Carbohydrate Research, 212 (1991) 77–91
Elsevier Science Publishers B.V., Amsterdam

A new stereospecific method for 1,2-*cis*-glycosylation

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(Received July 24th, 1990; accepted for publication, September 26th, 1990)

ABSTRACT

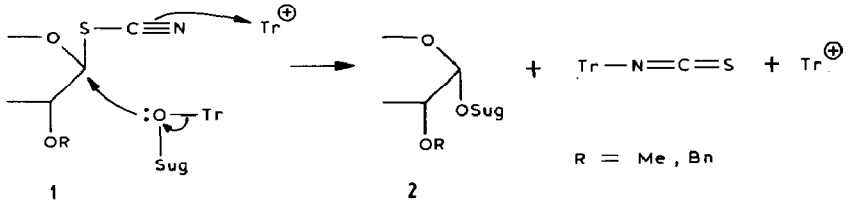
A new stereospecific method for 1,2-*cis*-glycosylation involves the reaction of 1,2-*trans*-glycosyl thiocyanates with sugar trityl ethers in the presence of triphenylmethylium perchlorate. The method has been applied to give disaccharide derivatives with (1→6), (1→4), (1→3), and (1→2) linkages.

INTRODUCTION

In spite of recent progress in the synthesis of oligosaccharides[1], the stereospecific formation of 1,2-*cis*-linkages still remains a problem. A more reliable approach to 1,2-*cis*-glycosylation could be based on S_N2 reactions at the anomeric centre. Taking into account the well known complications that arise due to the behaviour of reducing sugars in solution and the stereoelectronic factors involved, one possibility is to carry out this substitution as a concerted "push-pull" process.

This objective can be realised by the appropriate choice of the leaving group and by exclusion of participation by the 2-substituent, so that an irreversible S_N2-like substitution will yield a 1,2-*cis*-linkage from a 1,2-*trans* monosaccharide derivative.

Such a reaction has been found[2], and involves the reaction of glycosyl thiocyanates (**1**) as donors with trityl ethers as acceptors in the presence of triphenylmethylium perchlorate, to give α-glycosides (**2**).



1 2

Although the mechanism of the reaction **1**→**2** remains to be defined precisely, it seems resonable to assume that the triphenylmethylium cation attacks the nitrogen of the thiocyanate group whilst the oxygen of the trityl ether attacks the anomeric carbon in a "push-pull" process. The trityl isothiocyanate formed is non-reactive under the conditions used; hence, the reaction is irreversible. At the same time, the triphenyl-

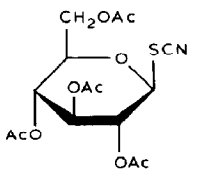
0008-6215/91/$03.50

methylium cation is regenerated so that the reaction is a catalytic process. For steric reasons, attack at the anomeric centre is possible from the rear side only, so that 1,2-*cis*-glycosides are formed from 1,2-*trans*-thiocyanates.

This new glycosylation reaction is related closely to the stereospecific 1,2-*trans*-glycosylation effected by the reaction of 1,2-*O*-cyanoethylidene derivatives with trityl ethers.

Synthesis of glycosyl thiocyanates. — Few compounds of this type are known. D-Glucosyl[3] and 6-bromo-6-deoxy-D-glucosyl[4] derivatives have been reported, but their chemical properties and application in synthesis were not elaborated. A convenient and general method for the synthesis of glycosyl thiocyanates involves treatment of hexo- or pento-pyranosyl bromides, particularly 1,2-*cis*-bromides, with potassium thiocyanate in dry acetone in the presence of 18-crown-6 ether. The reactions, which proceeded to completion in a few hours at room temperature, were monitored by t.l.c. and interrupted as soon as the content of sugar thiocyanate in the reaction mixture reached a maximum before the isomeric isothiocyanates appeared. The latter compounds could be isolated from reaction mixtures (as, for example, ~20% in the synthesis of the arabinose derivative).

The glycosyl thiocyanates **3–7**, which were obtained in yields of 55–70%, had a signal at 107–108.5 p.p.m. in their ^{13}C-n.m.r. spectra and an i.r. band at 2160 cm^{-1} which confirmed the presence of a thiocyanate group[3] (*cf.* 2050–2080 cm^{-1} for isothiocyanates[5]). That **3–7** were β was confirmed by the n.m.r. signals for C-1 at 83–85 p.p.m. and for H-1 at 4.6–4.9 p.p.m. ($J_{1,2}$ 9.5 Hz).



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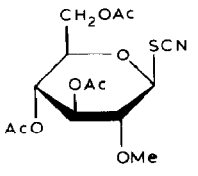

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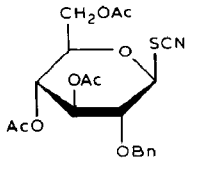

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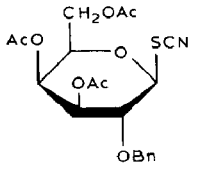

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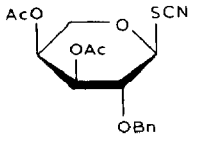

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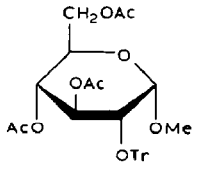
Compounds **4** (D-*gluco*), **5** (D-*gluco*), **6** (D-*galacto*), and **7** (L-*arabino*), which contained non-participating 2-*O*-methyl or 2-*O*-benzyl groups, were obtained. 2,3,4,6-Tetra-*O*-acetyl-D-glucopyranosyl thiocyanate (**3**) was used for control experiments. The L-*arabino* derivative **7** was synthesised as follows. 2,3,4-Tri-*O*-acetyl-β-L-arabinopyranosyl bromide (**8**) was converted into 3,4-di-*O*-acetyl-1,2-*O*-(1-ethoxyethylidene)-β-L-arabinopyranose (**9**, 4:1 *endo,exo*-mixture), treatment of which with aqueous 95%

acetic acid gave 1,3,4-tri-*O*-acetyl-β-L-arabinopyranose (**10**). Benzylation of **10** gave the 2-*O*-benzyl derivative (**11**) which, with $HBr–CH_2Cl_2$, gave the glycosyl bromide (**12**) that reacted with potassium thiocyanate to give **7**. In spite of the low temperature (−40°) of the last reaction, a mixture of the 1,2-*trans* (**7**) and 1,2-*cis* derivative (**13**) was obtained in the ratio 6:1, probably due to the greater lability of bromides in the pentopyranose series. The glycosyl thiocyanates **3–6** were crystalline and had reasonable stability, but **7** was an oil with lower stability.

In solution, the glycosyl thiocyanates can isomerise into isothiocyanates. The probable intramolecular rearrangement proceeded slowly at room temperature. Purification of the glycosyl thiocyanates was achieved easily by chromatography on silica gel, but additional h.p.l.c. was necessary for the L-*arabino* derivative **7**. All attempts to separate the anomeric xylopyranosyl thiocyanates failed.

Synthesis of disaccharides. — The efficiency of the new method of glycosylation was studied by the synthesis of disaccharide derivatives with (1→6), (1→4), (1→3), and (1→2) linkages. The acylated trityl derivatives **14–17**, used as the "aglyconic" components, were obtained as described[5–8], and 1,3,4,6-tetra-*O*-acetyl-2-*O*-trityl-α-D-galactopyranose (**18**) and benzyl 3-*O*-benzoyl-2,6-di-*O*-benzyl-4-*O*-trityl-β-D-galactopyranoside (**19**) were synthesised by tritylation of the appropriate hydroxy derivatives.



