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SYNTHESIS OF METHYL α- AND β-MALTOTRIOSIDES AND ARYL β-MALTOTRIOSIDES*

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ABSTRACT

Reaction of β-maltotriose hendecaacetate with phosphorus pentachloride gave 2′,2″,3,3′,3″,4″,6,6′,6″-nona-*O*-acetyl-2-*O*-trichloroacetyl-β-maltotriosyl chloride (**2**) which was isomerized into the corresponding α anomer (**8**) Selective ammonolysis of **2** and **8** afforded the 2-hydroxy derivatives **3** and **9**, respectively, **3** was isomerized into the α anomer **9** Methanolysis of **2** and **3** in the presence of pyridine and silver nitrate and subsequent deacetylation gave methyl α-maltotrioside Likewise, methanolysis and *O*-deacetylation of **9** gave methyl β-maltotrioside which was identical with the compound prepared by the Koenigs–Knorr reaction of 2,2′,2″,3,3′,3″,4″,6,6′,6″-deca-*O*-acetyl-α-maltotriosyl bromide (**12**) with methanol followed by *O*-deacetylation Several substituted phenyl β-glycosides of maltotriose were also obtained by condensation of phenols with **12** in an alkaline medium Alkaline degradation of the *o*-chlorophenyl β-glycoside decaacetate readily gave a high yield of 1,6-anhydro-β-maltotriose

INTRODUCTION

Maltotriose is of interest as one of the hydrolytic products of starch The maltotriose derivatives reported to date are the β-hendecaacetate[1] (**1**), the glycitol[1], the hendecamethyl ether[2], and the 1-phenylflavazole[3] Methyl α-maltotrioside[4,5] (**5**) was isolated in pure form by chromatographic fractionation of a series of methyl α-malto-oligosaccharides resulting from the glucosyl transferase activity of either potato D-enzyme[4] or *Bacillus macerans* amylase[5] Similarly, methyl β-maltotrioside (**14**) was also prepared enzymically, but the physical properties of this compound were not well defined

We have synthesized several maltotriose derivatives which may serve not only as substrates in mechanistic studies of various starch-metabolizing enzymes but also as a model for solvolytic and displacement reactions of higher members of malto-

*Chemical modification of maltotriose Part I

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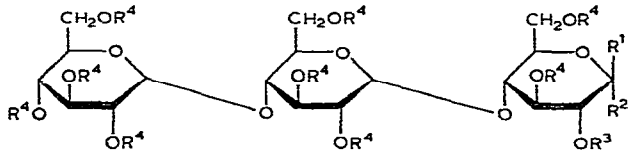


1 R^1 = OAc, R^2 = H, R^3 = R^4 = Ac
2 R^1 = Cl, R^2 = H, R^3 = $COCCl_3$, R^4 = Ac
3 R^1 = Cl, R^2 = R^3 = H, R^4 = Ac
4 R^1 = R^3 = H R^2 = OMe R^4 = Ac
5 R^2 = OMe, R^1 = R^3 = R^4 = H
6 R^1 = H, R^2 = OMe, R^3 = R^4 = Ac
7 R^1 = H, R^2 = OMe R^3 = Ms R^4 = Ac
8 R^1 = H, R^2 = Cl, R^3 = $COCCl_3$, R^4 = Ac
9 R^1 = R^3 = H R^2 = Cl, R^4 = Ac
10 R^1 = OMe, R^2 = R^3 = H, R^4 = Ac
11 R^1 = OMe R^2 = H R^3 = Ms, R^4 = Ac
12 R^1 = H, R^2 = Br R^3 = R^4 = Ac
13 R^1 = OMe, R^2 = H R^3 = R^4 = Ac
14 R^1 = OMe R^2 = R^3 = R^4 = H
15 R^1 = OAc R^2 = R^3 = H R^4 = Ac
16 R^1 = OAc, R^2 = H, R^3 = Ms, R^4 = Ac

oligosaccharides and starch This paper describes the chemical synthesis of **5** and **14**, prepared previously by enzymic procedures[4,5], and of several substituted phenyl β-glycosides of maltotriose The preparation of 1,6-anhydro-β-maltotriose (**18**) and its nonaacetate (**17**) by alkaline degradation of the deca-*O*-acetyl derivatives of aryl β-glycosides was also investigated

RESULTS AND DISCUSSION

The preparation of **5** was based on the reaction of Hickinbottom[6], who prepared an α-D-glucopyranoside by inversion of configuration at C-1 of a β-D-glucopyranosyl chloride having either a trichloroacetoxyl or a hydroxyl group as the nonparticipating group at C-2

