
Δ Total ether-sol. P \div Δ total ether-sol. Mg	4.05	0.718	0.621	0.625
B. Leaves cut from the roots.				
Hours greened	2	24	46	
Increase in total ether-soluble, P, g. $\times 10^7$		175	580	439
Δ Total ether-sol. P \div Δ chlorophyll Mg		7.07	1.08	0.395
Δ Total ether-sol. P \div Δ total ether-sol. Mg		2.04	0.874	0.391

^a All weights in this table are referred to 1-g. dry weight of leaves.

phyll magnesium or total ether-soluble magnesium (Tables IIIA and IIIB). However, in the later stages of greening the increases in ether-soluble phosphorus are much less than the increases in the ether-soluble magnesium compounds.

Fifty years ago, Stoklasa¹⁰ discovered that seedlings germinated in the light for nine or ten days contained more phosphorus soluble in ether and alcohol than seedlings of the same age germinated in the dark. From his observations, however, it was impossible to determine whether the formation of organic phosphorus compounds was localized in the leaves or whether it was a function of the plant as a whole; neither could the rapidity with which this action took place nor its relation to chlorophyll formation be gauged.

The experiments reported in the present paper have also demonstrated the increase in ether-soluble phosphorus induced by light. They make it clear that this conversion of phosphorus into ether-soluble form is localized in the leaves, for whether or not the leaves are attached to the roots they possess the ability to synthesize such phosphorus compounds when illuminated. The rapidity with which such compounds are formed may be gauged by the fact that the ether-soluble phosphorus of etiolated leaves is nearly doubled by two hours of illumination.

Simultaneous production of ether-soluble phosphorus compounds and chlorophyll suggests that these two processes may be interlinked. This concept was put forward by Stoklasa¹⁰ when he said, "Es ist auf Grund meiner jetzigen Forschung die Möglichkeit nicht ausgeschlossen dass das Lecithin... unter Einwirkung der strahlenden Energie zur Ausbildung des Chlorophylls in der ersten Vegetationsperiode des Keimpflänzchens dient... Ohne Phosphor kein Lecithin... und auch kein Chlorophyll!" However, experimental demon-

(10) Stoklasa. *Ber.*, **29**, 2761 (1896).

stration of such intimate connection between the two processes is still lacking.

The increase in ether-soluble phosphorus accompanying the elaboration of the photosynthesis apparatus may have significance because of the role played by phosphorylations in the transformations of carbohydrates and in the formation of energy-rich bonds. Further examination of this reaction is contemplated.

Increase of Total Ether-soluble Material during Chlorophyll Formation.—A considerable amount of material soluble in ether is present in etiolated barley leaves. (Tables IA and IB.) On illumination, total ether-soluble material increases and the increase in all cases is greater than the increase in chlorophyll—in the first two hours it is many times greater (Tables IVA and IVB). This increase, coming as it does in the first stages of greening, raises the question, which could have been asked in the case of ether-soluble phosphorus compounds as well, whether or not a photochemical synthesis, independent of chlorophyll, is carried on by illuminated etiolated leaves. The facts as yet are not sufficient to answer this question.

TABLE IV

INCREASE OF TOTAL ETHER-SOLUBLE MATERIAL DURING GREENING OF ETIOLATED BARLEY LEAVES^a

A. Leaves attached to the roots.				
Hours greened	2	24	47	71
Increase in total ether-sol. matl. (g. $\times 10^2$)	0.10	1.20	2.16	1.70
Δ Total ether-sol. matl. \div Δ chlorophyll	8.12	2.46	3.03	2.56
B. Leaves cut from the roots.				
Hours greened	2	24	46	
Increase in total ether-sol. matl. (g. $\times 10^2$)		0.252	0.447	1.42
Δ Total ether-sol. matl. \div Δ chlorophyll		27.7	2.25	3.45

^a All weights in this table are referred to 1 g. dry weight of leaves.

Ether-soluble Magnesium Compounds in Albino Corn Seedlings.—A comparison of albino and green corn seedlings was made with respect to chlorophyll magnesium, total ether-soluble magnesium, ether-soluble phosphorus, and total ether-soluble material. The leaves which were used were grown in the greenhouse and harvested sixteen days after planting the seed. The results of the experiments are shown in Table V.