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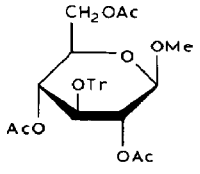

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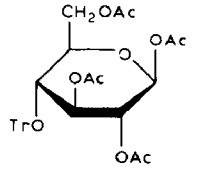

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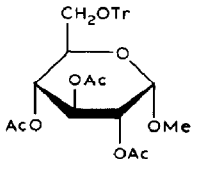

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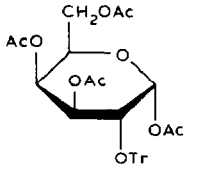

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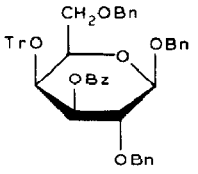

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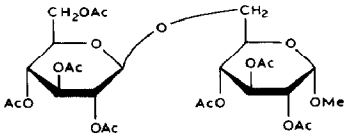
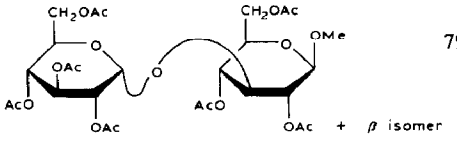
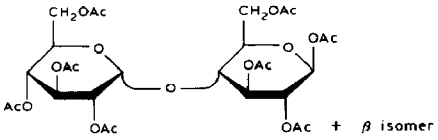
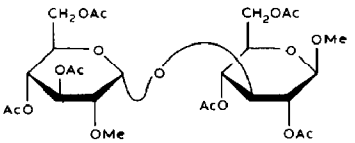
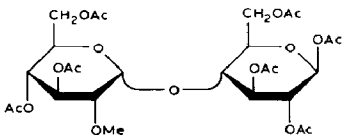
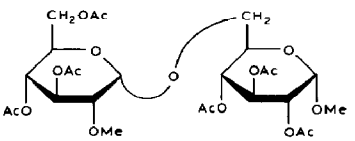
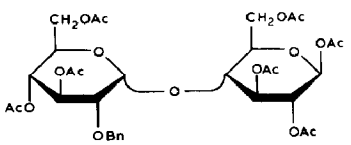
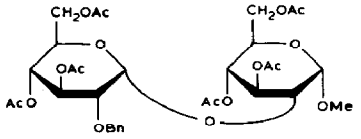
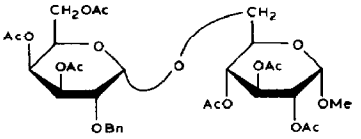
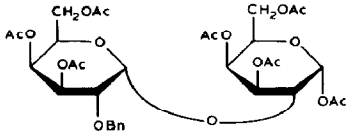
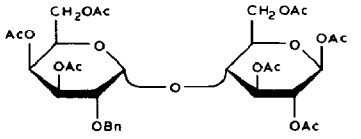
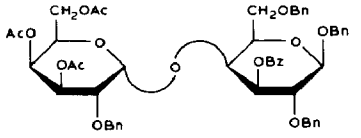
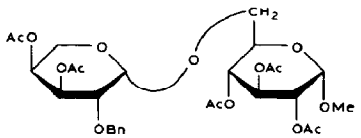
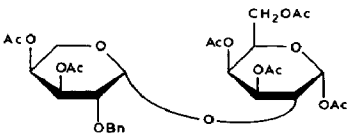
The glycosylation reactions were carried out under standard conditions analogous to those of the trityl–cyanoethylidene condensation[9], *i.e.*, in dry dichloromethane at room temperature in the presence of 0.1 equiv. of triphenylmethylium perchlorate. The reactions usually required 1–2 h for completion and were monitored by t.l.c. After quenching of the reaction with pyridine, the disaccharide derivatives were isolated by conventional methods. The results are summarised in Table I.

Experiments with 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl thiocyanate (**3**), which has a participating group at position 2, gave, as expected, α,β-mixtures from **15** and **16** (secondary trityl groups) but only the β anomer from **17** (primary trityl group).

TABLE I

Data on the synthesis of disaccharide derivatives

Run	*Thiocyanate (A)*	*Trityl ether (B)*	*Ratio A:B*	*Disaccharide derivative*	*Yield (%)*
1	**3**	**17**	1:1		65
2	**3**	**15**	1.3:1		79.5
3	**3**	**16**	1.1:1		71
4	**4**	**15**	1.5:1		77
5	**4**	**16**	1.5:1		82.5
6	**4**	**17**	1.1:1		77.5
7	**5**	**16**	1.5:1		77

8	**5**	**14**	1.5:1		55
9	**6**	**17**	1.2:1		70
10	**6**	**18**	1.9:1		59
11	**6**	**16**	1.7:1		33
12	**6**	**19**	1.5:1		52
13	**7**	**17**	1.7:1		77
14	**7**	**18**	2.4:1		52

Hence, in these reactions, glycosylation proceeds in the usual way, *i.e.*, through the acyloxonium ion. When glycosyl thiocyanates (**4–7**) with non-participating groups at C-2 were used for glycosylation, n.m.r. spectroscopy of the total disaccharide fraction isolated by chromatography showed the absence of derivatives with 1,2-*trans* linkages and indicated that clean S_N2 substitution at the anomeric centre had taken place. Trityl isothiocyanate[10] could be isolated from the reaction mixtures.

As seen from Table I, the reaction can be used for synthesis of derivatives with (1→6), (1→4), (1→3), and (1→2) linkages in yields of 33–82.5%.

The glycosylation by thiocyanates is sometimes accompanied by side-reactions and, for the optimisation of the yields, an excess (1.2–1.5 mol) of the glycosylating reagent is recommended. The main side-reaction involves the isomerisation of thiocyanates into the isothiocyanates. This rearrangement proceeds with inversion of configuration and the corresponding 1,2-*cis*-isothiocyanates, which could be isolated from the reaction mixture, had a characteristic intense i.r. band at 2040 cm^{-1} (NCS) together with n.m.r. signals for H-1 at at 5.4–5.8 p.p.m., for pyranose C-1 at 82.51–83.32 p.p.m., and at 144.30–144.55 p.p.m. (C of NCS). In some reactions, this rearrangement proceeded rather rapidly and an excess of the thiocyanate was used. Another important side-reaction is the detritylation of the aglyconic component and replacement of the trityl group by an acyloxy or hydroxyl group. This type of reaction was observed during the trityl–cyanoethylidene condensation[11] and appears to be a general phenomenon that accompanies the glycosylation of trityl ethers under tritylium-cation catalysis, and has been explained[12].

The presence of the 1,2-*cis* linkage in the disaccharide derivatives in Table I was confirmed by n.m.r. spectroscopy. The disaccharide derivatives obtained from thiocyanates (**4**–**7**) with non-participating groups gave signals for H-1′ at 4.85 (d, $J_{1,2}$ 3.5–3.6 Hz) and C-1 at 96.03–99.30 p.p.m.; signals for products with 1,2-*trans* linkages were not detected. The disaccharide derivatives could be deprotected by application in sequence of conventional Zemplén deacylation and hydrogenolysis, as illustrated for α-D-galactopyranosyl-(1→2)-D-galactopyranose and α-D-galactopyranosyl-(1→4)-D-galactopyranose.

The scope of the "trityl–thiocyanate" condensation is being evaluated further.

EXPERIMENTAL

General. — Dichloromethane and acetonitrile were distilled from P_2O_5 and, immediately before use, twice from CaH_2. Acetone was used without special purification. T.l.c. was performed on silica gel (Merck), column chromatography on Silica Gel L (40/100, CSFR), and preparative h.p.l.c. on a Silasorb 600 column, using heptane–ethyl acetate and a Knauer 88.00 u.v. detector. Solutions that contained thiocyanates were concentrated at $<30°$, and other solutions at $<40°$. M.p.s were determined on a Kofler block, optical rotations with a Jasco DIP-360 polarimeter, and i.r. spectra with a UR-20 spectrometer for KBr discs. The ^1H- and ^{13}C-n.m.r. spectra were recorded for solutions in $CDCl_3$ (internal Me_4Si) with Bruker WM-250 and AM-300 spectrometers, respectively.

1,3,4,6-Tetra-O-*acetyl-2*-O-*trityl*-α-D-*galactopyranose* (**18**). — A solution of 1,3,4,6-tetra-*O*-acetyl-α-D-galactopyranose[13] (1.0 g, 2.87 mmol) and triphenylmethylium perchlorate (1.47 g, 4.3 mmol) in dry CH_2Cl_2 (25 mL) that contained 2,4,6-trimethylpyridine (0.76 mL) was stored for 1 h at 20°, $CHCl_3$ (25 mL) was added, and the mixture was washed with water (5 × 30 mL), then concentrated to dryness. Column chromatography of the residue and recrystallisation from ether–benzene gave **18** (1.3 g, 77%), m.p. 161.5–162°, $[\alpha]_D^{25}$ +27° (*c* 2.0, chloroform). ^1H-N.m.r. data: δ 7.25–7.45 (15

H, 3 Ph), 5.61 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 5.46 (dd, 1 H, $J_{3,4}$ 3.6 Hz, H-3), 5.33 (dd, 1 H, $J_{4,5}$ 1.6 Hz, H-4), 4.19 (m, 1 H, H-5), 3.95 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-2), 3.94 (d, 2 H, H-6A,6B), 2.28, 1.99, 1.91, and 1.65 (4 s, each 3 H, 4 OAc).

Anal. Calc. for $C_{33}H_{34}O_9$: C, 68.97; H, 5.96. Found: C, 69.03; H, 5.95.

