Stannylene Derivatives in Glycoside Synthesis. Application to the Synthesis of the Blood-group B Antigenic Determinant

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Condensation of benzyl 2,6-di-*O*-benzyl-3,4-*O*-dibutylstannylene-α-D-galactopyranoside (9) with 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide in the presence of stannic chloride occurred at the 3- and 4-positions to give the branched trisaccharide (11) with two β-anomeric linkages. A (1→3)-linked ortho ester (13) was selectively obtained by reaction of compound (9) with 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl chloride in *NN'N''*-hexamethylphosphorotriamide; when the solvent was dichloroethane, a mixture of the ortho ester (13) and a branched product (15) with two ortho ester residues was obtained in a 2 : 1 ratio. 2,3,4,6-Tetra-*O*-benzyl-α-D-galactopyranosyl chloride selectively reacts at the 3-position of compound (9) in the presence of lithium iodide in *NN'N''*-hexamethylphosphorotriamide to give a 9 : 1 mixture of the α- and β-(1→3)-linked disaccharides (16) and (18) in 82% yield. The latter conditions were applied to the synthesis of the blood-group B antigenic determinant starting from the 2-*O*-allyl stannylene compound (10). Coupling of 2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl bromide under bromide-ion catalysis occurred at the 2-position of disaccharide (26) in 32% yield. Hydrogenation afforded the free trisaccharide (29), α-L-Fuc-(1→2)-[α-D-Gal-(1→3)]-D-Gal.

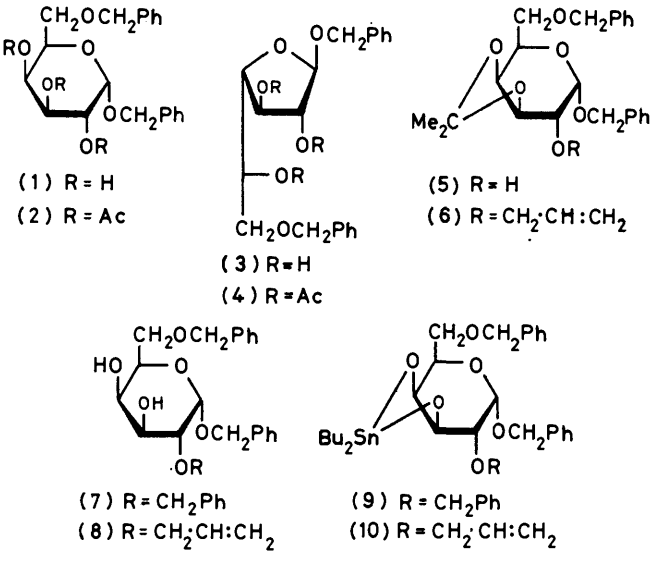
ONE possible approach to an efficient synthesis of glycosides is to increase the nucleophilicity of the oxygen atom of the aglycone compared with that of a free hydroxy-group.[1] Recently, Ogawa and Matsui [2] have obtained interesting results by trialkylstannylation of the alcohol to be glycosidated. We have previously reported [3] a complete regiospecificity in the benzylation of the 3,4-dibutylstannylene derivative of benzyl 6-*O*-allyl-2-*O*-benzyl-α-D-galactopyranoside; an exclusive substitution at the 3-position was observed under conditions which did not require the presence of a base such as potassium hydroxide, sodium hydride, or silver oxide, thus demonstrating an efficient enhancement of the nucleophilicity of the 3-equatorial oxygen atom.

Glycosidation of the 3-position of D-galactose is a critical step in the synthesis of several oligosaccharides related to the 'core' portion of the A, B, H, and Le blood-group substances [4,5] and the A and B antigenic determinants.[6,7]

Several authors [8-10] have noticed a low reactivity of the 4-axial hydroxy-group of galactopyranose derivatives in the $^4C_1$ conformation, so that a preferential glycosidation of the 3-hydroxy-group in 3,4-unsubstituted derivatives was feasible. However, when the glycosidating reagent is used in large excess because of its tendency to decompose, a subsequent glycosidation at the 4-position of the galactose unit was observed in one case.[4]

We therefore envisaged the use of dibutylstannylene derivatives of vicinal diols in glycosidation reactions, since it seemed reasonable to expect a regioselective enhancement of the nucleophilicity of one of the oxygen atoms.

The benzyl 2,6-di-*O*-benzyl-α-D-galactopyranoside (7) was chosen as a model vicinal diol in our studies. It was easily obtained through a sequence of reactions already used for the preparation of the benzyl 6-*O*-allyl-2-*O*-benzyl-α-D-galactopyranoside.[4] The starting material, 6-*O*-benzyl-1,2 : 3,4-di-*O*-isopropylidene-α-D-galactopyranose,[11] was treated with benzyl alcohol under acidic conditions to give the crystalline benzyl 6-*O*-benzyl-α-D-galactopyranoside (1) in 43% yield. From the mother liquor, the benzyl 6-*O*-benzyl-β-D-galactofuranoside (3) could be isolated in 25% yield. The 240-MHz ^{1}H n.m.r. spectrum of its tri-*O*-acetyl derivative (4) showed a



singlet at δ 5.09 for the anomeric proton, a quartet at δ 4.38 for 4-H, well shifted upfield when compared to 4-H in the tri-*O*-acetyl derivative (2) of compound (1) (δ 5.17), and a sextuplet at δ 5.34 for 5-H, well shifted downfield when compared to 5-H in compound (2) (δ 4.23). Compound (1) was converted into the 3,4-*O*-isopropylidene derivative (5). Benzylation, followed by acidic hydrolysis, gave the crystalline diol (7).

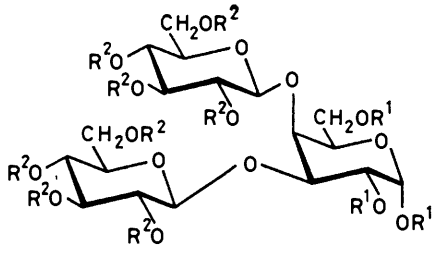
Alternatively, the alcohol (5) was *O*-allylated to give compound (6). Acidic hydrolysis removed the 3,4-*O*-isopropylidene group to afford benzyl 2-*O*-allyl-6-*O*-benzyl-α-D-galactopyranoside (8), a useful diol for the preparation of branched trisaccharides.

The diols (7) and (8) were converted into their dibutylstannylene derivatives (9) and (10) by reaction with polymeric dibutyltin oxide in benzene under azeotropic

removal of water. The absence of any hydroxy-absorption was verified in the i.r. spectrum and the products were directly used for the condensation studies.

We initially tried the condensation of 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide [12] with the stannylene compound (9) in *NN*-dimethylformamide at 60 °C. No condensation product could be isolated from the reaction mixture, but a mixture of 3- and 4-*O*-formyl derivatives of the diol (7) was formed by reaction with the solvent; the ^{1}H n.m.r. spectrum of this mixture showed a singlet at δ 8.17 which could be assigned to the formyl proton, and the i.r. spectrum a strong absorption at 1 740 cm^{-1}. Hough and Lewis [13] have also observed the formation of a 1-*O*-formyl ester by reaction of the same bromide with *NN*-dimethylformamide in the presence of mercuric cyanide.