Treatment[7] of **1** with 8 molar equivalents of phosphorus pentachloride in the presence of carbon tetrachloride gave a mixture of products from which crystalline 2′,2″,3,3′,3″,4″,6,6′,6″-nona-*O*-acetyl-2-*O*-trichloroacetyl-β-maltotriosyl chloride (**2**) was isolated in 42% yield by column chromatography on silica gel Selective ammonolysis[7] removed the trichloroacetyl group to give crystalline 2′,2″,3,3′,3″,4′,6,6′,6″-nona-*O*-acetyl-β-maltotriosyl chloride (**3**) in good yield (94%) Preliminary experiments of the reaction of **2** and **3** with methanol in the presence of pyridine and silver nitrate as acid acceptors[6] showed that the latter gave a higher yield of methyl 2′,2″,3,3′,3″,4″,6,6′,6″-nona-*O*-acetyl-α-maltotrioside (**4**) than the former, under these conditions, the 2-trichloroacetyl group of **2** was also removed Thus, **4** was isolated in crystalline form in 54 and 86% yield from **2** and **3**, respectively. Deacetylation of **4** gave **5** in crystalline form with physical constants in good agreement with those given in the literature[4,5]. The overall yield of **5** *via* **3** was 32% based on **1** Acetylation and methanesulfonylation of **4** afforded methyl 2,2′,2″,3,3′,3″,4″,6,6′,6″-deca-*O*-acetyl- and 2′,2″,3,3′,3″,4″,6,6′,6″-nona-*O*-acetyl-2-*O*-methylsulfonyl-α-maltotriosides (**6** and **7**), respectively.

Compound **14** was prepared (a) by treatment of 2′,2″,3,3′,3″,4″,6,6′,6″-nona-*O*-acetyl-α-maltotriosyl chloride (**9**), isomeric with **3**, with methanol and (b) by the

conventional Koenigs–Knorr condensation of 2,2′,2″,3,3′,3″,4″,6,6′,6″-deca-*O*-acetyl-α-maltotriosyl bromide (**12**) with methanol

In the first approach, **3** was isomerized[8] with titanium tetrachloride in chloroform to give crystalline **9** This compound was also obtained by the isomerization of **2** with titanium tetrachloride to give 2′,2″,3,3′,3″,4″,6,6′,6″-nona-*O*-acetyl-2-*O*-trichloroacetyl-α-maltotriosyl chloride (**8**), followed by selective removal of the 2-trichloroacetyl group Treatment of **9** with methanol under the same conditions as those of the preparation of **4** yielded crystalline methyl 2′,2″,3,3′,3″,4″,6,6′,6″-nona-*O*-acetyl-β-maltotrioside (**10**), which on deacetylation gave **14** in amorphous but chromatographically pure form Methanesulfonylation of **10** gave crystalline methyl 2′,2″,3,3′,3″,4″,6,6′,6″-nona-*O*-acetyl-2-*O*-methylsulfonyl-β-maltotrioside (**11**)

In the alternative synthesis of **14**, **1** was converted into the corresponding α-bromide **12** in crystalline form with hydrogen bromide in acetic acid Reaction of **12** with methanol in dry benzene at room temperature, in the presence of mercuric acetate, gave a mixture from which methyl 2,2′,2″,3,3′,3″,4″,6,6′,6″-deca-*O*-acetyl-β-maltotrioside **13** was isolated in 52% yield as an amorphous solid by column chromatography Deacetylation of **13** afforded **14**, its physical properties being in good agreement with those of the compound prepared *via* the methanolysis of **9** The n m r spectrum (deuterium oxide) of **14** showed a doublet at τ 5 63 with $J_{1,2}$ 8 0 Hz for the anomeric proton, consistent with the β-configuration at C-1

The α-chloride **9** was treated with mercuric acetate in acetic acid to give crystalline 1,2′,2″,3,3′,3″,4″,6,6′,6″-deca-*O*-acetyl-β-maltotriose (**15**), which on methanesulfonylation yielded crystalline 1,2′,2″,3,3′,3″,4″,6,6′,6″-deca-*O*-acetyl-2-*O*-methylsulfonyl-β-maltotriose (**16**)

Initial attempts to synthesize the aryl α- or β-glycosides of maltotriose by fusion of phenols with **1** under reaction conditions similar to those employed for the synthesis of phenyl α- or β-maltoside[9 10] were unsuccessful, a substantial amount of the starting sugar was recovered unchanged and modification of the reaction conditions did not improve the yield