The albino seedlings contained considerably more total ether-soluble magnesium than was attributable to the small amount of chlorophyll that they contained. With regard to this property, albino corn and etiolated barley leaves are similar (*cf.* Tables IA and IB, IIA and IIB, and V). The amounts of chlorophyll magnesium and ether-soluble magnesium, and the ratio of the two, in green corn seedlings are of the same order of mag-

TABLE V
COMPARISON OF ALBINO AND GREEN CORN SEEDLINGS
WITH RESPECT TO CERTAIN CONSTITUENTS

	Albino	Green
Fresh weight g.	24.0	25.0
Dry weight, g.	1.92	3.06
Weight per gram dry weight of leaves.		
Chlorophyll, g. $\times 10^6$	12.6	13800
Chlorophyll Mg, g. $\times 10^7$	3.40	3740
Total ether-soluble Mg, g. $\times 10^7$	66.8	4180
Total ether-soluble P, g. $\times 10^7$	359	1800
Total ether-soluble material, g. $\times 10^2$	3.63	7.94
Total ash, g. $\times 10^6$	1.27	1.53
Total magnesium, g. $\times 10^3$	2.49	2.30
Total phosphorus, g. $\times 10^2$	1.11	0.980
Chlorophyll Mg \div total ether-soluble Mg	0.051	0.895

^a Sulfate ash obtained after ashing with sulfuric acid, evaporation of the sulfuric acid and heating to redness.

nitude as in greened barley seedlings. Relative to the properties considered, albino corn and

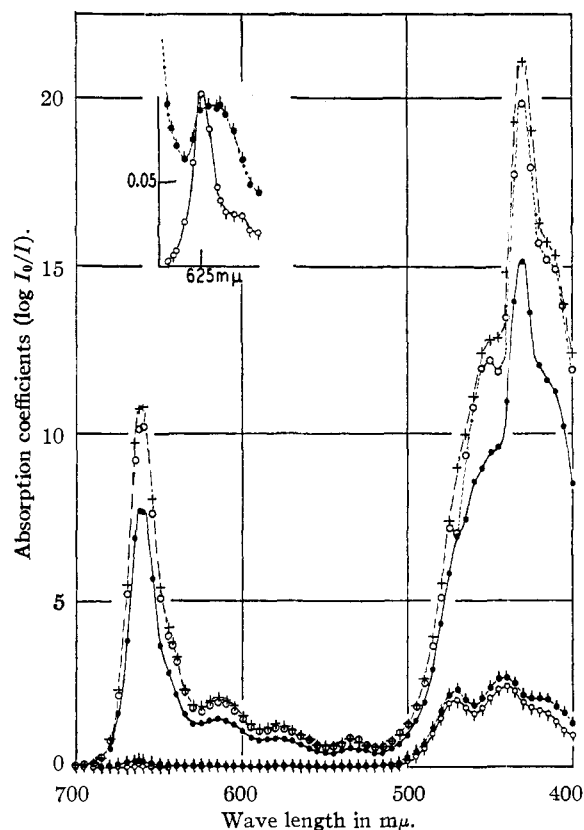


Fig. 1.—Absorption coefficients of ether extracts of 50 g. of barley leaves greened for different periods of time: —○—, 0 hours; —●—, 2 hours; —●—, 24 hours; —+—, 47 hours; and —○—, 71 hours.

etiolated barley seedlings are similar, as are also the green plants of the two species. From this work there is no indication of a critical deficiency in the albino plant which would account for its albinism.

Spectral Absorption Curves.—The spectral absorption curves of ether extracts of the pigments present in etiolated leaves and those formed during greening are shown in Fig. 1. In each case the curve represents the absorption of the ether extract from 50 g. of fresh leaves contained in 200.0 ml. of moist ether. From inspection of the curves it may be seen that the extracts from unilluminated leaves contain considerable amounts of yellow pigments but, at most, only a trace of chlorophyll. The maximum at 625 $m\mu$ may be ascribed to protochlorophyll. After two hours of illumination the chlorophyll absorption has become conspicuous whereas the protochlorophyll maximum at 625 $m\mu$ has decreased (*cf.* insert in Fig. 1). Longer periods of illumination produced greater amounts of chlorophyll but the rapid increase ceased after forty-eight hours.

The results obtained in these experiments agree in general with the results obtained by other investigators. This applies notably to the decrease in protochlorophyll on illumination.¹¹ No data are available from these experiments, however, to determine whether the protochlorophyll decrease is in any way connected with the chlorophyll increase, as has sometimes been conjectured.

Summary

Etiolated barley leaves contain ether-soluble magnesium and phosphorus compounds. The ether-soluble magnesium is far in excess of the magnesium which may be attributed to whatever chlorophyll is present but is insufficient for all of the chlorophyll produced during greening. Upon illumination, ether-soluble magnesium compounds, besides chlorophyll, are produced in the leaf. The evidence makes it plausible to assume that these compounds are intermediates in the formation of chlorophyll. Ether-soluble phosphorus compounds and lipoidal material are also synthesized when etiolated barley leaves are illuminated and the synthesis of these materials is rapid even when the chlorophyll content of the leaves is very low.

Albino corn seedlings are similar to etiolated barley seedlings in respect to their content of ether-soluble magnesium, phosphorus, and lipoidal material. There is no indication of a critical deficiency in these fractions which would account for the albinism of these seedlings.

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(11) Scharfnagel. *Planta*, **13**, 716 (1931).