Ogawa and Matsui [2] have shown that coupling between 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide and various tributylstannyl alkoxides occurred in the presence of a Lewis acid. When the stannylene compound (9) was treated with the glucosyl bromide in dichloromethane in the presence of 1.5 equiv. of stannic chloride, the only condensation product was a branched trisaccharide (11). The same compound was obtained when the bromide was replaced by the 1,2,3,4,6-penta-*O*-acetyl-β-D-glucopyranose. No condensation occurred



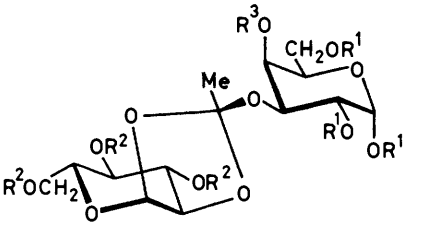
(11) R^1 = CH_2Ph, R^2 = Ac
(12) R^1 = R^2 = H

when the diol (7) was used in place of its stannylene derivative (9).

Compound (11) was deacetylated, then hydrogenated to give the free branched trisaccharide (12); its ^{1}H n.m.r. spectrum (solvent D_2O at 80 °C) showed two doublets at δ 4.60 and 4.61 (1 H, 2d, $J_{1'',2''}$ 7.7 Hz) corresponding to the anomeric proton of the β-(1→4)-linked D-glucose unit in the α- and β-tautomers (12), and one doublet at δ 4.76 (1 H, d, $J_{1',2'}$ 7.8 Hz) corresponding to the anomeric proton of the β-(1→3)- linked D-glucose unit. It is noticeable that no Lewis-acid catalysed anomerisation of the condensation product had occurred, although this might have been expected from earlier reports.[2,14]

The use of strong nucleophiles and a dipolar aprotic solvent has sometimes led to the conversion of 1,2-*trans*-glycosyl halides into 1,2-*cis*-glycosides through an S_N2 type reaction at the anomeric carbon atom.[15] Treatment of the stannylene compound (9) with 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl chloride [16] in *NN'*-*N''*-hexamethylphosphorotriamide gave the product (13) where an ortho-ester group was linked to the 3-position of the D-galactopyranose unit in 49% yield. The ^{1}H n.m.r. chemical shifts of the dioxolan 2-methyl protons [δ 1.81 (s)] and the anomeric proton of the D-glucose unit [δ 5.71 (d, $J_{1',2'}$ 5 Hz)] seemed to indicate an *exo*-configuration.[17] The ^{1}H n.m.r. spectrum of the acetylated derivative (14) shows a broad doublet at δ 5.46 indicative of an equatorial hydrogen, thus confirming a (1→3) glycosidic linkage.

The ortho-ester (13) was very easily hydrolysed, and could be converted into a mixture of the diol (7) and 3,4,6-tri-*O*-acetyl-1,2-*O*-[1-(ethoxy)ethylidene]-α-D-

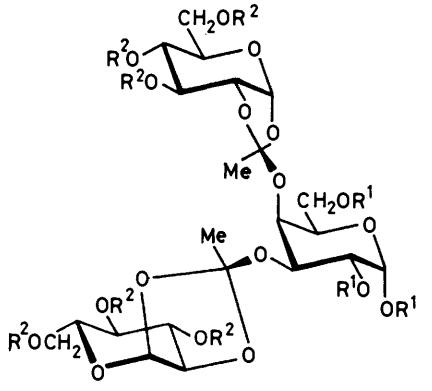


(13) R^1 = CH_2Ph, R^2 = Ac, R^3 = H
(14) R^1 = CH_2Ph, R^2 = R^3 = Ac

glucopyranose simply by heating in ethanol for a few minutes. Attempts to isomerise it into a β-(1→3) linked disaccharide with stannic chloride,[18] mercuric bromide,[19] or toluene-*p*-sulphonic acid [20] always failed, leading to complex mixtures.

When the condensation of the stannylene derivative (9) with the β-D-glucosyl chloride was run in dichloroethane at 45 °C, a mixture of the above ortho-ester (13) and a branched compound (15) with two ortho-ester residues was obtained in a ratio 2 : 1. The ^{1}H n.m.r. spectrum of compound (15) showed the presence of six acetyl groups and three phenyl rings, confirming the branched structure, dioxolan 2-methyl protons [δ 1.76 and 1.79 (2 s)], and anomeric protons of the two D-glucose units [δ 5.66 and 5.68 (2 H, 2 d, *J* 5 Hz)].

When 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide was used instead of the β-D-glucosyl chloride in

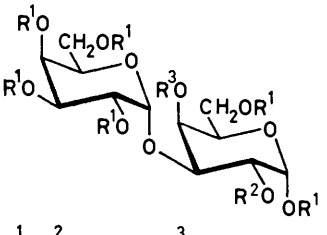


(15) R^1 = CH_2Ph, R^2 = Ac

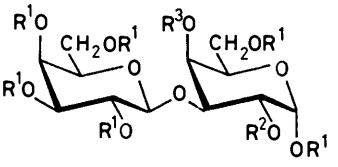
NN'N''-hexamethylphosphorotriamide, the ortho-ester (13) was again obtained although in lower yield, the reaction being much more sluggish.

The formation of the ortho-esters (13) and (15) was obviously due to the participation of the acetyl group at the 2-position of the glycosyl halide. The rearrangement of the ortho-ester (13) into the corresponding β-linked disaccharide having failed, such reactions of stannylene compounds could not be of great utility in glycoside synthesis.

Further, we examined the reaction of a stannylene compound with a glycosyl halide bearing no participating group on its 2-position. First, 2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl bromide [21] was selected for the synthesis of the blood-group B antigenic determinant. When the reaction with compound (9) was run in *NN'N''*-hexamethylphosphorotriamide at room temperature, a mixture of the α- and β-(1→3)-linked disaccharides (16) and (18) was obtained in the ratio 3 : 2; the position of the linkage was assigned from the ^{1}H n.m.r. signal of the equatorial proton 4-H in the acetylated disaccharides [δ 5.57 (d) in compound (17), and 5.46 (d) in compound (19)], then confirmed from the physical properties of the known free disaccharides (20) and (21).[22,23]



(16) R^1 = R^2 = CH_2Ph, R^3 = H
(17) R^1 = R^2 = CH_2Ph, R^3 = Ac
(20) R^1 = R^2 = R^3 = H
(22) R^1 = CH_2Ph, R^2 = $CH_2{\cdot}CH{:}CH_2$, R^3 = H
(23) R^1 = CH_2Ph, R^2 = $CH_2{\cdot}CH{:}CH_2$, R^3 = Ac
(26) R^1 = CH_2Ph, R^2 = R^3 = H



(18) R^1 = R^2 = CH_2Ph, R^3 = H
(19) R^1 = R^2 = CH_2Ph, R^3 = Ac
(21) R^1 = R^2 = R^3 = H
(24) R^1 = CH_2Ph, R^2 = $CH_2{\cdot}CH{:}CH_2$, R^3 = H
(25) R^1 = CH_2Ph, R^2 = $CH_2{\cdot}CH{:}CH_2$, R^3 = Ac

Gent and Gigg [24] have reported that in 1,2-*cis*-glycoside synthesis, tetraethylammonium bromide can convert a 1,2-*cis*-glycosyl chloride into a 1,2-*trans*-glycosyl bromide, thus avoiding the problems associated with the instability of the benzylated glycosyl bromides. Tetraethylammonium halides are not soluble enough in *NN'N''*-hexamethylphosphorotriamide, so that we had to replace them by lithium halide. 2,3,4,6-Tetra-*O*-benzyl-α-D-galactopyranosyl chloride [21] in the presence of lithium chloride was not reactive enough, but with lithium bromide or iodide, it gave high yields of the disaccharide mixture containing up to 90% of the α-linked component (see Table).