Subsequently, we found that the Koenigs–Knorr reaction used for the preparation of halophenyl β-glycosides of disaccharides[11,12] was adaptable to the synthesis of trisaccharide glycosides, when the α-bromide **12** was condensed with phenol, halophenol, or nitrophenol in the presence of potassium hydroxide in 50% aqueous acetone, the deca-*O*-acetyl derivatives of phenyl, *o*- and *p*-bromophenyl-, *o*-, *m*-, and *p*-chlorophenyl, and *p*-nitrophenyl β-glycosides of maltotriose were directly isolated crystalline from the reaction mixtures after the usual processing, whereas those of the *m*-bromophenyl and *m*-nitrophenyl β-glycosides were obtained in crystalline form after column chromatographic separation The physical properties of these compounds are listed in Table I It is noteworthy that all the bromo- and chloro-phenyl 2,2′,2″,3,3′,3″,4″,6,6′,6″-deca-*O*-acetyl-β-maltotriosides were obtained in yields much higher than those of the corresponding halophenyl 2,2′,3,3′,4′,6,6′-hepta-*O*-acetyl-β-maltosides (13 5–42% yield)[11 12]. Furthermore, it was found that the difference in the yields of halophenyl deca-*O*-acetyl-β-maltotriosides due to the

TABLE I

PHYSICAL AND ANALYTICAL DATA FOR ARYL 2,2′,2″,3,3′,3″,4′,6,6′,6″-DECA-*O* ACETYL-*β* MALTOTRIOSIDES

Deca-O acetyl-β-maltotrioside	*M p* (°)	$[\alpha]_D$ (°)	*Yield* (%)	*Formula*	*Elementary analysis*									
					Calc					*Found*				
					C	*H*	*Br*	*Cl*	*N*	*C*	*H*	*Br*	*Cl*	*N*
Phenyl	154	+72 8	65	$C_{44}H_{56}O_{26}$	52 80	5 64				52 75	5 69			
o-Bromophenyl	182.5	+52 6	62	$C_{44}H_{55}BrO_{26}$	48 94	5 13	7 40			48 82	5 19	7 45		
m-Bromophenyl	135	+66 6	53	$C_{44}H_{55}BrO_{26}$	48 94	5 13	7 40			48 78	5 26	7 25		
p-Bromophenyl	125–126	+69 8	58	$C_{44}H_{55}BrO_{26}$	48.94	5 13	7 40			48.90	5 20	7 38		
o-Chlorophenyl	189–190	+58 5	68	$C_{44}H_{55}ClO_{26}$	51.04	5 35		3 42		50 90	5 36		3.45	
m Chlorophenyl	110–111	+66 5	46	$C_{44}H_{55}ClO_{26}$	51 04	5 35		3 42		50.86	5 44		3 57	
p-Chlorophenyl	122–123	+71 8	64	$C_{44}H_{55}ClO_{26}$	51 04	5 35		3 42		51 01	5 41		3 34	
m-Nitrophenyl	98–99	+60 6	48	$C_{44}H_{55}NO_{28}$	50 53	5 30			1 34	50 41	5 39			1 45
p-Nitrophenyl	142- 143	+63 9	36	$C_{44}H_{55}NO_{28}$	50 53	5 30			1 34	50.38	5 45			1.32

TABLE II

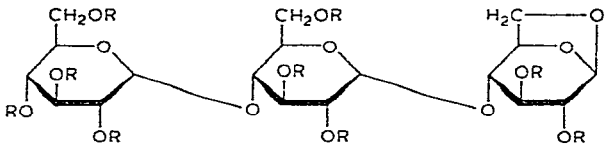
PHYSICAL AND ANALITICAL DATA FOR ARYL β-MALTOTRIOSIDLS

β-Maltotrioside	*M p* (°)	$[\alpha]_D$ (°)	*Formula*	*Elementary analysis*										*H-1 Resonances*[a]
				Calc					*Found*					
				C	*H*	*Br*	*Cl*	*N*	*C*	*H*	*Br*	*Cl*	*N*	
Phenyl	164–165	+88 0	$C_{24}H_{36}O_{16}$	49 65	6 25				49 53	6 30				4 90 (7 0)
o-Bromophenyl	175–176	+74 6	$C_{24}H_{35}BrO_{16}$	43 71	5 35	12 12			43 68	5 37	12 09			4 89 (7 5)
m-Bromophenyl		+69 2	$C_{24}H_{35}BrO_{16}$	43 71	5.35	12 12			43 60	5 44	12 00			5 01 (7.5)
p-Bromophenyl	164–165	+72 9	$C_{24}H_{35}BrO_{16}$	43 71	5 35	12 12			43 77	5 39	12 06			5 03 (7.0)
o-Chlorophenyl	174–175	+82 2	$C_{24}H_{35}ClO_{16}$	46 87	5 74		5 76		46 82	5 81		5 68		4 90 (7 0)
m-Chlorophenyl		+55 0	$C_{24}H_{35}ClO_{16}$	46 87	5 74		5 76		46 69	5 84		5 63		4 96 (7.5)
p-Chlorophenyl	163–164	+77 9	$C_{24}H_{35}ClO_{16}$	46 87	5.74		5 76		46 77	5 76		5 72		5 01 (7.5)
m-Nitrophenyl		+59 6	$C_{24}H_{35}NO_{18}$	46 08	5 64			2 24	45 90	5 83			2 29	4 83 (7 5)
p-Nitrophenyl		+57 6	$C_{24}H_{35}NO_{18}$	46 08	5 64			2 24	45 93	5 77			2 15	4 78 (7 5)