*Benzyl 3-*O*-benzoyl-2,6-di-*O*-benzyl-4-*O*-trityl-β-*D*-galactopyranoside* (**19**). — To a solution of benzyl 3-*O*-benzoyl-2,6-di-*O*-benzyl-β-D-galactopyranoside[14] (0.82 g, 1.48 mmol) in dry CH_2Cl_2 (15 mL) were added 2,4,6-trimethylpyridine (0.39 g, 2.96 mmol) and triphenylmethylium perchlorate (0.76 g, 2.22 mmol). The mixture was stored for 20 h at 20°, $CHCl_3$ (20 mL) was added, and the solution was washed with water and concentrated to dryness. Column chromatography of the residue and recrystallisation gave **19** (0.31 g, 27%), m.p. 145.5–147.5°, $[\alpha]_D^{26}$ +3.25° (*c* 3.2, chloroform). ^{1}H-N.m.r. data: δ 7.1–7.55 (35 H, 7 Ph), 5.03 (dd, 1 H, $J_{3,4}$ 3 Hz, H-3), 4.95 (dd, 2 H, ^2J 12 Hz, PhCH_2), 4.77 (dd, 2 H, ^2J 12 Hz, PhCH_2), 4.69 (d, 1 H, $J_{1,2}$ 7 Hz, H-1), 4.32 (dd, 2 H, ^2J 12 Hz, PhCH_2), 3.79 (dd, 1 H, $J_{5,6A}$ 8, $J_{6A,6B}$ 10.5 Hz, H-6A), 3.60–3.70 (m, 2 H, H-4,5), 3.42 (dd, 1 H, $J_{5,6B}$ 4 Hz, H-6B).

Anal. Calc. for $C_{53}H_{48}O_7$: C, 79.87; H, 6.07. Found: C, 80.01; H, 6.05.

*3,4-Di-*O*-acetyl-1,2-*O*-(1-ethoxyethylidene)-β-*L*-arabinopyranose* (**9**). — To a solution of **6** (ref. 15) (23.7 g, 7 mmol) in dry MeCN (75 mL) were added 2,4,6-trimethylpyridine (10.9 g, 82 mmol), tetrabutylammonium bromide (2.28 g, 7 mmol), and EtOH (6.7 mL, 115 mmol). The mixture was stirred for 4 h at 20°, then concentrated to dryness, $CHCl_3$ was added (300 mL), and the solution was washed with water (8 × 75 mL), filtered, and concentrated to dryness. Column chromatography (benzene–ether gradient) of the residue gave **9** (19.21 g, 90.4%) as a 7:1 *endo,exo*-mixture (n.m.r. data: integrated intensities of the CMe signals of the orthoester group). ^{1}H-N.m.r. data of the *endo*-methyl isomer, δ 5.56 (d, 1 H, $J_{1,2}$ 4 Hz, H-1), 5.29 (dd, 1 H, $J_{3,4}$ 3.5 Hz, H-3), 5.25 (m, 1 H, H-4), 4.29 (dd, 1 H, $J_{2,3}$ 5 Hz, H-2), 4.03 (dd, 1 H, $J_{4,5A}$ 4.5 Hz, H-5A), 3.73 (dd, 1 H, $J_{4,5B}$ 5 Hz, H-5B), 3.56 (dd, 2 H, J 7.5 Hz, CH_2CH$_3$), 2.10 and 2.07 (2 s, each 3 H, 2 OAc), 1.70 (s, 3 H, *endo*-Me), 1.57 (s, 3 H, *exo*-Me), 1.2 (t, 3 H, CH$_2$CH_3).

*1,3,4-Tri-*O*-acetyl-β-*L*-arabinopyranose* (**10**). — A solution of **9** (16.63 g, 5.5 mmol) in aqueous 95% CH_3COOH (60 mL) was stored for 15 min at 20°, $CHCl_3$ (250 mL) was added, and the solution was washed with cold water (150 mL). The aqueous layer was washed with $CHCl_3$ (2 × 50 mL), and the combined $CHCl_3$ solutions were washed with saturated aqueous $NaHCO_3$ and cold water (3 × 75 mL), dried by filtration through cotton wool, and concentrated. Benzene (50 mL) was evaporated from the residue, which crystallised on treatment with dry ether. Recrystallisation gave **10** (5.06 g, 33.5%), m.p. 101–102.5° (from ether–hexane), $[\alpha]_D^{30}$ +192° (*c* 1.7, chloroform). ^{1}H-N.m.r. data: δ 6.26 (d, 1 H, $J_{1,2}$ 4 Hz, H-1), 5.32 (m, 1 H, H-4), 5.19 (dd, 1 H, $J_{3,4}$ 3.5 Hz, H-3), 4.18 (m, 1 H, H-2), 3.99 (dd, 1 H, $J_{4,5A}$ 1.5 Hz, H-5A), 3.90 (dd, 1 H, $J_{4,5B}$ 2.25 Hz, H-5B), 2.17, 2.15, and 2.09 (3 s, each 3 H, 3 OAc).

Anal. Calc. for $C_{11}H_{16}O_8$: C, 47.82; H, 5.84. Found: C, 47.75; H, 5.90.

*1,3,4-Tri-*O*-acetyl-2-*O*-benzyl-*L*-arabinopyranose* (**11**). — To a solution of **10** (1.75 g, 6.36 mmol) in dry $CHCl_3$ (25 mL) and hexane (8 mL) were added benzyl trichloroacetimidate[16] (2.38 mL, 12.8 mmol) and trifluoromethanesulfonic acid (0.1

mL). The mixture was stirred for 3 h at 20°, $CHCl_3$ (60 mL) was added, and the mixture was washed with saturated aqueous $NaHCO_3$ and water (25 mL), dried by filtration through cotton wool, and concentrated to dryness. Column chromatography (benzene–ethyl acetate gradient) of the residue gave **11** (1.52 g, 65.5%) as an α,β-mixture (ratio 1:4). ^{1}H-N.m.r. data: β anomer, δ 7.25–7.4 (5 H, Ph), 6.38 (d, 1 H, $J_{1,2}$ 4 Hz, H-1), 5.36 (m, 1 H, H-4), 5.29 (dd, 1 H, $J_{3,4}$ 3.7 Hz, H-3), 4.64 (dd, 2 H, ^2J 12 Hz, PhCH_2), 4.03 (dd, 1 H, $J_{4,5A}$ 1.7 Hz, H-5A), 3.98 (dd, 1 H, $J_{1,2}$ 4 Hz, H-2), 3.77 (dd, 1 H, $J_{4,5B}$ 2.2 Hz, H-5B), 2.17, 2.12, and 2.04 (3 s, each 3 H, 3 OAc); α anomer, δ 7.25–7.40 (5 H, Ph), 5.65 (d, 1 H, $J_{1,2}$ 7 Hz, H-1), 5.36 (m, 1 H, H-4), 5.10 (dd, 1 H, $J_{3,4}$ 3.5 Hz, H-3), 4.79 (dd, 2 H, ^2J 12.5 Hz, PhCH_2), 4.07 (dd, 1 H, $J_{4,5A}$ 3.8 Hz, H-5A), 3.81 (dd, 1 H, $J_{1,2}$ 7 Hz, H-2), 3.63 (dd, 1 H, $J_{4,5B}$ 2 Hz, H-5B), 2.14, 2.10, and 2.02 (3 s, each 3 H, 3 OAc).

*3,4-Di-*O*-acetyl-2-*O*-benzyl-β-*L*-arabinopyranosyl bromide* (**12**). — To a solution of **11** (1.25 g, 3.4 mmol) in dry CH_2Cl_2 (20 mL) was added acetyl bromide (3.7 mL, 50 mmol) and then, dropwise during 15 min, a dry mixture of MeOH (1.92 mL, 47 mmol) and CH_2Cl_2 (5 mL). After 35 min, the mixture was concentrated to dryness, and toluene was evaporated thrice from the residue to leave syrupy **12**, $[\alpha]_D^{25}$ +122° (*c* 1.1, chloroform). ^{1}H-N.m.r. data: δ 7.28–7.4 (5 H, Ph), 6.49 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1), 5.38 (m, 1 H, H-4), 5.33 (dd, 1 H, $J_{3,4}$ 3.5 Hz, H-3), 4.68 (dd, 2 H, ^2J 12 Hz, PhCH_2), 4.2 (dd, 1 H, $J_{4,5A}$ 1.7 Hz, H-5A), 3.88 (dd, 1 H, $J_{4,5B}$ 2 Hz, H-5B), 3.85 (dd, 1 H, $J_{2,3}$ 9 Hz, H-2), 2.1 and 2.04 (2 s, each 3 H, 2 OAc).

*1,2-*cis*-Glycopyranosyl bromides with non-participating groups at C-2.* — These compounds were obtained by treatment of the corresponding 1-acetates with HBr/CH_2Cl_2.

3,4,6-Tri-*O*-acetyl-2-*O*-methyl-α-D-glucopyranosyl bromide, m.p. 86–87° (from ether), $[\alpha]_D$ +202° (*c* 4, dichloromethane). ^{1}H-N.m.r. data: δ 5.55 (d, 1 H, $J_{1,2}$ 3.8 Hz, H-1), 5.41 (dd, 1 H, $J_{3,4}$ 9.5 Hz, H-3), 5.09 (dd, 1 H, $J_{4,5}$ 10.5 Hz, H-4), 4.33 (m, 2 H, H-6A,6B), 4.24 (m, 1 H, H-5), 3.44 (s, 3 H, OMe), 2.09, 2.05, and 2.02 (3 s, each 3 H, 3 OAc).