Condensation of a 2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl halide with benzyl 2,6-di-*O*-benzyl-α-D-galactopyranoside (7) or its stannylene derivative (9) [a]

Nucleophilic component	Galactosyl halide (molar equiv.)	Salt added	Yield [b] (%)	Ratio α : β
(9)	Bromide (1 equiv.)		48	60 : 40
(7)	Bromide (1 equiv.)		20	67 : 33
(9)	Bromide [c] (2 equiv.)		67	50 : 50
(9)	Bromide [c] (2 equiv.)	LiBr	64	73 : 27
(7)	Bromide (1 equiv.)	LiBr	18	only α
(9)	Chloride [e] (1 equiv.)	LiCl	49	47 : 53
(9)	Chloride (1 equiv.)	LiBr	30	80 : 20
(7)	Chloride (1 equiv.)	LiBr	12	only α
(9)	Chloride [d] (2 equiv.)	LiBr	72	77 : 23
(9)	Chloride [d] (2 equiv.)	LiI	82	90 : 10
(7)	Chloride [f] (1 equiv.)	Et_4NBr	30	only α
(7)	Chloride [d,f] (2 equiv.)	Et_4NBr	53	only α
(7)	Chloride [d,f] (2 equiv.)	Bu_4NI	75	94 : 6

[a] Unless specified otherwise, the condensations were carried out at room temperature in dry *NN'N''*-hexamethylphosphorotriamide for 2 days. [b] Total yield of protected disaccharides (16) and (18) isolated by column chromatography; based on compound (7) or (9). [c] The second molar equivalent of glycosyl halide was added to the reaction mixture after 1 day. [d] The two molar equivalents of glycosyl halide were added at the beginning of the experiment. [e] The condensation was run at 45 °C. [f] The solvent was dry dichloromethane.

When the diol (7) was treated with the benzylated galactosyl bromide in *NN'N''*-hexamethylphosphorotriamide in the presence of bromide ions, the α-(1→3)-linked disaccharide (16) was obtained in a poor yield (10—20%); no trace of the β-(1→3)-linked isomer (18) however could be detected in reaction mixtures.

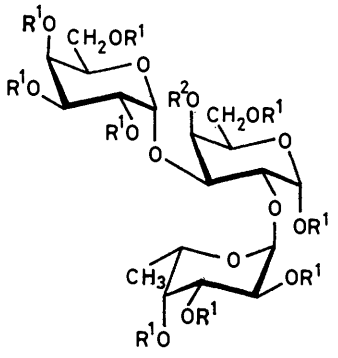
However, we found that under the conditions described by Lemieux *et al.*[7,23] (solvent dichloromethane, 4 Å molecular sieve as scavenger of hydrogen halide), the diol (7) gave results almost similar to those obtained above with the stannylene compound (9). Particularly, in no experiment was coupling at the 4-position of the 3,4-diol observed, even when 2—3 molar equivalents of glycosyl halide were used (see Table). Therefore, we believe that the use of stannylene compounds does not bring any convincing activation or selectivity in the reactions with benzylated glycosyl halides. The selective attack at the 3- position of the D-galactose unit, either as a 3,4-diol or a 3,4-dibutylstannylene derivative, might rather involve some steric factors related to the nature of the cumbersome glycosyl halide.

Nevertheless, our studies allowed us to improve the usual conditions of the halide-catalysed glycosidation reaction, by using a benzylated glycosyl chloride in the presence of iodide ions (tetrabutylammonium iodide for the reactions run in dichloromethane, and lithium iodide when the solvent is *NN'N''*-hexamethylphosphorotriamide.)

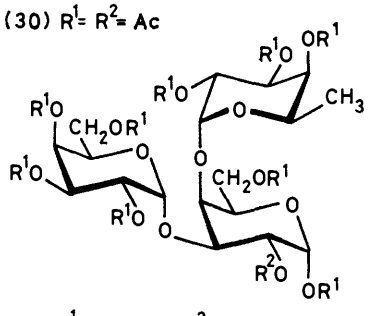
We applied our results to a new synthesis of the blood-group B antigenic determinant. The 2,3,4,6-tetra-*O*-

benzyl-α-D-galactopyranosyl chloride was coupled with the allylated stannylene compound (10) in *NN'N''*-hexamethylphosphorotriamide in the presence of lithium iodide. The desired α-linked disaccharide (22) was obtained in 74% yield after chromatographic separation of a small amount of the β-linked isomer (24) (8% yield). It was conventionally de-*O*-allylated to give the 2,4-diol (26) in 77% yield.

Condensation of 2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl bromide under the conditions given by Lemieux and Driguez [7] was very slow; after 4 days 39% of the starting diol had not reacted. Nevertheless, the reaction



(27) $R^1 = CH_2Ph$, $R^2 = H$
(28) $R^1 = CH_2Ph$, $R^2 = Ac$
(29) $R^1 = R^2 = H$
(30) $R^1 = R^2 = Ac$



(31) $R^1 = CH_2Ph$, $R^2 = H$
(32) $R^1 = CH_2Ph$, $R^2 = Ac$
(33) $R^1 = R^2 = H$

was stopped and the desired trisaccharide (27) was isolated in 32% yield. A 4-*O*-fucosyl product (31) was also obtained in 11% yield. The 4-position of the galactose unit was therefore appreciably reactive towards the fucosyl bromide although it was not towards the galactosyl halides. The moderate yield obtained in the condensation at the 2-position contrasts with the better results obtained by other workers [7,25] using different protective groups at the reacting galactose unit.

Hydrogenation of compound (27) gave the free trisaccharide (29) as a foam identical with the product described by Lemieux and Driguez.[7] The ^1H n.m.r. spectrum (solvent D_2O; at 20 °C) showed that the equilibrated solution contained α-pyranose, β-pyranose, and furanose, in the ratio 7 : 2 : 1; the signals of the corresponding anomeric protons were respectively observed at δ 5.40 (d, $J_{1,2}$ 3.5 Hz), 4.75 (d, $J_{1,2}$ 7.5 Hz), and 5.47 (s). The anomeric proton of the α-(1→2)-linked L-fucose unit gave two signals at δ 5.14 (d, $J_{1'',2''}$ 3.6 Hz), and 5.29 (d, $J_{1'',2''}$ 3.6 Hz) corresponding to the two α- and β-pyranose tautomers. The anomeric proton of the non-reducing D-galactose unit gave also two signals at δ 5.24 (d, $J_{1',2'}$ 3.4 Hz) and 5.27 (d, $J_{1',2'}$ 3.4 Hz). Acetylation of the trisaccharide (29) gave a crystalline derivative (30) which was a mixture of α- and β-pyranose acetates, in the ratio 4 : 1, as shown by ^1H n.m.r. spectroscopy.