[a]Chemical shifts (τ values) and coupling constants (Hz) of the doublets at 60 MHz in deuterium oxide

position of the halogen atom on the aglycon was not so much distinct as observed for the halophenyl analogs of β-maltosides, where there is always a decrease in yield for the series $p>m>o$[11,12]

O-Deacetylation of the peracetates of aryl β-maltotriosides was performed with methanolic sodium methoxide Phenyl, *o*- and *p*-bromophenyl, and *o*- and *p*-chlorophenyl β-glycosides were obtained in crystalline form, whereas *m*-bromophenyl, *m*-chlorophenyl, and *m*- and *p*-nitrophenyl β-glycosides were obtained in amorphous but chromatographically pure form The physical constants of these β-glycosides are presented in Table II In the n m r spectra (deuterium oxide) of the aryl β-glycosides, each anomeric proton appeared in the region of τ 4 78–5 03 as a doublet with a magnitude of the coupling constants of 7 0–7 5 Hz, consistent with the β-anomeric configuration



17 R = Ac
18 R = H

It has been pointed out that the 1,6-anhydro-ring formation by alkaline degradation of aryl β-glycosides of mono-[13] and disaccharides[14–16] is influenced by the substituents on the aglycone Preliminary experiments showed on t l c that among the nine peracetates of the aryl β-glycosides prepared, *o*-chlorophenyl 2,2′,2″,3,3′,3″,4″,6,6′,6″-deca-*O*-acetyl-β-maltotrioside (**19**) was the most suitable for the convenient preparation of **18**, in the disaccharide series, *p*-chlorophenyl 2,2′,3,3′,4′,6,6″-hepta-*O*-acetyl-β-maltoside was the most efficient intermediate for the synthesis of 1,6-anhydro-β-maltose[16]. Treatment of **19** with aqueous 2 6M potassium hydroxide for 6 h at 100°, followed by acetylation of the resulting crude **18** with acetic anhydride and sodium acetate gave, in 81% yield, crystalline **17** which on *O*-deacetylation furnished pure, crystalline **18** in 97% yield In the n m r spectrum (deuterium oxide) of **18**, the H-1 resonance appeared at the lowest field (τ 4 54) as a broad singlet due to the vicinal coupling with H-2 and the long-range coupling with H-3, indicating that the 1,6-anhydro ring of **18** adopts the $^1C_4$ conformation[17] in spite of the axial glycosyloxy-group at C-4

Wolfrom *et al* [18] isolated three anhydro trisaccharides as peracetates from the mixture obtained by the thermal polymerization of 1,6-anhydro-β-D-glucopyranose but did not elucidate their structures None of the physical constants of these compounds are in accord with those of **17**

EXPERIMENTAL

General methods — Unless otherwise stated, solutions were evaporated at a temperature below 40° under reduced pressure Melting points were determined with a Yanagimoto hot-stage microscope and are uncorrected Optical rotations were measured with an Ohyo Denki automatic polarimeter, Model MP-1T The specific rotations of the aryl β-glycoside acetates and the free β-glycosides (Table I and II) were determined at 20° in chloroform solutions (*c* 2 0) and in water (*c* 1.3), respectively N m r. spectra were recorded with a Varian A-60A spectrophotometer, tetramethylsilane (in chloroform-*d*, benzene-d_6, and dimethyl sulfoxide-d_6) and 2,2-dimethyl-2-silapentane-5-sulfonate (in deuterium oxide) were used as internal standards T l c was performed on Silica Gel G (Merck), the detection was effected by spraying a solution of 10% sulfuric acid, followed by heating Column chromatography was performed on Silica Gel No 7734 (Merck); the following solvent systems were used. (A) 2 1 (v/v) benzene–ethyl acetate, (B) 1 1 (v/v) benzene–ethyl acetate, and (C) 6 1 3 (v/v) 2-butanone–acetic acid–water[19] Phosphorus pentachloride was resublimed immediately before use

O-(*2,3,4,6-Tetra*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1*→*4*)-O-(*2,3,6-tri*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1*→*4*)-*3,6-di*-O-*acetyl*-*2*-O-*trichloroacetyl*-β-D-*glucopyranosyl chloride* (**2**) — The β-hendecaacetate[1] **1** (10 g) was thoroughly mixed with phosphorus pentachloride (17 2 g, 83 mmol), and dry carbon tetrachloride (5 ml) was added The mixture was heated at 100° with exclusion of moisture After about 1 h, vigorous evolution of hydrogen chloride ceased and the mixture became fluid After 3 h, t l c tively N m r spectra were recorded with a Varian A-60A spectrophotometer; tetra- (Solvent A) showed a complex mixture, the fastest-moving component being the major product The volatile by-products were evaporated under reduced pressure until the bath temperature had risen to about 60° The residual syrup was extracted with ether, and the extract was washed successively with cold, aqueous sodium hydrogencarbonate and water, dried (Na_2SO_4), and evaporated to a syrup, which was fractionated on a column of silica gel (200 g) in Solvent A The first fraction crystallized from ether–petroleum ether to give **2** (4 6 g, 42%), m p 129–131°, $[\alpha]_D^{15}$ +81 1° (*c* 2 1, benzene). n m r data (benzene-d_6) τ 4 29 (d, 1 H, $J_{1,2}$ 8 5 Hz, H-1)

