CCXCVI. CRESS SEED MUCILAGE.

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THE dispersed cellulose component which is found in white mustard seed mucilage [Bailey and Norris, 1932] and in quince seed mucilage [Schmidt, 1844; Kirchner and Tollens, 1874; Renfrew and Cretcher, 1932] has now been obtained from the mucilage of cress seed, *Lepidium sativum*. The present communication, which deals mainly with the chemistry of this seed mucilage, falls into three sections: (1) the products obtained by acid hydrolysis of cress seed mucilage are characterised; (2) the mucilage is shown to be a heterogeneous polysaccharide system, and its behaviour towards fractionating agents is contrasted and compared with those of the closely related mucilage of white mustard seed and the non-cellulosic mucilage of linseed; (3) the factors responsible for the hydration and dispersion of the cellulose component in seed mucilages and in other cellulose polyuronide systems are discussed.

Since the earlier review of Bailey and Norris [1932] several contributions to the chemistry of the mucilages have been made, chiefly by American workers in this field. *d*-Galactose, *l*-rhamnose and galacturonic acid have been found in the hydrolytic products of the mucilage of slippery elm bark [Anderson, 1934]. The uronic acid is combined in part as a rhamnosegalacturonide, an aldobionic acid found previously by Anderson and Crowder [1930] in the hydrolysis products of linseed mucilage. The latter mucilage has now been shown to contain the *l*-form of galactose [Anderson, 1933] and the *d*-form of galacturonic acid [Niemann and Link, 1934]. The frequent occurrence of structurally related carbohydrates, *i.e.* of *d*-galactose, *d*-galacturonic acid with *l*-arabinose, and of *d*-glucose, *d*-glycuronic acid with *d*-xylose, has given considerable support to the classical hypothesis of de Chalmot [1894, 1, 2], who first suggested that pentosan may arise from hexosan by a two-stage process; oxidation of the hexose to the uronic acid followed by decarboxylation to the pentose. The occurrence of *l*-galactose with *d*-galacturonic acid in linseed mucilage is therefore an interesting anomaly. The mucilage of *Psyllium* seed, investigated by Anderson and Fireman [1935] consisted of a mixture of polyuronides, which were hydrolysed to *d*-galacturonic acid, *l*-arabinose and *d*-xylose. This latter sugar has also been isolated from *Psyllium* seed mucilage by the present author. Quince seed mucilage on hydrolysis yields *d*-xylose, *l*-arabinose and a mixture of monomethylated and unmethylated pentoseuronic acid [Renfrew and Cretcher, 1932]. The ultimate constituents of white mustard seed mucilage are arabinose, rhamnose, galactose, galacturonic and glycuronic acids [Bailey and Norris, 1932].

EXPERIMENTAL.

Preparation of cress and other seed mucilages.

When cress seed is allowed to soak in water the mucilaginous layer of the seed testa swells but does not disperse and cannot be squeezed away, as in the case of mustard seed mucilage. The difficulty was overcome in the following

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way. 200 g. of seed were washed free of extraneous matter, mixed with 2 litres of distilled water and shaken mechanically in a Winchester bottle for 6 hours. The mucilage, gradually dispersed by the friction of the vessel walls and of seed against seed, constituted the topmost layer on centrifuging. The seed residues were treated once more in a similar way and then discarded. The mucilage was squeezed through muslin to remove seed fragments, poured into 95 % alcohol, dehydrated in absolute alcohol and finally dried *in vacuo* at room temperature. To reduce the high ash content (usually 6–7 %), the snow-white fibre was redispersed in water, 12 % HCl was added to a final concentration of 2 %, and the mucilage reprecipitated with 95 % alcohol. The product was then pressed free of excess liquor, washed with alcohol until free from acid and dried as before. The yield of mucilage was 2.6 % of the weight of the original seed.

In the preparation of both linseed and white mustard seed mucilages prolonged agitation of the seed was unnecessary and the mucilage was separated by pouring on to a Büchner filter, the perforations of which were sufficiently small to prevent the passage of the seed.

Methods of analysis.