Hydrogenation of compound (31) gave the isomeric free trisaccharide (33). The ^1H n.m.r. spectrum of the D_2O solution showed a mixture of two tautomers, α- and β-pyranose, in the ratio 3 : 7; no furanose form could be detected. The signals of the anomeric proton 1-H was observed at δ 5.73 (d, $J_{1,2}$ 3.5 Hz) for the α-tautomer, and 4.74 (d, $J_{1,2}$ 7 Hz) for the β-tautomer. The anomeric proton of the α-(1→4)-linked L-fucose unit gave only one signal at δ 5.43 (d, $J_{1'',2''}$ 4 Hz) and the anomeric proton of the α-(1→3)-linked D-galactose unit two signals at δ 5.27 (d, $J_{1',2'}$ 3.2 Hz) and 5.25 (d, $J_{1',2'}$ 3.2 Hz).

EXPERIMENTAL

Solvents were evaporated off under reduced pressure. Ether refers to diethyl ether throughout. Optical rotations were measured with a Roussel-Jouan electronic digital micropolarimeter. N.m.r. spectra were recorded with a spectrometer constructed in this University [26] at 240 MHz, with $CDCl_3$ as solvent and tetramethylsilane as internal standard, or with D_2O as solvent and tetramethylsilane (0.2% solution in $CDCl_3$) as external reference. T.l.c. was carried out on plates of silica gel (with fluorescence indicator; layer thickness 0.25 mm, E. Merck, Darmstadt, Germany); ethanolic sulphuric acid (19 : 1, v/v) with charring was used for component detection. Silica gel Merck (70—325 mesh; E. Merck) was used for column chromatography. Paper chromatography was performed on Whatman No. 1 paper. Free sugars were detected with the aniline hydrogenphthalate reagent. Elemental analyses were performed by the Laboratoire Central de Micro-Analyse du C.N.R.S.

Benzyl 6-O-*Benzyl*-α-D-*galactopyranoside* (1).—A solution of 6-*O*-benzyl-1,2 : 3,4-di-*O*-isopropylidene-α-D-galactopyranose (100 g, 0.29 mol) in benzyl alcohol (450 ml) containing hydrogen chloride (13.5 g) was heated at 120 °C for 3 h and then neutralised with potassium carbonate. The inorganic material was filtered off and the benzyl alcohol was evaporated off. The residue was chromatographed on silica gel (400 g); elution with chloroform–ethanol (9 : 1) gave a mixture of the glycosides from which the *benzyl* 6-O-*benzyl*-α-D-*galactopyranoside* (1) was obtained pure by crystallisation from ether (44.2 g, 43%), m.p. 126—127 °C, $[\alpha]_D^{20}$ +176° (*c* 1 in MeOH) (Found: C, 66.5; H, 6.7; O, 26.4. $C_{20}H_{24}O_6$ requires C, 66.7; H, 6.7; O, 26.6%).

A portion was acetylated overnight at room temperature to give the *benzyl* 2,3,4-*tri*-O-*acetyl*-6-O-*benzyl*-α-D-*galactopyranoside* (2) as a syrup which was distilled, b.p. 215 °C at 0.01 mmHg, $[\alpha]_D^{20}$ +82° (*c* 1.47 in $CHCl_3$), δ($CDCl_3$) 1.95, 2.00, and 2.02 (9 H, 3 OAc), 3.45 (2 H, 2d, 6-H), 4.23 (1 H, t, 5-H), 4.40 and 4.53 (2 H, 2 d, $J_{a,b}$ 12.5 Hz, $PhCH_aH_bO$),

4.51 and 4.72 (2 H, 2 d, $J_{a',b'}$ 12.5 Hz, $PhCH_{a'}H_{b'}O$), 5.13 (1 H, q, $J_{2.3}$ 11, $J_{3.4}$ 3.5 Hz, 3-H), 5.17 (1 H, d, $J_{3.4}$ 3.5 Hz, 4-H), 5.38 (1 H, q, $J_{1.2}$ 3, $J_{2.3}$ 11 Hz, 2-H), 5.52 (1 H, d, $J_{1.2}$ 3 Hz, 1-H), and 7.28 (10 H, 2 Ph) (Found: C, 64.2; H, 6.2; O, 29.4. $C_{26}H_{30}O_9$ requires C, 64.2; H, 6.2; O, 29.6%).

Benzyl 6-O-*Benzyl*-β-D-*galactofuranoside* (3).—The mother liquor of compound (1) was chromatographed on silica gel; elution with chloroform–ethanol (9 : 1) gave the pure *benzyl* 6-O-*benzyl*-β-D-*galactofuranoside* (3) (25.7 g, 25%), which could not be crystallised, $[\alpha]_D^{20}$ + 23° (*c* 0.95 in $CHCl_3$) (Found: C, 66.5; H, 6.9; O, 26.4. $C_{20}H_{24}O_6$ requires C, 66.7; H, 6.7; O, 26.6%).

A portion was acetylated to give the *benzyl* 2,3,5-*tri*-O-*acetyl*-6-O-*benzyl*-β-D-*galactofuranoside* (4) as a syrup which was distilled, b.p. 210 °C at 0.02 mmHg, $[\alpha]_D^{20}$ −66° (*c* 3.92 in $CHCl_3$), δ($CDCl_3$) 2.06 and 2.12 (9 H, 3 OAc), 3.66 (2 H, m, 6-H), 4.38 (1 H, q, $J_{3.4}$ 5.7, $J_{4.5}$ 3.4 Hz, 4-H), 4.53 (1 H, d, $J_{a,b}$ 12.1 Hz, $PhCH_aH_bO$), 4.54 (2 H, s, $PhCH_2O$), 4.74 (1 H, d, $J_{a,b}$ 12.1 Hz, $PhCH_aH_bO$), 5.03 (1 H, q, $J_{2.3}$ 1.9, $J_{3.4}$ 5.7 Hz, 3-H), 5.09 (1 H, s, 1-H), 5.11 (1 H, d, $J_{2.3}$ 1.9 Hz, 2-H), 5.34 (1 H, sext, 5-H), and 7.31 (10 H, 2 Ph) (Found: C, 64.0; H, 6.2; O, 29.4. $C_{26}H_{30}O_9$ requires C, 64.2; H, 6.2; O, 29.6%).

Benzyl 6-*O*-*Benzyl*-3,4-O-*isopropylidene*-α-D-*galactopyranoside* (5).—A solution of the triol (1) (36 g, 0.1 mol) in dry acetone (1 700 ml) containing toluene-*p*-sulphonic acid monohydrate (1.0 g) was stirred at room temperature for 3 h and then neutralised with sodium hydrogencarbonate, and filtered. The solvent was evaporated, and the residue was taken up in chloroform; the extract was washed with water, dried ($MgSO_4$), and evaporated to give the *product* (5) as a syrup (38.8 g, 97%). An analytical sample was obtained by column chromatography on silica gel with chloroform–ethanol (95 : 5), $[\alpha]_D^{20}$ +75° (*c* 3.4 in $CHCl_3$) (Found: C, 69.1; H, 7.0; O, 23.7. $C_{23}H_{28}O_6$ requires C, 69.0; H, 7.0; O, 24.0%).