Anal. Calc. for $C_{38}H_{48}Cl_4O_{25}$ C, 43 61, H, 4 62, Cl, 13.55 Found C, 43 81, H, 4 58; Cl, 13.47

O-(*2,3,4,6-Tetra*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1*→*4*)-O-(*2,3,6-tri*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1*→*4*)-*3,6-di*-O-*acetyl*-β-D-*glucopyranosyl chloride* (**3**) — Compound **2** (5 g) was finely powdered and rapidly dissolved at 0° in ether (100 ml) that had been saturated with ammonia The mixture was vigorously agitated for 15 min, and the precipitate formed was filtered off and crystallized from ethyl acetate–ether to give **3** (4 1 g, 94%), m p 119–120°, $[\alpha]_D^{15}$ +104 9° (*c* 2 0, benzene), n m r data (benzene-d_6) τ 4 28 (d, 1 H, $J_{1,2}$ 9 0 Hz, H-1), OH signal obscured by the overlapping with other ring protons

Anal Calc for $C_{36}H_{49}ClO_{24}$ C, 47 98; H, 5 48, Cl, 3 93 Found C, 47 71, H, 5 40, Cl, 3 82

Methyl O-(*2,3,4,6-tetra*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-O-(*2,3,6-tri*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-*3,6-di*-O-*acetyl*-α-D-*glucopyranoside* (**4**) — (*a*). Compound **2** (0 9 g) was heated for 2 h under reflux in anhydrous methanol (20 ml) containing pyridine (0 08 ml) and silver nitrate (161 mg) The solution was filtered and evaporated to a syrup that was dissolved in chloroform The solution was washed with water, dried (Na_2SO_4), and concentrated to dryness Crystallization from ethanol afforded **4** (417 mg, 54%), m p 185 5–186°, $[\alpha]_D^{20}$ +152 4° (*c* 1 4, chloroform), n m r. data (dimethyl sulfoxide-d_6) τ 4 93 (d, $J_{2,2-OH}$ 6 0 Hz, 1 H, exchangeable with D_2O, OH-2) and 6 67 (s, 3 H, OMe)

Anal Calc for $C_{37}H_{52}O_{25}$· C, 49 55, H, 5 84 Found· C, 49 41, H, 5 89

(*b*) The β-chloride **3** (5 g) in methanol (130 ml) containing pyridine (0 49 ml) was treated with silver nitrate (1 04 g) for 2 h under reflux The resulting product was processed as just described to give a compound (4 28 g, 86%), m p 185–186° (from ethanol), $[\alpha]_D^{20}$ +153 6° (*c* 2 0, chloroform), identical (mixed m p and n m r) with that obtained in (*a*).

Acetylation of **4** with acetic anhydride–pyridine gave methyl *O*-(2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-α-D-glucopyranosyl)-(1→4)-2,3,6-tri-*O*-acetyl-α-D-glucopyranoside (**6**) in amorphous form, $[\alpha]_D^{17}$ +136 6° (*c* 1.3, chloroform); t l c R_F 0 52 (Solvent B).

Anal Calc for $C_{39}H_{54}O_{26}$ C, 49 90, H, 5 80 Found C, 49 71, H, 5 98

Conventional methanesulfonylation of **4** gave methyl *O*-(2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl)-(1→4)-*O*-(2,3,6-tri-*O*-acetyl-α-D-glucopyranosyl)-(1→4)-3,6-di-*O*-acetyl-2-*O*-methylsulfonyl-α-D-glucopyranoside (**7**), m p 105–106° (from 2-propanol), $[\alpha]_D^{17}$ +122 3° (*c* 1 6, chloroform), n m r data (chloroform-*d*) τ 6 50 (s, 3 H, OMe), 6 93 (s, 3 H, $MeSO_2$).

Anal Calc. for $C_{38}H_{54}SO_{27}$ C, 46 82, H, 5 58; S, 3 29. Found C, 46 70, H, 5 71, S, 3 17.