The methods of analysis adopted throughout may conveniently be described here. Furfuraldehyde yields were determined by the standard Krüger-Tollens-Kröber method [Van der Haar, 1920; Browne, 1912]. The conversion of furfuraldehyde figures into terms of pentosan has been purposely avoided, since this procedure has been criticised by several authors in recent times [*e.g.* the critique of Peter *et al.*, 1933]. Even if the Kröber tables for such a conversion are substantially correct, it is essential to ascertain in the case of polyuronide material the proportion of furfuraldehyde arising from pentosan and uronic acids respectively. It has been erroneously assumed in the past that uronic anhydride groups gave one-sixth their weight of furfuraldehyde. Ehrlich and Schubert [1929], using pure *d*-galacturonic acid monohydrate, found that 2.64 parts of acid gave one part of furfuraldehydephloroglucide; *i.e.* 1 part of uronic anhydride yields 22.7 % of furfuraldehyde. These values have been confirmed by Norris and Resch [1935]. Since the amount of uronic anhydride in any material can be ascertained by the method of Lefèvre [1907] and subsequent modifications (*e.g.* those of Nanji *et al.*, 1925; Dickson *et al.*, 1930) it is now possible to calculate more accurately than hitherto the amount of furfuraldehyde which arises from pentose by making due allowance for the furfuraldehyde yield of the uronic anhydride.

The determination of methylpentosan in presence of other furfuraldehyde-yielding products appears to be wholly inaccurate. The original method proposed by Ellett and Tollens [1905] makes use of the fact that methylpentoses give rise on distillation with HCl to methylfurfuraldehyde, which unlike furfuraldehyde forms an alcohol-soluble phloroglucide. With material obtained from plant sources the alcoholic extract invariably contains ω -hydroxymethylfurfuraldehyde which arises in varying amounts from hexosan. The interpretation of alcohol-soluble phloroglucide material in terms of methylpentose becomes in consequence a doubtful procedure. Experience shows, moreover, that in duplicate experiments the amounts of alcohol-soluble phloroglucide are not concordant unless the rates of distillation are rigidly standardised, though small variations do not affect the absolute furfuraldehyde yield. The presence of methylfurfuraldehyde can at least be detected qualitatively by the reddish brown colour of the alcoholic extract, and products which contain no rhamnose, *e.g.* the Cross and Bevan cellulose fractions of the mucilages investigated, give

only a pale green phloroglucide extract. With these considerations in mind it has been thought advisable to record merely the amount of alcohol-soluble phloroglucides expressed as a percentage of the original material and to infer the presence or absence of methylpentose from the colour of the alcoholic extract.

Reducing groups were estimated by the Willstätter and Schudel hypoidite method [1918], care being taken to obtain conditions of quantitative oxidation as outlined by Bailey and Hopkins [1933]. Cellulose determinations were carried out by the Cross and Bevan [1899] method, nitrogen determinations by the micro-Kjeldahl method and methoxy-groups by a modification of the Zeisel method.

Acid hydrolysis of cress seed mucilage.

A typical analysis of cress seed mucilage gave: ash 1.0 %, uronic anhydride 25.8 %, furfuraldehyde 24.5 %, alcohol-soluble phloroglucides 2.86 %, Cross and Bevan cellulose 18.3 %, methoxyl 1.4 %, nitrogen 0.1 %.

In general the material was hydrolysed under standard conditions with dilute sulphuric acid, which was then removed by addition of barium carbonate with rapid mechanical stirring. After filtration, the clear liquid was evaporated *in vacuo* at 50°, filtered and poured into 95 % ethyl or methyl alcohol. The flocculum of barium salts was centrifuged off, washed with 95 % alcohol, redissolved in water, reprecipitated with methyl alcohol, once more dissolved and reprecipitated and finally filtered yielding a compact mass of barium salts. These were washed with absolute methyl alcohol and dried *in vacuo* over P₂O₅, first at room temperature and finally at 70°. The alcoholic solution containing the sugars was evaporated to a small bulk *in vacuo* and thinned with methyl alcohol to remove a small amount of barium salt, which was separated from the sugar solution by centrifuging. The resulting barium-free solution was reserved for fractionation and crystallisation.