Anal. Calc. for $C_{13}H_{19}BrO_8$: C, 40.75; H, 5.00; Br, 20.85. Found: C, 40.69; H, 4.95; Br, 20.60.

3,4,6-Tri-*O*-acetyl-2-*O*-benzyl-α-D-galactopyranosyl bromide, syrup, $[\alpha]_D^{32}$ +150° (*c* 1.9, chloroform). ^{1}H-N.m.r. data: δ 7.25–7.40 (5 H, Ph), 6.46 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 5.49 (dd, 1 H, $J_{4,5}$ 1.5 Hz, H-4), 5.33 (dd, 1 H, $J_{3,4}$ 3.2 Hz, H-3), 4.68 (d, 2 H, PhCH_2), 4.48 (m, 1 H, H-5), 4.15 (dd, 1 H, $J_{5,6A}$ 4.5 Hz, H-6A), 4.09 (dd, 1 H, $J_{5,6B}$ 7, $J_{6A,6B}$ 10 Hz, H-6B), 3.81 (dd, 1 H, $J_{2,3}$ 10 Hz, H-2), 2.13, 2.06, and 2.00 (3 s, each 3 H, 3 OAc).

Synthesis of glycosyl thiocyanates. — The α-glycosyl bromide (4.0 mmol), potassium thiocyanate (12.0 mmol, dried *in vacuo* at 110°), and 18-crown-6 (0.4 mmol, dried *in vacuo* for 24 h at 20°) were dissolved in dry acetone (10 mL). The reaction was monitored by t.l.c. and, when complete, the mixture was concentrated, traces of acetone were removed by co-evaporation with benzene, a solution of the residue in benzene was filtered through a thin layer of silica gel and concentrated, and the residue was subjected to column chromatography (benzene–ether gradient). The following compounds were obtained in this manner.

2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl thiocyanate (**3**, 62%), m.p. 132–133.5° (from benzene–hexane), $[\alpha]_D^{26}$ −21° (*c* 1.0, chloroform); ν_{max} 2160 cm^{-1} (S–C≡N). N.m.r. data: ^1H, δ 5.28 (dd, 1 H, $J_{3,4}$ 9 Hz, H-3), 5.15 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.15 (dd, 1 H, $J_{3,4}$ 9 Hz, H-4), 4.9 (d, 1 H, $J_{1,2}$ 9.5 Hz, H-1), 4.29 (dd, 1 H, $J_{5,6A}$ 4.8 Hz, H-6A), 4.19 (dd, 1 H, $J_{5,6B}$ 2.5, $J_{6A,6B}$ 12.5 Hz, H-6B), 3.84 (m, 1 H, H-5), 2.11, 2.10, 2.05, and 2.03 (4 s, each 3 H, 4 OAc); ^{13}C, δ 169.12–170.58 (C=O), 107.82 (SCN), 83.41 (C-1), 77.04 (C-2), 72.99 (C-3), 70.66 (C-5), 67.43 (C-4), 61.41 (C-6), 20.45, 20.63 ($OCOCH_3$).

Anal. Calc. for $C_{15}H_{19}NO_9S$: C, 46.27; H, 4.92; N, 3.61. Found: C, 46.38; H, 4.95; N, 3.50.

3,4,6-Tri-*O*-acetyl-2-*O*-methyl-β-D-glucopyranosyl thiocyanate (**4**, 69%), m.p. 127° (from ether–hexane), $[\alpha]_D^{28}$ −4.8° (*c* 1, chloroform); ν_{max} 2160 cm^{-1} (S–C≡N). N.m.r. data: ^1H, δ 5.19 (dd, 1 H, $J_{3,4}$ 9.5 Hz, H-3), 5.09 (dd, 1 H, $J_{4,5}$ 9.5 Hz, H-4), 4.59 (d, 1 H, $J_{1,2}$ 9.5 Hz, H-1), 4.24 (dd, 1 H, $J_{5,6A}$ 4.5 Hz, H-6A), 4.17 (dd, 1 H, $J_{5,6B}$ 3.4, $J_{6A,6B}$ 12.5 Hz, H-6B), 3.78 (m, 1 H, H-5), 3.60 (s, 3 H, OMe), 3.52 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2); ^{13}C, δ 169.5–170.6 (C=O), 108.16 (SCN), 83.96 (C-1), 80.53 (C-2), 76.84 (C-3), 75.29 (C-5), 67.82 (C-4), 61.67 (C-6), 61.31 (OCH_3), 20.58; 20.77 ($OCOCH_3$).

Anal. Calc. for $C_{14}H_{19}NO_8S$: C, 46.53; H, 5.30; N, 3.89. Found: C, 46.40; H, 5.33; N, 3.85.

3,4,6-Tri-*O*-acetyl-2-*O*-benzyl-β-D-glucopyranosyl thiocyanate (**5**, 72%), m.p. 110–111°, $[\alpha]_D^{29}$ +16° (*c* 1.6, chloroform); ν_{max} 2160 cm^{-1} (S–C≡N). N.m.r. data: ^1H, δ 7.25–7.40 (5 H, Ph), 5.26 (dd, 1 H, $J_{3,4}$ 9.2 Hz, H-3), 5.07 (dd, 1 H, $J_{4,5}$ 9.2 Hz, H-4), 4.76 (dd, 2 H, $PhCH_2$), 4.66 (d, 1 H, $J_{1,2}$ 9.2 Hz, H-1), 4.25 (dd, 1 H, $J_{5,6A}$ 4.8 Hz, H-6A), 4.18 (dd, 1 H, $J_{5,6B}$ 2.5, $J_{6A,6B}$ 12.4 Hz, H-6B), 3.81 (dd, 1 H, $J_{2,3}$ 9.2 Hz, H-2), 3.79 (m, 1 H, H-5), 2.11, 2.05, and 1.94 (3 s, each 3 H, 3 OAc); ^{13}C, δ 168.8–170.0 (C=O), 128.3–128.8 (C aromatic), 108.27 (SCN), 84.23 (C-1), 78.76 (C-2), 76.71 (C-5), 75.84 (CH_2), 72.25 (C-3), 67.95 (C-4), 62.00 (C-6), 20.60–20.75 ($OCOCH_3$).

Anal. Calc. for $C_{20}H_{23}NO_8S$: C, 54.91; H, 5.30; N, 3.20. Found: C, 54.82; H, 5.23; N, 3.24.

3,4,6-Tri-*O*-acetyl-2-*O*-benzyl-β-D-galactopyranosyl thiocyanate (**6**, 54%), $[\alpha]_D^{30}$ +56° (*c* 2.1, chloroform); ν_{max} 2160 cm^{-1} (S–C≡N). N.m.r. data: ^1H, δ 7.25–7.40 (5 H, Ph), 5.43 (dd, 1 H, $J_{4,5}$ 1.5 Hz, H-4), 5.06 (dd, 1 H, $J_{3,4}$ 3.5 Hz, H-3), 4.79 (dd, 2 H, $PhCH_2$), 4.68 (d, 1 H, $J_{1,2}$ 9.5 Hz, H-1), 4.3–4.8 (m, 2 H, H-6A,6B), 4.0 (m, 1 H, H-5), 3.98 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 2.19, 2.07, and 1.97 (3 s, each 3 H, 3 OAc); ^{13}C, δ 169.81–170.43 (C=O), 128.00–128.79 (C aromatic), 108.47 (SCN), 84.61 (C-1), 76.03 (CH_2), 75.84 [C-2 (or 5)], 75.64 [C-5 (or 2)], 73.93 (C-3), 67.24 (C-4), 61.32 (C-6), 20.68 ($OCOCH_3$).

3,4-Di-*O*-acetyl-2-*O*-benzyl-α-L-arabinopyranosyl thiocyanate (**7**), obtained after reaction at −35 to −40° for 2.5 h, was a 6:1 α,β-mixture (^1H-n.m.r. data). The pure α isomer (53%), isolated by h.p.l.c., was a syrup, $[\alpha]_D^{26}$ −50.5° (*c* 2.3, chloroform); ν_{max} 2160 cm^{-1} (S–C≡N). N.m.r. data: ^1H, δ 7.26–7.38 (5 H, Ph), 5.32 (m, 1 H, H-4), 5.21 (dd, 1 H, $J_{3,4}$ 3 Hz, H-3), 5.12 (d, 1 H, $J_{1,2}$ 6 Hz, H-1), 4.75 (dd, 2 H, ^2J 11 Hz, $PhCH_2$), 4.12 (dd, 1 H, $J_{4,5A}$ 5.5 Hz, H-5A), 3.92 (dd, 1 H, $J_{2,3}$ 7 Hz, H-2), 3.79 (dd, 1 H, $J_{4,5B}$ 2.7 Hz, H-5B), 2.14 and 2.07 (2 s, each 3 H, 2 OAc); ^{13}C, δ 169.46 (C=O), 128.00–128.69 (C aromatic),

109.78 (SCN), 85.80 (C-1), 76.13 (C-2), 74.71 (CH_2), 70.82 (C-3), 66.61 (C-4), 64.60 (C-5), 20.75–20.81 ($OCOCH_3$).