Benzyl 2,6-*Di*-O-*benzyl*-α-D-*galactopyranoside* (7).—A solution of compound (5) (20 g, 50 mmol) in dry benzene (200 ml) was treated with sodium hydride (2.4 g, 0.1 mol) and benzyl bromide (12 ml, 0.1 mol) at room temperature for 1 h, and then under reflux for 4 h. The excess of hydride was decomposed by the addition of methanol to the cooled mixture; the solution was washed with water, dried ($MgSO_4$), and evaporated. The residue was dissolved in methanol (60 ml) and 0.5M-hydrochloric acid (20 ml); the solution was boiled under reflux until t.l.c. (toluene–acetone, 5 : 1) showed complete hydrolysis (*ca.* 30 min). An excess of sodium hydrogencarbonate was added and the solvents were evaporated. The residue was extracted with chloroform; the extract was washed with water, dried ($MgSO_4$), and evaporated. Crystallisation from ethanol gave the pure product (7) (15.7 g, 70%), m.p. 107.5 °C, $[\alpha]_D^{20}$ +113° (*c* 1 in MeOH) (Found: C, 72.1; H, 6.7; O, 21.1. $C_{27}H_{30}O_6$ requires C, 72.0; H, 6.7; O, 21.3%).

Benzyl 2-O-*Allyl*-6-O-*benzyl*-3,4-O-*isopropylidene*-α-D-*galactopyranoside* (6).—A solution of compound (5) (20 g, 50 mmol) in dry benzene (200 ml) was treated with sodium hydride (2.4 g, 0.1 mol) and allyl bromide (9 ml, 0.1 mol) at room temperature for 1 h, and then under reflux for 4 h. The mixture was worked up as above, to give compound (6) (20.0 g, 91%) as a syrup. An analytical sample was obtained by distillation, b.p. 150 °C at 0.02 mmHg, $[\alpha]_D^{20}$ +115° (*c* 1.91 in $CHCl_3$) (Found: C, 71.1; H, 7.4; O, 21.5. $C_{26}H_{32}O_6$ requires C, 70.9; H, 7.3; O, 21.8%).

Benzyl 2-O-*Allyl*-6-O-*benzyl*-α-D-*galactopyranoside* (8).—A solution of crude compound (6) (11 g, 25 mmol) in methanol (30 ml) and 0.5M-hydrochloric acid (10 ml) was heated under reflux until t.l.c. (chloroform–ethanol, 95 : 5) showed complete hydrolysis (*ca.* 30 min). The mixture was worked up as above to give compound (8) (9.2 g, 92%) as a syrup which crystallised slowly as a hydrated form. An analytical sample was obtained by distillation, b.p. 210 °C at 0.01 mmHg, $[\alpha]_D^{20}$ +116° (*c* 2 in $CHCl_3$) (Found: C, 69.0; H, 7.3; O, 24.0. $C_{23}H_{28}O_6$ requires C, 69.0; H, 7.0; O, 24.0%).

Preparation of the Stannylene Derivatives (9) *and* (10).—A mixture of the diol (7) or (8) (1 mmol) and dibutyltin oxide (0.27 g, 1.1 mmol) in dry benzene (50 ml) was heated under reflux for 6 h with continuous removal of water; the solvent was then removed under diminished pressure. The i.r. spectrum of the syrupy products (9) and (10) showed no OH signal.

Condensation of 2,3,4,6-*Tetra*-O-*acetyl*-α-D-*glucopyranosyl Bromide with Benzyl* 2,6-*Di*-O-*benzyl*-3,4-O-*dibutylstannylene*-α-D-*galactopyranoside* (9) *in the Presence of Tin*(IV) *Chloride*.—A mixture of 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide (0.82 g, 2 mmol) and tin(IV) chloride (0.35 ml, 3 mmol) in dry dichloromethane (10 ml) was stirred at 0 °C for 10 min. A solution of the stannylene derivative (9) (1.36 g, 2 mmol) in dry dichloromethane (10 ml) was added dropwise at 0 °C and the mixture was stirred at room temperature for 24 h with exclusion of moisture; t.l.c. (benzene–ether–methanol, 7 : 7 : 1) then showed the absence of bromide (R_F 0.63) and the presence of a new compound (R_F 0.59) and the diol (7) (R_F 0.42) derived from hydrolysis of compound (9). A further amount of bromide (0.41 g, 1 mmol) was added and the mixture was stirred at room temperature for a further 12 h. The reaction solution was diluted with dichloromethane, washed with 20% aqueous potassium hydrogencarbonate solution, and water, dried ($MgSO_4$), and evaporated. The residue (1.8 g) was chromatographed on silica gel; elution with toluene–ether–methanol (7 : 7 : 1) gave the trisaccharide (11) (0.55 g, 25%), then the unchanged diol (7) (0.47 g, 52%). For analysis, a portion of compound (11) was rechromatographed, $[\alpha]_D^{20}$ +23° (*c* 1 in $CHCl_3$), δ($CDCl_3$) 1.89, 2.00, and 2.02 (24 H, 8 OAc) and 7.31 (15 H, 3 Ph) (Found: C, 59.2; H, 6.0; O, 34.3. $C_{55}H_{66}O_{24}$ requires C, 59.4; H, 6.0; O, 34.6%).

3,4-*Di*-O-(β-D-*glucopyranosyl*)-D-*galactopyranose* (12).—Compound (11) (0.30 g) was deacetylated with triethylamine (1.2 ml) in methanol–water (4 : 1, 15 ml) at room temperature for 2 days. The solvents were evaporated; the residue was dried by several evaporations with absolute ethanol, then dissolved in glacial acetic acid (13 ml), and hydrogenated at room temperature and atmospheric pressure for 2 days in the presence of 10% palladium–charcoal (0.21 g). After removal of the catalyst, the solution was evaporated and the residue was chromatographed on silica gel; elution with propan-2-ol–ethyl acetate–water 3 : 3 : 2) gave the free trisaccharide (12) which crystallised from methanol–ether (80 mg, 55%), m.p. 126—130 °C, $[\alpha]_D^{20}$ +27.5° (*c* 0.8 in H_2O; no mutarotation), δ(D_2O; 80 °C) 4.56 (0.7 H, d, $J_{1,2}$ 7.6 Hz, 1-H_β), 4.60 and 4.61 (1 H, 2 d, $J_{1'',2''}$ 7.7 Hz, 1''-H), 4.76 (1 H, d, $J_{1',2'}$ 7.8 Hz, 1'-H), and 5.21br (0.3 H, d, 1-H_α), paper chromatography: R_{glc} 0.63 and $R_{lactose}$ 0.91 in ethyl acetate–pyridine–water (2 : 1 : 2, upper layer); R_{glc} 0.38 and $R_{lactose}$ 0.76 in butanol–pyridine–water (5 : 3 : 2); g.l.c. at 270 °C of the per-*O*-(trimethylsilyltrisaccharide gave two peaks of equal intensities

at 4.1 and 4.7 min; after borohydride reduction and per-*O*-trimethylsilylation, compound (12) gave only one peak at 5.4 min [*cf.* per-*O*-(trimethylsilyl)raffinose, 3.4 min] (Found: C, 39.8; H, 6.5; O, 53.1. $C_{18}H_{32}O_{16}$, $2H_2O$ requires C, 40.0; H, 6.7; O, 53.3%).