Methyl O-α-D-*glucopyranosyl*-(*1→4*)-O-α-D-*glucopyranosyl*-(*1→4*)-α-D-*glucopyranoside* (**5**) — To a solution of **4** (3 g) in dry methanol (40 ml) was added 0 1M sodium methoxide in methanol (10 ml), the mixture was stirred for 1 h at room temperature Dry Amberlite IR-120 (H^+) ion-exchange resin was added, and the suspension was stirred for 20 min, and then filtered Removal of the solvent afforded a hygroscopic solid, which was crystallized from water to give **5** (1 66 g, 96%), m.p 146–147 5°, $[\alpha]_D^{17}$ +203.0° (*c* 1.6, water), n m r data (deuterium oxide) τ 4 64 (d, 2 H, $J_{1',2'}$ and $J_{1'',2''}$ 3 0 Hz, H-1′ and H-1″), 5 20 (d, 1 H, $J_{1,2}$ 3 5 Hz, H-1), and 6 39 (s, 3 H, OMe), lit.[5]. m p 145–147 5°, $[\alpha]_D$ +202° (water)

O-(*2,3,4,6-Tetra*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-O-(*2,3,6-tri*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-*3,6-di*-O-*acetyl*-*2*-O-*trichloroacetyl*-α-D-*glucopyranosyl chloride* (**8**) — Compound **2** (1 g) was isomerized with titanium tetrachloride (6 ml) in chloroform (40 ml), according to the procedure of Wolfrom *et al*[8], to give **8** as an

amorphous solid (0 93 g), $[\alpha]_D^{17}$ +137 8° (*c* 1 6, chloroform), t l c R_F 0 35 (Solvent A), n m r data (chloroform-*d*)· τ 3 72 (d, 1 H, $J_{1,2}$ 3 8 Hz, H-1)

Anal Calc for $C_{38}H_{48}Cl_4O_{25}$ C, 43 61; H, 4 62; Cl, 13 55 Found C, 43 84; H, 4 78, Cl, 13 31

O-(*2,3,4,6-Tetra*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-O-(*2,3,6-tri*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-*3,6-di*-O-*acetyl*-α-D-*glucopyranosyl chloride* (**9**) — (*a*) Compound **8** (2 1 g) was treated at 0°, as described for **2**, in ether (40 ml) saturated with ammonia to afford **9** (1 56 g, 86%), m p 187–188° (from ethyl acetate–petroleum ether), $[\alpha]_D^{20}$ +167 0° (*c* 2 0, chloroform), n m r data (chloroform-*d*)· τ 3 90 (d, 1 H, $J_{1\ 2}$ 4 0 Hz, H-1), OH proton obscured by the overlapping with other ring protons

Anal Calc for $C_{36}H_{49}ClO_{24}$. C, 47 98, H, 5 48, Cl, 3 93. Found C, 47 86, H, 5 22, Cl, 3 99

(*b*) Compound **3** (4 2 g) was isomerized[8] with titanium tetrachloride (25 ml) in chloroform (170 ml) to give **9** (3 9 g, 93%), m p 188–189° (from ethyl acetate–ether), $[\alpha]_D^{15}$ +166 0° (*c* 1 7, chloroform), identical (mixed m p and n m r) with that prepared in (*a*)

Methyl O-(*2,3,4,6-tetra*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-O-(*2,3,6-tri*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-*3,6-di*-O-*acetyl*-β-D-*glucopyranoside* (**10**) — The α-chloride **9** (4 8 g) was treated with pyridine (0.47 ml) and silver nitrate (1 0 g) in methanol (120 ml), as described for the preparation of **4**, to give **10** (3 54 g, 74%), m p. 138–139° (from ethanol), $[\alpha]_D^{17}$ +109 3° (*c* 1.7, chloroform), n m r data (dimethyl sulfoxide-d_6) τ 4 63 (d, 1 H, $J_{2,2-OH}$ 5 5 Hz, exchangeable with D_2O, OH-2 and 6 63 (s, 3 H, OMe)

Anal Calc for $C_{37}H_{52}O_{25}$ C, 49 55, H, 5 84 Found C, 49 72, H, 5 77

Methyl O-(*2,3,4,6-tetra*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-O-(*2,3,6-tri*-O-*tri*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-*3,6-di*-O-*acetyl-2*-O-*methylsulfonyl*-β-D-*glucopyranoside* (**11**) — Methanesulfonylation of **10** gave **11**, m p 173–174° (from ethanol), $[\alpha]_D^{17}$ +82 5° (*c* 1 0, chloroform), n m r data (chloroform-*d*) τ 6 46 (s, 3H, OMe) and 6 97 (s, 3 H, $MeSO_2$)

Anal Calc for $C_{38}H_{54}SO_{27}$ C, 46 82, H, 5 58, S, 3 29 Found· C, 46 86, H, 5 41, S, 3 20