36 g. of mucilage (ash- and moisture-free basis) were hydrolysed at 80° for 20 hours in 1 litre of 2 % sulphuric acid. After separation of the cellulose residue (*A*) the hydrolysate was treated in the manner described above and gave rise to a sugar fraction (*B*) and the barium salt (*C*). On drying (*C*) weighed 11 g. and contained 15.1 % of barium and 40.0 % of uronic anhydride, values which do not quite satisfy the requirements of a product composed solely of one or of several aldobionic nuclei. The salt was therefore decomposed with the calculated amount of sulphuric acid and subjected to further hydrolysis with 2 % acid at 97° for 6 hours. From the hydrolysis products were isolated 8 g. of barium salt (*D*) and a sugar fraction (*E*). The cellulose residue (*A*) was further hydrolysed under the same conditions as barium salt (*C*) and the final residue (*F*) was freed from acid by washing in water, dehydrated in boiling alcohol and finally dried at 105°.

Characterisation of the hydrolysis products.

Sugar fractions. Fraction (*B*) was evaporated to dryness and extracted with 750 ml. of boiling absolute alcohol in 50 ml. portions. The united extracts were concentrated to a syrup, thinned with 90 % alcohol and left in the ice-chest to crystallise. The separated material was filtered on a coarse sintered glass filter, washed with absolute alcohol and ether and dried *in vacuo* at 70° over P₂O₅. It weighed 1.1 g. and proved to be *l*-arabinose: $[\alpha]_D^{18} + 103^\circ$ ($c = 1.8$). The diphenylhydrazone and *asmethylphenylhydrazone* separated from alcoholic solution in the cold and after two recrystallisations from dilute alcohol melted at 204° and 164.5° respectively.

The sugar fraction (*E*) together with the mother-liquor remaining after crystallisation of the arabinose from fraction (*B*) were combined and gave 1.1 g. of galactose *as* methylphenylhydrazone when treated by the procedure of Van der Haar [1920]. The hydrazone was decomposed by formaldehyde by Van der Haar's modification of earlier methods. The final syrup readily crystallised, and the sugar, isolated by the method given above, weighed 0.2 g. and proved to be *d*-galactose: $[\alpha]_D^{18} + 81.7$ ($c=1.2$). On oxidation with nitric acid (sp. gr. 1.12), mucic acid was obtained, M.P. 220°.

d-Glucose from the cellulose residue (*F*). The residue on analysis gave: ash 2.5 %, uronic anhydride 1.8 %, furfuraldehyde 6.7 %. 2.5 g. were hydrolysed with cold 72 % sulphuric acid according to the method of Monier-Williams [1921]. Of the original residue 0.21 g. remained insoluble. The amount of sugar recovered, estimated as glucose by the hypiodite method, was 90 % of the theoretical, and the specific rotation, also calculated on this basis, was $[\alpha]_D^{18} + 40.1^\circ$. The aqueous sugar solution was evaporated *in vacuo* and alcohol was added to a concentration of 75 %. On standing 0.97 g. of crystalline glucose, $[\alpha]_D^{18} + 50^\circ$ ($c=1.5$), was obtained. The phenylosazone prepared both from the mother-liquor and the sugar had the characteristics of glucosazone, and after several recrystallisations from dilute alcohol melted at 205°. Specific tests for arabinose were negative, although some pentose was present.