Condensation of 2,3,4,6-*Tetra*-O-*acetyl*-β-D-*glucopyranosyl Chloride with Benzyl* 2,6-*Di*-O-*benzyl*-3,4-O-*dibutylstannylene*-α-D-*galactopyranoside* (9).—(*a*) *In* NN'N''-*hexamethylphosphorotriamide*. A mixture of 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl chloride (0.37 g, 1 mmol) and the stannylene derivative (9) (0.68 g, 1 mmol) in dry *NN'N''*-hexamethylphosphorotriamide (5 ml) was stirred at 60 °C for 3 h; t.l.c. (chloroform–acetone, 4 : 1) then showed the presence of a new compound (R_F 0.62) and the diol (7) (R_F 0.37). The solution was cooled and poured into ice–water; the gummy precipitate was filtered off, washed with cold water, dried, and chromatographed on silica gel; elution with chloroform–acetone (4 : 1) gave the ortho-ester (13) (0.38 g, 49%) as an easily hydrolysable foam; δ($CDCl_3$) 1.81 (3 H, s, CH_3·C), 2.06 and 2.11 (9 H, 3 OAc), 4.89 (1 H, d, $J_{1,2}$ 3.5 Hz, 1-H), 4.90 (1 H, $J_{4',5'}$ 9.0 Hz, 4'-H), 5.20 (1 H, t, $J_{2',3'}$ 2.2, $J_{3',4'}$ 2.2 Hz, 3'-H), 5.71 (1 H, d, $J_{1',2'}$ 5 Hz, 1'-H), and 7.36 (15 H, 3 Ph).

A portion was acetylated overnight at room temperature. After removal of the solvents, the residue was dried and examined by n.m.r. spectroscopy: δ($CDCl_3$) 1.79 (3 H, s, CH_3·C), 2.06, 2.12, 2.13, and 2.14 (12 H, 4 OAc), 4.93 (d, 1 H, $J_{1,2}$ 3.5 Hz, 1-H), 4.94 (1 H, $J_{4',5'}$ 9.0 Hz, 4'-H), 5.19 (1 H, t, $J_{2'3'}$ 2.1, $J_{3',4'}$ 2.1 Hz, 3'-H), 5.46 (1 H, d, 4-H), 5.93 (1 H, d, $J_{1',2'}$ 5 Hz, 1'-H), and 7.38 (15 H, 3 Ph).

(b) *In dichloroethane*. A mixture of 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl chloride (0.45 g, 1.23 mmol) and the stannylene derivative (9) (0.84 g, 1.23 mmol) in dry dichloroethane (6.5 ml) was stirred overnight at 45 °C; t.l.c. (chloroform–acetone, 4 : 1) then showed the presence of two new compounds at R_F 0.62 and 0.67 in an approximate ratio of 2 : 1. The solution was diluted with dichloroethane, washed with 10% aqueous potassium hydrogencarbonate solution and water, and then dried ($MgSO_4$) and evaporated. The residue (1.0 g) was chromatographed on silica gel; elution with chloroform–acetone (4 : 1) gave a small amount of the pure faster-moving compound (15) (R_F 0.67); δ($CDCl_3$) 1.76 (3 H, s, CH_3·C), 1.79 (3 H, s, CH_3·C), 1.99, 2.05, 2.10 and 2.11 (18 H, 6 OAc), 4.84 (1 H, q, $J_{3',4'}$ 2 Hz, 4'-H), 4.86 (1 H, d, $J_{1,2}$ 3.5 Hz, 1-H), 4.94 (1 H, q, $J_{3'',4''}$ 3.5, $J_{4'',5''}$ 9.5 Hz, 4''-H), 5.09 (1 H, t, $J_{2',3'}$ 2.5, $J_{3',4'}$ 2.0 Hz, 3'-H), 5.14 (1 H, t, $J_{2'',3''}$ 2.5, $J_{3'',4''}$ 3.5 Hz, 3''-H), 5.66 (1 H, d, $J_{1',2'}$ 5.0 Hz, 1'-H), 5.68 (1 H, d, $J_{1'',2''}$ 5.0 Hz, 1''-H), and 7.29—7.35 (15 H, 3 Ph); a mixture of the two compounds (13) and (15) was obtained, and then finally a small amount of the pure slower-moving compound (R_F 0.62), the n.m.r. spectrum of which was identical to the spectrum of compound (13). The total yield of products (13) and (15) was 0.58 g.

Condensation of 2,3,4,6-*Tetra*-O-*benzyl*-α-D-*galactopyranosyl Bromide with Benzyl* 2,6-*Di*-O-*benzyl*-3,4-O-*dibutylstannylene*-α-D-*galactopyranoside* (9).—A mixture of 2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl bromide (0.60 g, 1 mmol), the stannylene derivative (9) (0.68 g, 1 mmol), and 4 Å molecular sieve (1.0 g) in dry *NN'N''*-hexamethylphosphorotriamide (8 ml) was stirred in the dark at room temperature for 2 days. T.l.c. (toluene–ether–light petroleum, 4 : 1 : 1) then showed two new compounds at R_F 0.27 and 0.38, some 2,3,4,6-tetra-*O*-benzyl-D-galactopyranose (R_F 0.15) derived from hydrolysis of the bromide, and some diol (7) (R_F 0.05) derived from hydrolysis of the stannylene derivative (9). After dilution with ethyl acetate and removal of molecular sieve, the solution was washed with 1M-hydrochloric acid and then 10% aqueous sodium hydrogencarbonate solution and water; it was then dried ($MgSO_4$) and evaporated. The residue was chromatographed on silica gel; elution with toluene–ether–light petroleum (4 : 1 : 1) gave the pure *benzyl* 2,6-*di*-O-*benzyl*-3-O-(2,3,4,6-*tetra*-O-*benzyl*-α-D-*galactopyranosyl*)α-D-*galactopyranoside* (16) (0.28 g, 29%), R_F 0.38, m.p. 122 °C (from ether–light petroleum), $[\alpha]_D^{20}$ +86° (*c* 1.15 in $CHCl_3$) (Found: C, 75.1; H, 6.7; O, 18.1. $C_{61}H_{64}O_{11}$ requires C, 75.3; H, 6.6; O, 18.1%).

A portion was acetylated at room temperature for 3 days. After purification by chromatography on silica gel in toluene–ether–light petroleum (4 : 1 : 1), the product (17) was obtained as a syrup, $[\alpha]_D^{20}$ +110.5° (*c* 2.33 in $CHCl_3$), δ($CDCl_3$) 1.81 (3 H, s, OAc), 4.89 (1 H, d, $J_{1,2}$ 3.5 Hz, 1-H), 5.24 (1 H, d, $J_{1',2'}$ 3 Hz, 1'-H), 5.57 (1 H, d, 4-H), and 7.32 (35 H, 7 Ph) (Found: C, 74.5; H, 6.7; O, 18.9. $C_{63}H_{66}O_{12}$ requires C, 74.5; H, 6.6; O, 18.9%).

Further elution of the condensation products gave the pure β-linked disaccharide (18) (0.19 g, 19%), R_F 0.27, m.p. 144—146 °C (from ether–light petroleum), $[\alpha]_D^{20}$ +35° (*c* 0.8 in $CHCl_3$) (Found: C, 75.0; H, 6.4; O, 17.8. $C_{61}H_{64}O_{11}$ requires C, 75.3; H, 6.6; O, 18.1%).