O-(*2,3,4,6-Tetra*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-O-(*2,3,6-tri*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-*2,3,6-tri*-O-*acetyl*-α-D-*glucopyranosyl bromide* (**12**) — To a chilled solution of the β-hendecaacetate **1** (10 g) in acetic acid (35 ml) was added an acetic acid solution (25 ml) that had been saturated with hydrogen bromide at 0° The mixture was stirred for 1 h at room temperature, chloroform was added, and the mixture was poured into ice–water The organic layer was separated, washed successively with water, aqueous sodium hydrogencarbonate, and water, dried ($MgSO_4$), and evaporated to a syrup which crystallized from ether–ethyl acetate to give **12** (9 0 g, 88%), m p. 105–106°, $[\alpha]_D^{15}$ +153 8° (*c* 1 5, chloroform), n m r data (chloroform-*d*) τ 3 50 (d, 1 H, $J_{1,2}$ 4 0 Hz, H-1).

Anal Calc for $C_{38}H_{51}BrO_{25}$· C, 46 21; H, 5 20, Br, 8 09 Found· C, 46 40; H, 5 11, Br, 7 89

Methyl O-(*2,3,4,6-tetra*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-O-(*2,3,6-tri*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-*2,3,6-tri*-O-*acetyl*-β-D-*glucopyranoside* (**13**) — To a solution of the α-bromide **12** (5 g) in dry benzene (30 ml) was added anhydrous calcium sulfate (4 g), mercuric acetate (3 g), and dry methanol (10 ml) The mixture was stirred overnight at room temperature, and then filtered through a Celite pad after dilution with benzene. The filtrate was washed with water, dried (Na_2SO_4), and evaporated to a syrup This was shown, by t l c (Solvent B), to be composed of a major product and a slower-moving contaminant, which was removed by column chromatography with Solvent B. The fractions containing **13** were evaporated to give an amorphous powder that could not be crystallized (2 4 g, 52%), $[\alpha]_D^{20}$ +77 8° (*c* 1 0, chloroform), t l c R_F 0 50 (Solvent B); n m r data (chloroform-*d*) τ 6 52 (s, 3 H, OMe)

Anal Calc for $C_{39}H_{54}O_{26}$ C, 49 90, H, 5 80 Found C, 49 69, H, 5 87

The compound was shown to be identical ($[\alpha]_D$, n m r, and t l c) with that obtained by acetylation of **10**

Methyl O-α-D-*glucopyranosyl*-(*1→4*)-O-α-D-*glucopyranosyl*-(*1→4*)-β-D-*glucopyranoside* (**14**) — (*a*) Treatment of **13** (1 8 g) with methanolic 0 1M sodium methoxide (5 ml) in methanol (20 ml), as described for the preparation of **5**, gave **14** as a chromatographically homogeneous powder (1 0 g, 96%), $[\alpha]_D^{25}$ +111 9° (*c* 2 3, water), t l c· R_F 0 68 (Solvent C), n m r. data (deuterium oxide)· τ 4 64 (d, 1 H, $J_{1\ 2'}$ and $J_{1''2}$ 3 0 Hz, H-1′ and H-1″), 5 63 (d, 1 H, $J_{1,2}$ 8 0 Hz, H-1), and 6 38 (s, 3 H, OMe)

Anal Calc for $C_{19}H_{34}O_{16}$ C, 44 02, H, 6 61 Found C, 44 07, H, 6 82

(*b*) An analogous *O*-deacetylation of **10** (0 8 g) with methanolic 0 1M sodium methoxide (2 ml) in methanol (10 ml) gave **14** (0 43 g, 93%), $[\alpha]_D^{25}$ +111 2° (*c* 1 1, water), which was identical (n m r and t l c) with the compound obtained in (*a*)

O-(*2,3,4,6-Tetra*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-O-(*2,3,6-tri*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-*1,3,6-tri*-O-*acetyl*-β-D-*glucopyranose* (**15**) — The α-chloride **9** (1 g) was treated with a solution of mercuric acetate (1 g) in acetic acid (10 ml) for 4 h at room temperature The solution was diluted with chloroform, washed with water, dried (Na_2SO_4), and evaporated to a crystalline mass, which was recrystallized from ethanol to give **15** (790 mg, 77%), m p. 126–127°, $[\alpha]_D^{20}$ +103 2° (*c* 1 7, chloroform), n m r data (dimethyl sulfoxide-d_6) τ 4 40 (d, 1 H, $J_{2,2-OH}$ 5.8 Hz, exchangeable with D_2O, OH-2) and 4 43 (d, 1 H, $J_{1,2}$ 9 0 Hz, H-1).