Barium salt (D). After reprecipitating twice from methyl alcohol, the dried salt weighed 8.5 g. and gave on analysis; barium 16.9 %, uronic anhydride 41.5 %, methoxyl 2.4 %, furfuraldehyde 10.4 %, alcohol-soluble phloroglucides 11.8 %, —CHO 3.96 %, nitrogen 0.009 %; $[\alpha]_D^{18} + 89^\circ$ ($c=5.8$). Except for the low reducing power, the analytical figures would indicate that salt (*D*) consists of a mixture of methylpentose barium uronide and hexose barium uronide. The —CHO content of the former is 7.1 %, of the latter 6.85 %. The salt in question, with a value of 3.96 %, approximates more closely to a molecule which could arise by linkage of two aldobionic acids. This preliminary supposition as to the nature of salt (*D*) is borne out by later experiments. Since, however, the salt gives on hydrolysis rhamnose and galactose two possibilities arise: (1) that these sugars, linked to galacturonic acid, form part of the same skeletal molecule; (2) that each sugar is a component of distinct skeletal molecules. For purposes of analytical comparison it is more convenient to represent salt (*D*) under the first category. The results quoted above are therefore recalculated on a methoxy-free basis, and compared with the calculated values for the barium salt of an acid produced by linking galactose barium uronide with rhamnose barium uronide.

	Found %	Calculated for $C_{24}H_{36}O_{22}Ba$ %
Barium	17.1	16.85
Uronic anhydride	42.0	43.3
Furfuraldehyde	10.5	9.8*
Alcohol-soluble phloroglucides	11.9	—
—CHO	4.0	3.6
C	35.0	35.4
H	4.97	4.43

* Calculated by the factor of Ehrlich and Schubert [1929].

Oxidation of the barium salt (D). 0.5 g. was simultaneously hydrolysed and oxidised in presence of 7 % HBr and bromine by the method of Heidelberger and Goebel [1927]. 0.05 g. of purified mucic acid, M.P. 220°, was obtained, derived solely by oxidation of galacturonic acid and not of galactose.

1.62 g. were oxidised by barium hypoiodite, following closely the method of Goebel [1927]. The free carbonyl group was thus oxidised to carboxyl, and the fully oxidised acid was isolated as the barium salt which contained, after one precipitation from methyl alcohol, 23.0% of barium, a value which remained unchanged after two further precipitations. On analysis the final product gave: barium 23.0%, furfuraldehyde 8.6%, alcohol-soluble phloroglucides 8.0%, methoxyl 0.6%, —CHO 0.6%; calculated barium content 22.9%. By way of comparison, the barium salt of an oxidised hexoseuronide is 27.0% and of an oxidised methylpentoseuronide 27.9%. If a correction be made for the increase in molecular weight which occurs on oxidation, the furfuraldehyde yield of the oxidised salt is 9.5%, and of the alcohol-soluble phloroglucides 8.8%, corresponding to the values 10.4% and 11.9% in the case of the original salt. Since furfuraldehyde arises solely from uronic acid, and alcohol-soluble phloroglucides from rhamnose, the figures indicate that no appreciable oxidation of these two components has occurred.

Hydrolysis of salt (D). 8 g. of the salt after precipitation of the barium were hydrolysed for 16 hours with 2.5% sulphuric acid in an oil-bath at 105°, and after appropriate treatment gave a syrupy sugar fraction (*G*) and a barium salt (*H*). The former was dissolved in water, cleared with norite, evaporated to a thin syrup and allowed to crystallise in the ice-chest. Crystals of *l*-rhamnose monohydrate appeared after 2 days and were filtered off after standing for a week. They were washed rapidly with dilute alcohol and dried on a porous plate. They weighed 0.36 g. and melted at 94°; $[\alpha]_D^{18}$, calculated for the anhydrous form, +9.2° ($c=1.5$). The *p*-bromophenylosazone melted at 218° and the phenylosazone at 181°. A portion of the mother-liquor after crystallisation of rhamnose was treated with *asmethylphenylhydrazine* in alcoholic solution. A copious precipitate of the galactosehydrazone separated on standing overnight in the cold and after two recrystallisations from alcohol melted at 189°. Another portion of the mother-liquor was oxidised with nitric acid and gave a precipitate of mucic acid, melting after purification at 220°. No other sugars could be detected.