3,4-Di-*O*-acetyl-2-*O*-benzyl-α-L-arabinopyranosyl isothiocyanate was also isolated (20%), as a side product of the reaction, as a syrup, $[\alpha]_D^{29}$ −38° (*c* 1.0, chloroform). ^{1}H-N.m.r. data: 7.26–7.40 (5 H, Ph), 5.28 (m, 1 H, H-4), 5.13 (dd, 1 H, $J_{3,4}$ 3.5 Hz, H-3), 4.94 (d, 1 H, $J_{1,2}$ 6.5 Hz, H-1), 4.77 (dd, 2 H, ^2J 11.5 Hz, PhCH_2), 4.03 (dd, 1 H, $J_{4,5A}$ 5 Hz, H-5A), 3.78 (dd, 1 H, $J_{2,3}$ 8 Hz, H-2), 3.70 (dd, 1 H, $J_{4,5B}$ 2.5 Hz, H-5B), 2.13 and 2.07 (2 s, each 3 H, 2 OAc).

Synthesis of the disaccharide derivatives. — Thiocyanate (0.20 mmol), trityl derivative (0.2 mmol), and triphenylmethylium perchlorate (0.02 mmol) were dissolved in dry CH_2Cl_2 (2.0–2.5 mL). Each reaction was monitored by t.l.c. and allowed to continue until the trityl derivative disappeared. More thiocyanate was added if necessary (see Table I). A few drops of pyridine were added to quench the reaction, and the mixture was diluted with $CHCl_3$ (30 mL), washed with water, and concentrated to dryness. In order to isolate the disaccharide derivative, the mobility of which often coincided with that of the product of "aglycon" detritylation, the residue was dissolved in dry pyridine (2 mL), Ac_2O (1 mL) was added, and the mixture was stored overnight at room temperature. Methanol was added, the mixture was co-concentrated several times with toluene, and the residue was subjected to column chromatography. Elution with benzene–ether gave, in sequence, trityl isothiocyanate, α-glycosyl isothiocyanate, the acetylated detritylated derivative of the "aglycon", and the disaccharide derivative. The following compounds were prepared in this manner.

Methyl 2,3,4-tri-*O*-acetyl-6-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-α-D-glucopyranoside[18] (run 1), m.p. 94–96° (from ethanol), $[\alpha]_D^{27}$ +62° (*c* 2, chloroform); lit.[18] m.p. 96°, $[\alpha]_D^{28}$ +64.5° (chloroform). ^{13}C-N.m.r. data: δ 96.53 (C-1), 100.99 (C-1′).

Methyl 2,4,6-tri-*O*-acetyl-3-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl)-β-D-glucopyranoside (run 2), m.p. 146–147° (from ether), $[\alpha]_D^{30}$ +50° (*c* 1.2, chloroform). ^{13}C-N.m.r. data: δ 101.74 (C-1) and 96.15 (C-1′).

Anal. Calc. for $C_{27}H_{38}O_{18}$: C, 49.84; H, 5.89. Found: C, 49.75; H, 5.94.

Methyl 2,4,6-tri-*O*-acetyl-3-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-β-D-glucopyranoside[19] (run 2), m.p. 178° (from ether), $[\alpha]_D^{28}$ −42° (*c* 2.75, chloroform); lit.[19] m.p. 179–180°, $[\alpha]_D$ −45° (chloroform). ^{13}C-N.m.r. data: δ 101.83 (C-1), and 101.06 (C-1′).

1,2,3,6-Tetra-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl)-β-D-glucopyranose[20] (run 3), m.p. 159–160° (from ethanol), $[\alpha]_D^{24}$ +64° (*c* 1.0, chloroform); lit.[20] m.p. 159–161°, $[\alpha]_D$ +62.6° (chloroform). ^{13}C-N.m.r. data: δ 91.38 (C-1) and 95.84 (C-1′).

1,2,3,6-Tetra-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-β-D-glucopyranose[20] (run 3), m.p. 198–200° (from ethanol), $[\alpha]_D^{25}$ −12° (*c* 2.6, chloroform); lit.[20] m.p. 197°, $[\alpha]_D$ −15.7° (chloroform). ^{13}C-N.m.r. data: δ 91.89 (C-1) and 100.69 (C-1′).

Methyl 2,4,6-tri-*O*-acetyl-3-*O*-(3,4,6-tri-*O*-acetyl-2-*O*-methyl-α-D-glucopyranosyl)-β-D-glucopyranoside (run 4), m.p. 147° (from ethanol), $[\alpha]_D^{28}$ +49.5° (*c* 1.1, chloro-

form). ^{1}H-N.m.r. data: δ 5.22 (dd, 1 H, $J_{3',4'}$ 10 Hz, H-3'), 5.18 (dd, 1 H, $J_{4,5}$ 9.2 Hz, H-4), 5.02 (d, 1 H, $J_{1',2'}$ 3.5 Hz, H-1'), 5.00 (dd, 1 H, $J_{2,3}$ 9.2 Hz, H-2), 4.98 (dd, 1 H, $J_{4',5'}$ 10 Hz, H-4'), 4.29 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 4.26 (dd, 1 H, $J_{5,6A}$ 4.6 Hz, H-6A), 4.20 (dd, 1 H, $J_{5',6'A}$ 3 Hz, H-6'A), 4.15 (dd, 1 H, $J_{5,6B}$ 2.6, $J_{6A,6B}$ 12.5 Hz, H-6B), 4.05 (dd, 1 H, $J_{5',6'B}$ 2.0, $J_{6'A,6'B}$ 12.5 Hz, H-6'B), 4.01 (m, 1 H, H-5'), 3.76 (dd, 1 H, $J_{3,4}$ 9.2 Hz, H-3), 3.64 (m, 1 H, H-5), 3.48 and 3.39 (2 s, each 3 H, 2 OMe), 1.98–2.10 (6 s, 18 H, 6 OAc); ^{13}C, 169.4–170.9 (C=O), 101.73 (C-1), 98.74 (C-1'), 81.87 (C-3), 79.79 (C-2'), 72.60 (C-2), 71.96 (C-5), 71.67 (C-3'), 68.79 (C-5'), 68.32 (C-4), 67.99 (C-4'), 62.14 (C-6), 61.32 (C-6'), 59.10 (CH_3O-2'), 56.85 (CH_3O-1), 20.71–21.10 ($OCOCH_3$).

Anal. Calc. for $C_{26}H_{38}O_{17}$: C, 50.16; H, 6.15. Found: 50.09; H, 6.22.

1,2,3,6-Tetra-*O*-acetyl-4-*O*-(3,4,6-tri-*O*-acetyl-2-*O*-methyl-α-D-glucopyranosyl)-β-D-glucopyranose (run 5), m.p. 179–180.5° (from ethanol), $[\alpha]_D^{28}$ +55° (*c* 1.7, chloroform). N.m.r. data: ^{1}H, δ 5.72 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 5.31 (dd, 1 H, $J_{3,4}$ 8.5 Hz, H-3), 5.27 (dd, 1 H, $J_{3',4'}$ 9.8 Hz, H-3'), 5.15 (d, 1 H, $J_{1',2'}$ 3.7 Hz, H-1'), 5.01 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 4.95 (dd, 1 H, $J_{4',5'}$ 9.5 Hz, H-4'), 4.48 (dd, 1 H, $J_{5,6A}$ 2.5 Hz, H-6A), 4.26 (dd, 1 H, $J_{5,6B}$ 4.7 Hz, H-6B), 4.34 (dd, 1 H, $J_{5',6'B}$ 4.5 Hz, H-6'B), 4.01 (m, 2 H, H-5',6'A), 3.89 (dd, 1 H, $J_{4,5}$ 8.5 Hz, H-4), 3.79 (m, 1 H, H-5), 3.40 (s, 3 H, OMe), 3.37 (dd, 1 H, $J_{2',3'}$ 9.5 Hz, H-2'), 2.01–2.11 (7 s, 21 H, 7 OAc); ^{13}C, δ 169.0–170.4 (C=O), 98.54 (C-1'), 91.57 (C-1), 79.06 (C-2'), 75.99 (C-4), 74.10 (C-3), 73.54 (C-5), 72.00 (C-3'), 70.79 (C-2), 68.69 (C-5'), 68.47 (C-4'), 62.71 (C-6), 61.93 (C-6'), 59.81 (CH_3O-2'), 20.66–20.88 ($OCOCH_3$).