A portion was acetylated as above to give compound (19) as a syrup, $[\alpha]_D^{20}$ +53° (*c* 1.39 in $CHCl_3$); δ($CDCl_3$) 2.05 (3 H, s, OAc), 4.84 (1 H, d, $J_{1,2}$ 3.5 Hz, 1-H), 5.46 (1 H, d, 4-H), and 7.32 (35 H, 7 Ph) (Found: C, 74.4; H, 6.4; O, 18.7. $C_{36}H_{66}O_{12}$ requires C, 74.5; H, 6.6; O, 18.9%).

3-O-α-D-*Galactopyranosyl*-D-*galactopyranose* (20).—The benzylated disaccharide (16) (0.10 g) dissolved in glacial acetic acid (10 ml) was hydrogenated at room temperature and atmospheric pressure in the presence of 10% palladium–charcoal (0.10 g) for 24 h. After removal of the catalyst, the solution was evaporated to dryness and the residue was chromatographed on silica gel; elution with propan-2-ol–ethyl acetate–water (3 : 3 : 2) gave the free disaccharide (20) as an amorphous product (30 mg, 80%), $[\alpha]_D^{20}$ +145° (*c* 0.76 in H_2O) {lit.,[22] $[\alpha]_D^{26}$ +149° (*c* 1.6 in H_2O); lit.,[23] $[\alpha]_D$ +184° (*c* 1.25 in H_2O)}, δ(D_2O; 20 °C) 4.75 (0.5 H, d, $J_{1,2}$ 7.8 Hz, 1-H_β), 5.25 (0.5 H, d, $J_{1',2'}$ 3.5 Hz, 1'-H), 5.27 (0.5 H, d, $J_{1',2'}$ 3.5 Hz, 1'-H), and 5.41 (0.5 H, d, $J_{1,2}$ 2.5 Hz, 1-H_α).

3-O-β-D-*Galactopyranosyl*-D-*galactopyranose* (21).—The benzylated disaccharide (18) was hydrogenated as above to give the free disaccharide (21) as a crystalline hydrate, m.p. 126—127 °C, $[\alpha]_D^{20}$ +70 to +60° (*c* 0.65 in H_2O) {lit.,[22] m.p. 165—168 °C, $[\alpha]_D^{26}$ +71 to +62° (*c* 1 in H_2O)}; δ(D_2O; 20 °C) 4.70 (0.5 H, d, $J_{1',2'}$ 7.5 Hz, 1'-H), 4.71 (0.5 H, d, $J_{1',2'}$ 7.5 Hz, 1'-H), 4.73 (0.5 H, d, $J_{1,2}$ 7.8 Hz, 1-H_β), and 5.38br (0.5 H, 1-H_α).

Benzyl 2-*O*-*Allyl*-6-O-*benzyl*-3-O-(2,3,4,6-*tetra*-O-*benzyl*-α-D-*galactopyranosyl*)-α-D-*galactopyranoside* (22).—A solution of the stannylene derivative (10) (0.63 g, 1 mmol) in dry *NN'N''*-hexamethylphosphorotriamide (3.5 ml) was added to a solution of 2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl chloride (1.12 g, 2 mmol) in dry *NN'N''*-hexamethylphosphorotriamide (5 ml) containing anhydrous lithium iodide (0.67 g, 5 mmol) and 4 Å molecular sieve (1.0 g). The mixture was stirred in the dark at room temperature for 2 days and then worked up and chromatographed as for compound (16). The first eluted fractions contained the pure α-linked disaccharide (22) (0.68 g, 74%) which crystal-

lised from ether–light petroleum, m.p. 96—98 °C, $[\alpha]_D^{20}$ +91° (*c* 1 in $CHCl_3$) (Found: C, 74.1; H, 6.7; O, 19.2. $C_{57}H_{62}O_{11}$ requires C, 74.1; H, 6.8; O, 19.1%).

A portion was acetylated at room temperature for 3 days to give compound (23) as a syrup; δ($CDCl_3$) 1.81 (3 H, s, OAc), 5.02 (1 H, d, $J_{1,2}$ 3.5 Hz, 1-H), 5.24 (1 H, d, $J_{1',2'}$ 3 Hz, 1'-H), 5.57 (1 H, d, 4-H), 5.79 (1 H, m, O–CH_2CH=CH_2), and 7.31 (30 H, 6 Ph).

The β-linked disaccharide was eluted next (24) (75 mg, 8%) and crystallised from ether–light petroleum, m.p. 139—140 °C, $[\alpha]_D^{20}$ +55° (*c* 0.8 in $CHCl_3$) (Found: C, 73.5; H, 6.7; O, 19.5. $C_{57}H_{62}O_{11}$ requires C, 74.1; H, 6.8; O, 19.1%).

A fraction was acetylated overnight at room temperature to give compound (25) as a syrup; δ($CDCl_3$) 2.04 (3 H, s, OAc), 5.45 (1 H, d, 4-H), 5.71 (1 H, m, OCH_2CH=CH_2), and 7.31 (30 H, 6 Ph).

Benzyl 6-*O*-*Benzyl*-3-*O*-(2,3,4,6-*tetra*-O-*benzyl*-α-D-*galactopyranosyl*)-α-D-*galactopyranoside* (26).—A solution of the allyl ether (22) (1.3 g, 1.4 mmol) in dry dimethyl sulphoxide (3 ml) containing potassium t-butoxide (0.40 g, 3.6 mmol) was stirred under nitrogen at 100 °C for 2 h. The cooled mixture was diluted with water and extracted with ether; the extract was washed with water until neutral, dried ($MgSO_4$), and evaporated. The residue was dissolved in acetone–1M-hydrochloric acid (4 : 1) (22.5 ml) and the solution set aside at room temperature for 210 min; it was then neutralised with potassium hydrogencarbonate. After evaporation of the acetone the aqueous solution was extracted with chloroform. The extract was dried ($MgSO_4$) and evaporated and the residue was chromatographed on silica gel; elution with ether–light petroleum (2 : 1) gave the diol (26) (0.95 g, 77%) as a syrup, $[\alpha]_D^{20}$ +93.5° (*c* 2.19 in $CHCl_3$), δ($CDCl_3$) 5.03 (1 H, d, $J_{1,2}$ 3.5 Hz, 1-H) and 7.31 (30 H, 6 Ph) (Found: C, 72.8; H, 6.6; O, 19.9. $C_{54}H_{58}O_{11}$ requires C, 73.5; H, 6.6; O, 19.9%).

Benzyl 6-O-*Benzyl*-3-O-(2,3,4,6-*tetra*-O-*benzyl*-α-D-*galactopyranosyl*)-2-O-(2,3,4-*tri*-O-*benzyl*-α-L-*fucopyranosyl*)-α-D-*galactopyranoside* (27).—A solution of freshly prepared 2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl bromide (0.53 g, 1.07 mmol) in dry dichloromethane (3 ml) was stirred under nitrogen at room temperature for 1 h in the presence of tetraethylammonium bromide (0.53 g, 2.5 mmol) and 4 Å molecular sieve (0.50 g). A solution of the diol (26) (0.31 g, 0.35 mmol) in dry *NN*-dimethylformamide (1 ml) was added; the reaction mixture was stirred under nitrogen at room temperature for 4 days and then diluted with dichloromethane and filtered. The filtrate was washed with water, dried ($MgSO_4$), and evaporated. The residue was chromatographed on silica gel; elution with toluene–ether–light petroleum (4 : 1 : 1) gave four main fractions.