The barium salt (*H*) after purification weighed 2 g. and contained 26.7% of barium (calculated for barium galacturonate, 26.2%). 1.74 g. were decomposed with the calculated amount of *N*/10 sulphuric acid, and the aqueous solution after filtration was evaporated *in vacuo* at 35°, taken up in alcohol and again evaporated to a thick syrup, which crystallised on standing for several days in a desiccator. The crystals of β -*D*-galacturonic acid were filtered off, washed with absolute alcohol and dried on a porous plate over sulphuric acid. The acid turned brown at 158° and decomposed at 166°; $[\alpha]_D^{18}$, at 11 min., +40°; at constant rotation, +55.4° ($c=1.2$). On titration against standard NaOH, using phenolphthalein as indicator, 12.10 mg. acid required 3.10 ml. of *N*/50 NaOH; calculated, 3.14 ml. The —CHO content, determined by the hypoiodite method was 13.8%; calculated 14.9%. 0.14 g. oxidised by bromine water at room temperature for a week gave 0.06 g. of mucic acid, m.p. 220°. With Schiff's reagent the acid gave a colour only after long standing. The β -*D*-galacturonic acid isolated by Ehrlich and Schubert [1929] had the following constants: m.p. 160°, $[\alpha]_D^{20}$, at 1 min., +27°, at 24 hours +55.3°. α -*D*-Galacturonic acid monohydrate has the same final rotation as the β -form, but exhibits a downward mutarotation. The two forms are readily interconvertible.

Constitution of the salt (D). The experimental data leave the exact constitution of the salt an open question. After oxidation by hypoiodite the methyl-furfuraldehyde and furfuraldehyde yields indicate that the rhamnose and uronic acid components are not appreciably affected and that in consequence the free

aldehyde group belongs to the remaining component, galactose. If this be the case, the galactose moiety occupies a terminal position in the skeletal molecule. These conclusions, based merely on furfuraldehyde and methylfurfuraldehyde yields, would indicate that the salt is a homogeneous product representable by the formula already given, but on such data alone it is perhaps unwise to stress the homogeneity of the salt since the mucilage itself is an essentially heterogeneous system. The experimental data considered *in toto* however do conform with the view that the hydrolysis has been arrested at a stage in which two molecules of galacturonic acid are linked to two sugar molecules.

Fractionation of cress and other seed mucilages.

Bailey and Norris [1932] showed that white mustard seed mucilage could be separated into at least three components by fractionation methods involving the use of cold baryta and hot sodium hydroxide solution. In the following experiments the cellulose-containing mucilages of cress and white mustard seed and the non-cellulosic mucilage of linseed have been subjected to the action of baryta in the cold and of boiling 1 % NaOH; in two cases fractional precipitation by alcohol has been achieved.

Fractionation by means of baryta. 10 g. of mustard seed mucilage, 10 g. of cress seed mucilage and 40 g. of linseed mucilage (on an ash- and moisture-free basis) were used. The mucilage was dispersed in 100 parts of water and an equal volume of saturated baryta was added, CO₂ being rigidly excluded. After mixing and allowing to stand overnight the supernatant liquor was separated from the baryta-insoluble residue by decantation or by centrifuging. The residue was squeezed free of excess liquor in muslin, redispersed in water and made neutral by addition of HCl; more acid was added to a concentration of 2 %, and complete precipitation was effected by pouring into 95 % alcohol. The resulting product was freed from acid by repeated washings with absolute alcohol and dried first *in vacuo* at room temperature and then at 105° to constant weight.

Fractionation by means of sodium hydroxide. The procedure was incorporated in the general method for the preparation of Cross and Bevan cellulose, whereby polyuronide material was removed by a preliminary boiling with 1 % NaOH for 30 min.