Anal. Calc. for $C_{27}H_{38}O_{18}$: C, 49.84; H, 5.89. Found: C, 49.90; H, 5.82.

Also isolated were the following compounds.

3,4,6-Tri-*O*-acetyl-2-*O*-methyl-α-D-glucopyranosyl isothiocyanate (76 mg, 0.21 mmol), m.p. 136–137° (from ether–hexane), $[\alpha]_D^{26}$ +135.5° (*c* 1.6, chloroform); ν_{max} 2040 cm^{-1} (N=C=S). N.m.r. data: ^{1}H, δ 5.78 (d, 1 H, $J_{1,2}$ 4.5 Hz, H-1), 5.29 (dd, 1 H, $J_{3,4}$ 10 Hz, H-3), 4.99 (dd, 1 H, $J_{4,5}$ 10 Hz, H-4), 4.28 (dd, 1 H, $J_{5,6A}$ 5.5 Hz, H-6A), 4.08 (dd, 1 H, $J_{5,6B}$ 2.6, $J_{6A,6B}$ 13.5 Hz, H-6B), 3.56 (dd, 1 H, $J_{2,3}$ 10 Hz, H-2), 3.50 (s, 3 H, OMe), 2.08, 2.06, and 2.02 (3 s, each 3 H, OAc); ^{13}C, δ 169.7–170.5 (C=O), 144.30 (NCS), 82.51 (C-1), 79.07 (C-2), 71.76 (C-3), 70.56 (C-5), 67.74 (C-4), 61.51 (C-6), 59.07 (OCH_3), 20.62–20.78 ($OCOCH_3$).

Anal. Calc. for $C_{14}H_{19}NO_8S$: C, 46.53; H, 5.30; N, 3.89. Found: C, 46.59; H, 5.27; N, 3.90.

1,2,3,4,6-Penta-*O*-acetyl-β-D-glucopyranose (14.3%), m.p. 133–135° (from ethanol), $[\alpha]_D$ +5.2° (*c* 2, chloroform).

Methyl 2,3,4-tri-*O*-acetyl-6-*O*-(3,4,6-tri-*O*-acetyl-2-*O*-methyl-α-D-glucopyranosyl)-α-D-glucopyranoside (run 6), m.p. 138–139° (from ether–hexane), $[\alpha]_D^{26}$ +147° (*c* 2, chloroform). N.m.r. data: ^{1}H, δ 5.49 (dd, 1 H, $J_{3,4}$ 9.4 Hz, H-3), 5.37 (dd, 1 H, $J_{3',4'}$ 9.6 Hz, H-3'), 5.01 (d, 1 H, $J_{1',2'}$ 3.4 Hz, H-1'), 4.79 (dd, 1 H, $J_{4',5'}$ 11 Hz, H-4'), 4.94 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1), 4.95 (dd, 1 H, $J_{4,5}$ 9.7 Hz, H-4), 4.84 (dd, 1 H, $J_{2,3}$ 10 Hz, H-2), 4.22 (dd, 1 H, $J_{5',6'A}$ 5.5 Hz, H-6'A), 4.15 (m, 1 H, H-5'), 4.08 (dd, 1 H, $J_{5',6'B}$ 2.5 Hz, H-6'B), 4.06 (m, 1 H, H-5), 3.76 (dd, 1 H, $J_{5,6A}$ 7 Hz, H-6A), 3.59 (dd, 1 H, $J_{5,6B}$ 2.7 Hz, H-6B), 3.44–3.45 (2 s, 6 H, 2 OMe), 3.40 (dd, 1 H, $J_{2',3'}$ 9.7 Hz, H-2'); ^{13}C, δ 169.8–170.7 (C=O), 96.35 (C-1), 95.96 (C-1'), 78.95 (C-2'), 71.77 (C-3'), 70.98 (C-2), 70.05 (C-3), 69.55 (C-4), 68.63 (C-4'),

67.95 (C-5), 67.49 (C-5′), 66.72 (C-6), 62.09 (C-6′), 59.15 (CH_3O-2′), 55.40 (CH_3O-1), 20.7–20.8 ($OCOCH_3$).

Anal. Calc. for $C_{26}H_{38}O_{17}$: C, 50.16; H, 6.15. Found: 50.27; H, 6.09.

1,2,3,6-Tetra-*O*-acetyl-4-*O*-(3,4,6-tri-*O*-acetyl-2-*O*-benzyl-α-D-glucopyranosyl)-β-D-glucopyranose (run 7), syrup, $[\alpha]_D^{30}$ +33° (*c* 3.75, chloroform). N.m.r. data: ^1H, δ 7.25–7.40 (5 H, Ph), 5.71 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 5.35 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.30 (dd, 1 H, $J_{3',4'}$ 10 Hz, H-3′), 5.06 (dd, 1 H, $J_{3,4}$ 9.5 Hz, H-3), 4.91 (dd, 1 H, $J_{4',5'}$ 10 Hz, H-4′), 4.89 (d, 1 H, $J_{1',2'}$ 3.5 Hz, H-1′), 4.57 (s, 2 H, PhCH_2), 4.53 (dd, 1 H, $J_{5,6B}$ 2 Hz, H-6B), 4.26 (dd, 1 H, $J_{5,6A}$ 4.5 Hz, H-6A), 4.23 (dd, 1 H, $J_{5',6'A}$ 5 Hz, H-6′A), 4.03 (m, 1 H, H-5′), 3.96 (dd, 1 H, $J_{5',6'B}$ 2, $J_{6'A,6'B}$ 12 Hz, H-6′B), 3.84 (dd, 1 H, $J_{4,5}$ 9.5 Hz, H-4), 3.77 (m, 1 H, H-5), 3.51 (dd, 1 H, $J_{2',3'}$ 10 Hz, H-2′), 1.9–2.1 (7 s, 21 H, 7 OAc); ^{13}C, δ 168.9–170.6 (C=O), 127.99–128.70 (C aromatic), 98.46 (C-1′), 91.66 (C-1), 77.21 (C-2′), 76.19 (C-4), 73.76 (C-5, CH_2), 73.06 (C-2), 71.36 (C-3′), 70.50 (C-3), 68.59 (C-5′), 68.44 (C-4′), 62.57 (C-6), 62.07 (C-6′), 20.65 – 20.84 ($OCOCH_3$).

Methyl 3,4,6-tri-*O*-acetyl-2-*O*-(3,4,6-tri-*O*-acetyl-2-*O*-benzyl-α-D-glucopyranosyl)-α-D-glucopyranoside (run 8), syrup, $]\alpha]_D^{28}$ +127° (*c* 4.5, chloroform). N.m.r. data: ^1H, δ 7.25–7.40 (5 Hz, Ph), 5.46 (dd, 1 H, $J_{3,4}$ 10 Hz, H-3), 5.41 (dd, 1 H, $J_{3',4'}$ 10 Hz, H-3′), 4.97 (dd, 1 H, $J_{4,5}$ 10 Hz, H-4), 4.96 (dd, 1 H, $J_{4',5'}$ 10 Hz, H-4′), 4.90 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 4.85 (d, 1 H, $J_{1',2'}$ 3.6 Hz, H-1′), 4.60 (dd, 2 H, PhCH_2), 4.28 (dd, 1 H, $J_{5,6A}$ 5 Hz, H-6A), 4.22 (dd, 1 H, $J_{5',6'A}$ 4 Hz, H-6′A), 4.07 (dd, 1 H, $J_{5,6B}$ 2.5 Hz, H-6B), 4.05 (m, 2 H, H-5′,6′B), 4.00 (m, 1 H, H-5), 3.70 (dd, 1 H, $J_{2,3}$ 10 Hz, H-2), 3.55 (dd, 1 H, $J_{2',3'}$ 10 Hz, H-2′), 3.44 (s, 3 H, OMe), 1.96–2.12 (6 s, 18 H, 6 OAc); ^{13}C, δ 169.9–170.6 (C=O), 127.8–128.7 (C aromatic), 97.76 (C-1,C-1′), 77.08 (C-2′), 76.93 (C-2), 73.28 (CH_2), 71.98 (C-3′), 71.68 (C-3), 68.82 (C-4), 68.56 (C-5′), 68.48 (C-4′), 67.30 (C-5), 62.19 [C-6 (or 6′)], 61.70 [C-6′ (or 6)].

The following compounds were isolated also.