Anal Calc for $C_{38}H_{51}O_{26}$· C, 49 41; H, 5 56 Found· C, 49 23; H, 5.69

Acetylation of **15** with acetic anhydride–pyridine gave the β-hendecaacetate **1**

O-(*2,3,4,6-Tetra*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-O-(*2,3,6-tri*-O-*acetyl*-α-D-*glucopyranosyl*)-(*1→4*)-*1,3,6-tri*-O-*acetyl*-*2*-O-*methylsulfonyl*-β-D-*glucopyranose* (**16**) — Methanesulfonylation of **15** gave **16**, m p. 113–114° (from ethanol), $[\alpha]_D^{17}$ +90 5° (*c* 1 2, chloroform), n m r data τ 4 22 (d, 1 H, $J_{1\ 2}$ 8 0 Hz, H-1) and 7 02 (s, 3 H, $MeSO_2$)

Anal Calc. for $C_{39}H_{53}SO_{28}$. C, 46 75, H, 5 33, S, 3 20 Found· C, 46 72; H, 5.50, S, 3 09.

General procedure for the preparation of aryl 2,2',2",3,3',3",4",6,6',6"-deca-O-acetyl-β-maltotriosides — The procedure used was essentially that described by Dea[12,13] The phenol (3 7 equiv based on the α-bromide **12**) in a solution of potassium hydroxide (3 7 equiv based on **12**) in water (1 g/10 ml) was added to a solution of **12** in acetone (equal volume to the water used) The mixture was stirred for 15 h at room temperature and then the acetone removed under reduced pressure The resulting residue was extracted with benzene and the extract washed successively with M sodium hydroxide and water, dried (Na_2SO_4), and evaporated to dryness The deca-*O*-acetyl derivatives of phenyl, *p*-bromophenyl, *m*- and *p*-chlorophenyl β-glycosides crystallized from methanol, and those of *o*-bromophenyl, *p*-chlorophenyl, and *p*-nitrophenyl β-glycosides from methanol–chloroform In the case of *m*-bromophenyl and *m*-nitrophenyl glycoside acetates, the resulting syrup was purified by column chromatography on silica gel with Solvent B In each instance, the first fraction from the column containing the major product was evaporated to a syrup, which on crystallization from ethanol gave the crystalline glycoside acetate

General procedure for the O-*deacetylation of aryl deca*-O-*acetyl-β-maltotriosides* — A solution of the glycoside acetate in dry methanol (1 g/10 ml) was treated with methanolic M sodium methoxide in methanol (0 5 ml) The solution was stirred for 1 h at room temperature, and then neutralized with Amberlite IR-120 (H^+) ion-exchage resin, filtered, and evaporated to dryness Crystallization of the phenyl, *o*- and *p*-bromophenyl- and *o*- and *p*-chlorophenyl β-glycosides from methanol yielded crystals *m*-Bromophenyl, *m*-chlorophenyl, and *m*- and *p*-nitrophenyl β-glycosides could not be crystallized, but these glycosides were shown to be homogeneous on t l c with Solvent C

O-(*2,3,4,6-Tetra*-O-*acetyl-α-*D-*glucopyranosyl*)-(*1→4*)-O-(*2,3,6-tri*-O-*acetyl-α-*D-*glucopyranosyl*)-(*1→4*)-*2,3-di*-O-*acetyl-1,6-anhydro-β-*D-*glucopyranose* (**17**) — A mixture of **19** (8 7 g) and aqueous 2 6M potassium hydroxide (80 ml) was heated for 6 h on a boiling water-bath The solution was cooled, neutralized with 6M sulfuric acid, and concentrated to dryness The distillation was interrupted thrice and the precipitated salts were removed by filtration To the completely dried syrup obtained by repeated azeotropic distillation with ethanol were added acetic anhydride (45ml) and anhydrous sodium acetate (45 g) The mixture was heated for 3 h on a boiling steam-bath, and then poured into ice–water The resulting precipitate was filtered off, washed well with water, and dried Crystallization from methanol gave **17**, (6 0 g, 81%), m p 156 5–157°, $[\alpha]_D^{15}$ +82 4° (*c* 1 5, chloroform)

Anal Calc for $C_{36}H_{48}O_{24}$ C, 50 00, H, 5 60 Found: C, 49 83, H, 5 52

O-α-D-*Glucopyranosyl-(1→4)*-O-α-D-*glucopyranosyl-(1→4)-1,6-anhydro-β-*D-*glucopyranose* (**18**) — *O*-Deacetylation of the nonaacetate **17** (5 3 g) with M sodium methoxide (1 ml) in methanol (10 ml) as just described gave **18** (2 9 g, 97%), m p 254–254 5° (from methanol), $[\alpha]_D^{15}$ +130 2° (*c* 1 1, water), n m r data (deuterium oxide) τ 4 54 (broad singlet, 1 H, H-1), 4 61 (d, 1 H, $J_{1'',2''}$ 3.0 Hz, H-1"), and 4 87 (d, 1 H, $J_{1',2'}$ 3 5 Hz, H-1'), the compound did not reduce a boiling Fehling solution

Anal Calc for $C_{18}H_{30}O_{15}$ C, 44 45; H, 6 22 Found C, 44 39, H, 6 25

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