The analysis of each fraction is given in Table I. In the case of the baryta-insoluble residues the ash consisted almost entirely of barium carbonate, and the barium content only is recorded. The extent of partition of pentosan between the various fractions can be ascertained from the column which records the amount of furfuraldehyde arising solely from pentosan. Attention may be drawn to the following points: (1) the extent of solvation of each mucilage in cold baryta is deduced from the experimental yield of insoluble residue and can also be calculated from the amounts of Cross and Bevan cellulose in both products. The baryta-soluble portion amounts to 32 % for mustard seed mucilage, 35 % for cress seed mucilage and 84 % for linseed mucilage; (2) in general, the baryta-insoluble residues, in comparison with the original mucilage, contain the same amount of pentosan, less methylpentosan and less uronic anhydride, except in the case of the linseed residue in which the uronic anhydride content reaches 41 %; (3) the mucilages incompletely precipitated by alcohol contain less uronide and less pentosan than those completely precipitated; (4) the Cross and Bevan cellulose residue of mustard seed contains 5 % uronic anhydride and a trace of pentosan, whilst that from cress mucilage contains 2 % of uronic anhydride but yields 20 % of furfuraldehyde, a figure which is reduced to about 7 % if the cellulose is prepared by mild acid hydrolysis of the mucilage. The cellulosic

Table I. *Analysis of various fractions of cress, mustard and linseed mucilage.*

(All results calculated on an ash free basis.)

Substance	Ash	Uronic anhydride	Furfur-aldehyde	Furfur-aldehyde from pentosan	Alcohol-soluble phloroglucides. (Colour of extract in brackets)*	Cross and Bevan cellulose	Methoxyl	Nitrogen
Mustard seed mucilage	2.0	18.0	7.27	3.18	2.85 (r.b.)	43.1	1.60	0.3
Mustard seed mucilage in-completely pptd. by alcohol	0.65	9.7	3.79	1.59	2.76 (r.b.)	61.5	1.42	0.3
Baryta-insoluble residue of mustard seed mucilage	Ba=2.2	11.3	5.56	2.99	1.24 (r.b.)	62.8	1.06	0.3
Cross and Bevan cellulose	(1) 0.7 (2) 0.5	4.2 5.8	2.96 2.96	2.00 1.64	0.38 (g.) 0.40 (g.)	—	0.9 0.7	0.1 0.1
Cress seed mucilage	1.0	25.8	24.5	18.6	2.86 (r.b.)	18.3	1.40	0.1
Cress seed mucilage in-completely pptd. by alcohol	2.6	19.6	16.5	12.0	0.43 (g.)	19.6	1.37	0.9
Baryta-insoluble residue of cress seed mucilage	Ba=1.6	18.2	26.2	22.1	1.95 (r.b.)	27.9	1.80	0.1
Cross and Bevan cellulose	3.2	1.7	19.9	19.5	1.83 (g.)	—	0.70	0.1
Linseed mucilage	1.1	29.2	21.9	15.3	11.3 (r.b.)	0.5	0.4	0.2
Baryta-insoluble residue of linseed mucilage	Ba=3.1	41.2	26.6	17.2	6.3 (r.b.)	3.3	0.2	0.7

* r.b. reddish brown; g. green.

residue of linseed amounts only to 0.5 % and was not investigated; (5) the nitrogen content, which exceeds 0.3 % only in two cases, probably arises from protein impurities. The methoxyl groups persist through the fractionating process.

From these results it is clear that the three mucilages investigated are systems of mixed polyuronides. Those components containing most uronic acid groups are dissolved, as one would expect, by dilute baryta, whilst complete or almost complete solution of the polyuronide is effected by boiling with 1 % NaOH. Cautious addition of alcohol to the aqueous dispersate of the mucilage precipitates fractions poor in uronic acid. It is probable that a more rigorous fractionation by alkali and/or alcohol would permit the preparation of homogeneous fractions, but this has not yet been attempted.

Dispersibility of cellulose polyuronide systems.

The complexity of seed mucilages is illustrated not only by the variety of ultimate hydrolysis products but also by their amenity to methods of fractionation, and it is of great interest to consider how the dispersion of a cellulose component in such a heterogeneous system can arise. Firstly it must be borne in mind that the polysaccharide chains of the cellulose-containing mucilages are definitely oriented and are precipitated by alcohol from their aqueous dispersates in the form of short fibres. These are best obtained from mustard seed mucilage, which has a high cellulose content, and the fibrous form indicates that the polysaccharide chains are oriented parallel or approximately parallel with each other and with the fibre axis. Although the polyuronide chains may not penetrate the cellulose micelle they must at least surround it and since they are of comparatively low molecular weight they must also reduce the lateral intermicellar