3,4,6-Tri-*O*-acetyl-2-*O*-benzyl-α-D-glucopyranosyl isothiocyanate, ν_{max} 2040 cm^{-1} (N=C=S). N.m.r. data: ^1H, δ 7.25–7.40 (5 H, Ph), 5.45 (d, 1 H, $J_{1,2}$ 4.2 Hz, H-1), 5.35 (dd, 1 H, $J_{3,4}$ 10 Hz, H-3), 4.97 (dd, 1 H, $J_{4,5}$ 10 Hz, H-4), 4.67 (dd, 2 H, PhCH_2), 4.29 (dd, 1 H, $J_{5,6A}$ 4.5, $J_{6A,6B}$ 12 Hz, H-6A), 4.07 (dd, 1 H, $J_{5,6B}$ 2 Hz, H-6B), 4.06 (m, 1 H, H-5), 3.72 (dd, 1 H, $J_{2,3}$ 10 Hz, H-2); ^{13}C, δ 169.8–170.6 (C=O), 144.55 (NCS), 127.5–128.8 (C aromatic), 83.32 (C-1), 76.88 (C-2), 73.65 (CH_2), 71.86 (C-3), 70.59 (C-5), 67.88 (C-4), 61.57 (C-6).

Methyl 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranoside, m.p. 100–101° (from ethanol), $[\alpha]_D^{28}$ +132.5° (*c* 2, chloroform).

Methyl 2,3,4-tri-*O*-acetyl-6-*O*-(3,4,6-tri-*O*-acetyl-2-*O*-benzyl-α-D-galactopyranosyl)-α-D-glucopyranoside (run 9), syrup, $[\alpha]_D^{23}$ +142.5° (*c* 2.3, chloroform). N.m.r. data: ^1H, δ 7.26–7.36 (5 H, Ph), 5.48 (dd, 1 H, $J_{3,4}$ 9.5 Hz, H-3), 5.42 (dd, 1 H, $J_{4',5'}$ 1.6 Hz, H-4′), 5.31 (dd, 1 H, $J_{3',4'}$ 3.5 Hz, H-3′), 4.94 (dd, 1 H, $J_{4,5}$ 10 Hz, H-4), 4.92 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 4.85 (d, 1 H, $J_{1',2'}$ 3.5 Hz, H-1′), 4.83 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-2), 4.65 (dd, 2 H, ^2J 12.5 Hz, PhCH_2), 4.29 (m, 1 H, H-5′), 3.96–4.13 (m, 3 H, H-5,6′A,6′B), 3.84 (dd, 1 H, $J_{2',3'}$ 10.5 Hz, H-2′), 3.69 (dd, 1 H, $J_{5,6A}$ 6.7 Hz, H-6A), 3.47 (dd, 1 H, $J_{5,6B}$ 2.4, $J_{6A,6B}$ 11 Hz, H-6B), 3.40 (s, 3 H, OMe), 1.96–2.09 (6 s, 18 H, 6 OAc); ^{13}C, δ 169.85–170.5 (C=O),

127.7–128.4 (C aromatic), 97.28 (C-1'), 96.39 (C-1), 73.58 (C-2'), 73.15 (CH_2), 70.98 (C-2), 70.14 (C-3), 69.49 (C-3',C-4), 68.65 (C-4'), 67.99 (C-5), 66.71 (C-6), 66.50 (C-5'), 61.97 (C-6'), 55.38 (OCH_3), 20.60–20.72 ($OCOCH_3$).

1,3,4,6-Tetra-*O*-acetyl-2-*O*-(3,4,6-tri-*O*-acetyl-2-*O*-benzyl-α-D-galactopyranosyl)-α-D-galactopyranose (run 10), syrup, $[\alpha]_D^{30}$ +112° (*c* 2.1, chloroform). N.m.r. data: ^1H, δ 7.25–7.40 (5 H, Ph), 6.41 (d, 1 H, $J_{1,2}$ 4 Hz, H-1), 5.53 (dd, 1 H, $J_{4,5}$ 1.2 Hz, H-4), 5.40 (dd, 1 H, $J_{4',5'}$ 1.5 Hz, H-4'), 5.28 (dd, 1 H, $J_{3,4}$ 3.8 Hz, H-3), 5.21 (dd, 1 H, $J_{3',4'}$ 3.8 Hz, H-3'), 5.01 (d, 1 H, $J_{1',2'}$ 3.5 Hz, H-1'), 4.51–4.63 (dd, 2 H, PhCH_2), 4.30 (m, 1 H, H-5), 4.20 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-2), 3.99–4.30 (m, 5 H, H-5',6A,6B,6'A,6'B), 3.80 (dd, 1 H, $J_{2',3'}$ 3.8 Hz, H-2'), 1,92–2.16 (7 s, 21 H, 7 OAc); ^{13}C, δ 169.5–170.5 (C=O), 127.9–128.5 (C aromatic), 96.35 (C-1'), 88.88 (C-1), 73.60 (CH_2), 73.05 (C-2'), 69.75 (C-2), 69.65 (C-3), 68.90 (C-3'), 68.59 (C-5'), 68.20 (C-4'), 67.69 (C-4), 66.75 (C-5), 61.26 (C-6,6'), 20.62–20.74 ($OCOCH_3$).

A solution of this disaccharide derivative (89.5 mg) in EtOH (20 mL) was hydrogenolysed over 10% Pd–C (50 mg) at 40° for 2 h. The mixture was filtered, the catalyst was washed with EtOH (5 × 50 mL), the combined filtrate and washings were concentrated, and the residue was vacuum-dried, dissolved in abs. MeOH (2 mL), and *O*-deacetylated with methanolic M sodium methoxide (0.1 mL) at 20° for 16 h. The mixture was diluted with water (5 mL), neutralised by KU-2 (H^+) resin, filtered, concentrated to 0.5 mL, and then lyophilised to give 2-*O*-α-D-galactopyranosyl-α,β-D-galactopyranose (40 mg, 100%), $[\alpha]_D^{22}$ +106° (20 h, *c* 2.9, water). ^{13}C-N.m.r. data: α anomer, δ 97.85 (C-1'), 91.02 (C-1), 74.53 (C-2), 72.41 [C-5' (or 5 of β anomer)], 71.85 (C-5), 70.61 (C-3',4',4), 69.76 (C-2'), 69.14 (C-3), 62.48 [C-6' (or 6)], 62.35 [C-6 (or 6')]; β anomer: 99.38 (C-1'), 98.01 (C-1), 78.20 (C-2), 76.45 (C-5), 72.95 (C-3), 72.06 [C-5' (or 5 of α anomer)], 70.61 (C-3',4'), 70.37 (C-4), 69.76 (C-2'), 62.48 (C-6'), 62.35 (C-6).

1,2,3,6-Tetra-*O*-acetyl-4-*O*-(3,4,6-tri-*O*-acetyl-2-*O*-benzyl-α-D-galactopyranosyl)-β-D-glucopyranose (run 11), syrup, $[\alpha]_D^{25}$ +32° (*c* 2.0, chloroform). N.m.r. data: ^1H, δ 7.25–7.40 (5 H, Ph), 5.71 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 5.38 (dd, 1 H, $J_{4',5'}$ 1.5 Hz, H-4'), 5.33 (dd, 1 H, $J_{3,4}$ 9.5 Hz, H-3), 5.19 (dd, 1 H, $J_{3',4'}$ 3.2 Hz, H-3'), 5.06 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 4.97 (d, 1 H, $J_{1',2'}$ 3.6 Hz, H-1'), 4.62 (s, 2 H, PhCH_2), 4.48 (dd, 1 H, $J_{5,6A}$ 2.2 Hz, H-6A), 4.32 (dd, 1 H, $J_{5,6B}$ 4.8 Hz, H-6B), 4.24 (m, 1 H, H-5'), 4.05 (dd, 1 H, $J_{5',6'A}$ 6.5 Hz, H-6'A), 3.96 (dd, 1 H, $J_{5',6'B}$ 4.5, $J_{6'A,6'B}$ 11 Hz, H-6'B), 3.88 (dd, 1 H, $J_{4,5}$ 9.5 Hz, H-4), 3.79 (dd, 1 H, $J_{2',3'}$ 10.8 Hz, H-2'), 3.77 (m, 1 H, H-5), 1.90–2.13 (7 s, 21 H, 7 OAc); ^{13}C, δ 169.7–170.3 (C=O), 128.2–128.6 (C aromatic), 99.30 (C-1'), 91.67 (C-1), 76.03 (C-4), 73.87 (C-2',5), 73.81 (CH_2), 73.45 (C-3), 70.63 (C-2), 69.17 (C-3'), 68.34 (C-4'), 67.60 (C-5'), 62.68 [C-6 (or 6')], 61.68 [C-6' (or 6)], 20.52–20.76 ($OCOCH_3$).