(a) The first-eluted fraction (0.15 g) contained the trisaccharide (31) contaminated by degradation products derived from the fucosyl bromide; it was rechromatographed (ether–light petroleum, 1 : 2) to give the pure product (31) (50 mg, 11%) as a foam $[\alpha]_D^{20}$ +2.5° (*c* 1.9 in $CHCl_3$); δ($CDCl_3$) 1.09 (3 H, d, $J_{6'',5''}$ 6 Hz, CH_3), 6.00 (1 H, d, *J* 3 Hz, not attributed), and 7.25 (45 H, 9 Ph) (Found: C, 74.7; H, 6.6; O, 18.3. $C_{81}H_{86}O_{15}$ requires C, 74.8; H, 6.7; O, 18.5%).

A fraction was acetylated overnight at room temperature to give compound (32) as a syrup; δ($CDCl_3$) 1.08 (3 H, d, $J_{6'',5''}$ 6 Hz, CH_3), 1.88 (3 H, s, OAc), 5.15 (1 H, d, *J* 3.5 Hz, not attributed), 5.26 (1 H, d, *J* 3.5 Hz, not attributed), 5.39 (1 H, q, $J_{1,2}$ 3.5, $J_{2,3}$ 10 Hz, 2-H), 5.95 (1 H, d, *J* 3 Hz, not attributed), and 7.26 (45 H, 9 Ph).

(b) The second fraction contained the pure trisaccharide (27) (0.145 g, 32%) which crystallised from ether–light petroleum, m.p. 126 °C, $[\alpha]_D^{20}$ +46° (*c* 1 in $CHCl_3$); δ($CDCl_3$) 0.89 (3 H, d, $J_{6'',5''}$ 6 Hz, CH_3), 5.28 (1 H, d, *J* 3 Hz, not attributed), and 7.26 (45 H, 9 Ph) (Found: C, 74.8; H, 6.7; O, 18.6. $C_{81}H_{88}O_{15}$ requires C, 74.8; H, 6.7; O, 18.5%).

A fraction was acetylated at room temperature for 3 days to give compound (28) as a syrup; δ($CDCl_3$) 0.85 (3 H, d, $J_{6'',5''}$ 6 Hz, CH_3), 1.81 (3 H, s, OAc), 5.18 (1 H, d, *J* 3 Hz, not attributed), 5.34 (1 H, d, *J* 3 Hz, not attributed), 5.65 (1 H, d, 4-H), and 7.26 (45 H, 9 Ph).

(c) 2,3,4,-Tri-*O*-benzyl-α-L-fucopyranose, derived from hydrolysis of the corresponding bromide, was eluted next.

(d) Finally, unchanged diol (26) (0.12 g, 39%) was eluted.

2-*O*-(α-L-*Fucopyranosyl*)-3-O-(α-D-*galactopyranosyl*)-D-*galactose* (29).—A solution of the benzylated trisaccharide (27) (0.33 g) in glacial acetic acid (33 ml) was hydrogenated at room temperature and atmospheric pressure for 20 h in the presence of 10% palladium–charcoal (0.35 g). The mixture was worked up and chromatographed on silica gel; elution with propan-2-ol–ethyl acetate–water (3 : 3 : 2) gave the free trisaccharide (29) (0.12 g, 87%) as a foam, $[\alpha]_D^{20}$ +38° (*c* 1.13 in H_2O) {lit.,[7] $[\alpha]_D^{24}$ +35.2° (*c* 1.1 in H_2O)}; δ(D_2O; 20 °C) 1.21 (3 H, d, $J_{6'',5''}$ 6 Hz, CH_3), 4.75 (0.2 H, d, $J_{1,2}$ 7.5 Hz, 1-H_β), 5.14 (0.7 H, d, $J_{1'',2''}$ 3.6 Hz, 1''-H), 5.24 (0.7 H, d, $J_{1',2'}$ 3.4 Hz, 1'-H), 5.27 (0.2 H, d, $J_{1',2'}$ 3.4 Hz, 1'-H), 5.29 (0.2 H, d, $J_{1'',2''}$ 3.6 Hz, 1''-H), 5.40 (0.7 H, d, $J_{1',2'}$ 3.5 Hz, 1-H_α), and 5.47 (0.1 H, s, 1-$H_{furanose}$); paper chromatography: $R_{lactose}$ 0.70 in ethyl acetate–pyridine–water (10 : 4 : 3) (lit.,[7] $R_{lactose}$ 0.73), $R_{lactose}$ 1.0 in propan-2-ol–ethyl acetate–water (3 : 3 : 2) (Found: C, 41.6; H, 6.9; O, 50.2. $C_{18}H_{32}O_{15}\cdot 1.5H_2O$ requires C, 41.9; H, 6.8; O, 51.2%).

A portion (50 mg) of the trisaccharide (29) was acetylated at 0 °C for 1 h and then at room temperature for 2 days. The main component (30) of the reaction mixture was isolated by column chromatography on silica gel in chloroform–acetone (9 : 1); it crystallised from ethanol (30 mg, 32%), m.p. 207—208 °C, $[\alpha]_D^{20}$ +46° (*c* 0.83 in $CHCl_3$); δ($CDCl_3$) 1.91, 2.02, 2.04, 2.07, 2.09, 2.11, 2.16, 2.18, 2.20 (30 H, 10 OAc), 5.68 (0.18 H, d, $J_{1,2}$ 8 Hz, 1-H_β), and 6.42 (0.82 H, d, $J_{1,2}$ 3.25 Hz, 1-H_α) (Found: C, 49.9; H, 6.0; O, 43.7. $C_{38}H_{52}O_{25}$ requires C, 50.2; H, 5.8; O, 44.0%).

4-O-(α-L-*Fucopyranosyl*)-3-O-(α-D-*galactopyranosyl*)-D-*galactose* (33).—The benzylated trisaccharide (31) (0.2 g) was hydrogenated as above to give the free trisaccharide (32) (60 mg, 80%) as a foam, $[\alpha]_D^{20}$ +45° (*c* 1.11 in H_2O); δ(D_2O, 20 °C) 1.22 (3 H, d, $J_{6'',5''}$ 6 Hz, CH_3), 4.74 (0.7 H, d, $J_{1,2}$ 7 Hz, 1-H_β), 5.25 (0.7 H, d, $J_{1',2'}$ 3.2 Hz, 1'-H), 5.27 (0.3 H, d, $J_{1',2'}$ 3.2 Hz, 1'-H), 5.37 (0.3 H, d, $J_{1,2}$ 3.5 Hz, 1-H_α), and 5.43 (1 H, d, $J_{1'',2''}$ 4 Hz, 1''-H); paper chromatography: $R_{lactose}$ 0.67 in ethyl acetate–pyridine–water (10 : 4 : 3); $R_{lactose}$ 1.0 in propan-2-ol–ethyl acetate–water (3 : 3 : 2) (Found: C, 40.3; H, 7.0; O, 51.8. $C_{18}H_{32}O_{15}\cdot 2.5H_2O$ requires C, 40.5; H, 7.0; O, 52.5%).

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