forces between such micelles. Of these forces little is known, but in the case of normal cotton fibre they are sufficiently large to prevent dispersion. On immersion in water, the polyuronide chains, containing ionisable carboxyl groups, become hydrated and swell, and the cellulose micelles become dispersed. These latter may themselves become hydrated since their affinity for water molecules will be enhanced if some of the hexose molecules are oxidised to uronic acid. This appears probable in the case of mustard seed mucilage, in which some uronic groups resist alkaline leaching. Furthermore, if the individual skeletal chains of the cellulose component are shorter than those of normal cotton fibre, the secondary valency or Van der Waal forces between neighbouring chains will not be so large and will facilitate the entry of water molecules.

In the dispersed condition, therefore, the mucilage consists of a network of hydrated cellulose micelles, interspersed with the more heavily hydrated uronide chains. The extent of dispersion will depend ultimately on the size of the cellulose micelle, the chain length and the proportion of hydrated (as distinct from dissolved) polyuronides. When these latter are completely dissolved by alkali, the cellulose micelles are drawn together and a visible separation of the cellulose component occurs. When, on the other hand, dilute acid is added to the aqueous mucilage dispersate, no separation occurs until the polyuronides are hydrolysed by heating, and the cellulose component then appears in a gel-like condition and can be obtained in fibrous form by squeezing in muslin. Some of the polyuronides in aqueous dispersates of cress seed mucilage are already dissolved and can be precipitated by alcohol from the clear aqueous layer which separates on high speed centrifuging.

The importance of the factors responsible for the hydration and dispersion of cellulose polyuronide systems is not confined to the products examined here. The cell wall itself is essentially heterogeneous, consisting in the simplest cases of a cellulose matrix in close association with polyuronide (*i.e.* pectin and hemicellulose) material. In the walls of the meristematic tissue of the shoot apex it has been observed that the pectin-cellulose complex is heavily hydrated and allows of rapid diffusion of soluble substances [Tupper-Carey and Priestley, 1923]. Clearly, if cellulose and polyuronide chains are laid down simultaneously, the physical condition (hydration, colloidal state *etc.*) of the whole system will be influenced by the exact structural arrangements of its components. In the present state of cell wall chemistry it is impossible to compare the cell wall system with the cellulose-containing mucilages, since it is essential to ascertain the orientation and distribution of the polyuronides in the cell wall. The pectin for instance may occupy a regional position, as in the middle lamella, may be distributed uniformly or may alternate with the cellulose in well defined layers, a structure which has been assigned by Anderson [1927] to the collenchyma cells of flax bast fibres. A more detailed discussion of these problems will be found in recent papers by Seifriz [1934] and Buston [1935]. It is sufficient to emphasise here that the colloidal condition of the cell wall, before deposition of fat and lignin, is intimately related to the molecular architecture of the cellulose and polyuronide components.

SUMMARY.

1. Cress seed mucilage, like white mustard and quince seed mucilages, contains a dispersible cellulose component and gives rise on acid hydrolysis to *l*-arabinose, *d*-galactose, *l*-rhamnose, *d*-glucose (from the cellulose component) and *d*-galacturonic acid, all of which have been isolated in crystalline forms. At a given stage in the hydrolysis the uronic acid is obtained in a fragment formed

probably by linkage of two aldobionic acids. The barium salt of the uronide present at this stage thus conforms analytically, except for the reducing power, to the requirements of a barium aldobionate. From the hydrolytic products of the salt were isolated β -*D*-galacturonic acid, *l*-rhamnose monohydrate and the *o*-methylphenylhydrazone of galactose. Whether the two sugars constitute part of one or of separate units is an open question.

2. The two cellulose-containing mucilages of white mustard seed and the non-cellulosic mucilage of linseed are found to be heterogeneous polysaccharide systems which lend themselves to methods of fractionation.

3. The factors responsible for the hydration and dispersion of the cellulose component in seed mucilages and other cellulose polyuronide systems are discussed.

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