Benzyl 3-*O*-benzoyl-2,6-di-*O*-benzyl-4-*O*-(3,4,6-tri-*O*-acetyl-2-*O*-benzyl-α-D-galactopyranosyl)-β-D-galactopyranoside (run 12), syrup, $[\alpha]_D^{25}$ +85° (*c* 2.7, chloroform). N.m.r. data: ^1H, δ 7.15–7.50 (m, 25 H, 5 Ph), 5.45 (dd, 1 H, $J_{3',4'}$ 3.5 Hz, H-3'), 5.42 (m, 1 H, H-4'), 5.18 (dd, 1 H, $J_{3,4}$ 3.25 Hz, H-3), 5.05 (d, 1 H, $J_{1',2'}$ 3.5 Hz, H-1'), 4.87 (dd, 2 H, ^2J 12 Hz, PhCH_2), 4.83 (dd, 2 H, ^2J 11.5 Hz, PhCH_2), 4.63 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 4.61 (dd, 2 H, ^2J 12 Hz, PhCH_2), 4.48 (m, 1 H, H-5'), 4.41 (dd, 2 H, ^2J 12 Hz, PhCH_2), 4.31 (m, 1 H, H-4), 3.96 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-2), 3.91 (dd, 1 H, $J_{5,6A}$ 6.5, $J_{6A,6B}$ 9.5 Hz, H-6A),

3.86 (dd, 1 H, $J_{2',3'}$ 9.5 Hz, H-2'), 3.81 (m, 1 H, H-5), 3.81 (dd, 1 H, $J_{5',6'A}$ 7.5, $J_{6'A,6'B}$ 11 Hz, H-6'A), 3.70 (dd, 1 H, $J_{5,6B}$ 6 Hz, H-6B), 3.45 (dd, 1 H, $J_{5,6B}$ 6.5 Hz, H-6'B), 2.07, 2.00, and 1.84 (3 s, each 3 H, 3 OAc); ^{13}C, δ 170.09 (C=O), 127.63–129.9 (C aromatic), 102.93 (C-1), 99.20 (C-1'), 76.84 (C-2), 75.37 (C-4), 74.89 (C-3, CH_2), 74.15 (C-2'), 73.70 (C-5), 73.28 (CH_2), 71.17 (CH_2), 69.57 (C-3'), 68.48 (CH_2), 68.27 (C-4'), 66.72 (C-5'), 60.99 (C-6,6'), 20.59–20.91 (OCO*C*H$_3$).

Hydrogenolysis of the foregoing compound and deacetylation of the product gave 4-*O*-α-D-galactopyranosyl-α,β-D-galactopyranose, syrup, $[\alpha]_D^{24}$ +66° (24 h, *c* 3.2, water). ^{13}C-N.m.r. data: α anomer, δ 101.83 (C-1'), 93.86 (C-1), 80.73 (C-4), 72.96 (C-5), 72.44 (C-5'), 70.70 (C-3',4'), 70.57 (C-3), 70.23 (C-2,2'), 62.77 (C-6'), 62.16 [C-6 (or C-6β)]; β anomer, 102.02 (C-1'), 98.16 (C-1), 79.10 (C-4), 76.60 (C-5), 73.50 (C-3), 72.44 (C-5'), 71.08 (C-2), 70.57 (C-4'), 70.23 (C-2',3'), 62.50 (C-6'), 61.83 [C-6 (or C-6α)].

Also isolated from the reaction mixture obtained after glycosylation was benzyl 3-*O*-benzoyl-2,6-di-*O*-benzyl-β-D-galactopyranoside (48%), m.p. 89.5–90.5° (from ether–hexane), $[\alpha]_D^{24}$ +45° (*c* 1.4, chloroform).

Methyl 2,3,4-tri-*O*-acetyl-6-*O*-(3,4-di-*O*-acetyl-2-*O*-benzyl-β-L-arabinopyranosyl)-α-D-glucopyranoside (run 13), obtained after reaction at −5° for 3 h, was a syrup, $[\alpha]_D^{27}$ +138° (*c* 3, chloroform). N.m.r. data: ^{1}H, δ 7.25–7.38 (5 H, Ph), 5.48 (dd, 1 H, $J_{3,4}$ 10 Hz, H-3), 5.32 (m, 2 H, H-3',4'), 4.95 (dd, 1 H, $J_{3,4}$ 10 Hz, H-4), 4.92 (d, 1 H, $J_{1,2}$ 4 Hz, H-1), 4.83 (d, 1 H, $J_{1',2'}$ 3.5 Hz, H-1'), 4.82 (dd, 1 H, $J_{2,3}$ 10 Hz, H-2), 4.67 (dd, 2 H, ^2J 12.5 Hz, PhCH_2), 4.03 (m, 1 H, H-5), 4.01 (m, 1 H, H-5'A), 3.87 (dd, 1 H, $J_{2',3'}$ 10.5 Hz, H-2'), 3.71 (dd, 1 H, $J_{5,6A}$ 7, $J_{6A,6B}$ 11 Hz, H-6A), 3.57 (dd, 1 H, $J_{4',5'B}$ 1.7 Hz, H-5'B), 3.47 (dd, 1 H, $J_{5,6B}$ 2.5 Hz, H-6B), 3.40 (s, 3 H, OMe), 2.13, 2.08, 2.04, 2.02, 2.00 (5 s, each 3 H, 5 OAc); ^{13}C, δ 170.04 (C=O), 127.66–128.48 (C aromatic), 97.77 (C-1'), 96.42 (C-1), 73.9 (C-2'), 73.06 (CH_2), 71.01 (C-2), 70.16 (C-3), 69.59 (C-4,4'), 69.14 (C-3'), 68.07 (C-5), 66.72 (C-5'), 60.67 (C-6), 20.73–20.99 (OCO*C*H$_3$).

The following compounds were also isolated.

3,4-Di-*O*-acetyl-2-*O*-benzyl-β-L-arabinopyranosyl isothiocyanate, syrup, $[\alpha]_D^{28}$ +181° (*c* 3.4, chloroform). N.m.r. data: ^{1}H, δ 7.25–7.40 (5 H, Ph), 5.54 (d, 1 H, $J_{1,2}$ 4 Hz, H-1), 5.33 (m, 1 H, H-4), 5.19 (dd, 1 H, $J_{3,4}$ 3.5 Hz, H-3), 4.71 (dd, 2 H, ^2J 12.5 Hz, PhCH_2), 4.02 (dd, 1 H, $J_{4,5A}$ 1.7 Hz, H-5A), 3.97 (dd, 1 H, $J_{2,3}$ 10 Hz, H-2), 3.78 (dd, 1 H, $J_{4,5B}$ 2.2 Hz, H-5B), 2.12 and 2.03 (2 s, each 3 H, 2 OAc); ^{13}C, δ 170.0–170.05 (C=O), 143.3 (NCS), 127.88–128.15 (C aromatic), 84.59 (C-1), 73.61 (C-2), 73.58 (CH_2), 69.21 (C-3), 68.47 (C-4), 63.21 (C-5), 20.8–20.9 (OCO*C*H$_3$).

Methyl 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranoside (yield, 22%).

1,3,4,6-Tetra-*O*-acetyl-2-*O*-(3,4-di-*O*-acetyl-2-*O*-benzyl-β-L-arabinopyranosyl)-α-D-galactopyranose (run 14), obtained after reaction at −5° for 5.5 h, was a syryp, $[\alpha]_D^{27}$ +146° (*c* 2.25, chloroform). N.m.r. data: ^{1}H, δ 7.25–7.40 (5 H, Ph), 6.43 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1), 5.51 (dd, 1 H, H-4), 5.29 (dd, 1 H, $J_{3,4}$ 3.5 Hz, H-3), 5.27 (m, 1 H, H-4'), 5.20 (dd, 1 H, $J_{3',4'}$ 3.5 Hz, H-3'), 4.98 (d, 1 H, $J_{1',2'}$ 3.5 Hz, H-1'), 4.58 (dd, 2 H, ^2J 12 Hz, PhCH_2), 4.29 (m, 1 H, H-5), 4.17 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-2), 4.08 (d, 2 H, $J_{5,6} = J_{6A,6B}$ = 7 Hz, H-6A,6B), 4.00 (dd, 1 H, H-5'A), 3.82 (dd, 1 H, $J_{2',3'}$ 10.5 Hz, H-2'), 3.60 (dd, 1 H, $J_{4',5'B}$ 2 Hz, H-5'B), 2.16, 2.12, 2.05, 2.04, 1.97, 1.94 (6 s, each 3 H, 6 OAc); ^{13}C, δ

169.3–170.1 (C=O), 128.50–138.15 (C aromatic), 97.02 (C-1'), 89.08 (C-1), 73.60 (CH_2) 73.48 (C-2'), 70.12 (C-2), 69.54 (C-3), 69.37 (C-3'), 68.92 (C-4'), 68.63 (C-5), 67.79 (C-4), 61.34 [C-5' (or 6)], 60.99 [C-6 (or 5')], 20.7–20.95 ($OCOCH_3$).

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