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Thio and epidithio derivatives of methyl β-lactoside*,†

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ABSTRACT

Treatment of methyl β-lactoside with triphenylphosphine–carbon tetrabromide in pyridine gave the 3′,6′-anhydro-6-bromo-6-deoxy derivative, from which 6-thio derivatives were prepared, and methyl 3′,4′-*O*-isopropylidene-β-lactoside gave the 6,6′-dibromo-6,6′-dideoxy derivative. A dibromide was prepared also from methyl 4′,6′-*O*-benzylidene-β-lactoside by bromination with Ph_3P–CBr_4, acetylation, and then treatment with *N*-bromosuccinimide. Various 6,6′-dithio derivatives were prepared from the 6,6′-dibromide by nucleophilic substitution reactions. Reaction of the 6,6′-dibromide with thiourea led to the 6,6′-epidithio derivative and, with potassium trithiocarbonate, the bridged 6,6′-trithiocarbonate was formed. The 6,6′-dibromo derivative underwent selective nucleophilic substitution to give a variety of 6′-bromo-6-thio derivatives. Likewise, with azide, the 6-azide was formed first, followed by the 6,6′-diazide and the product of elimination, the 6-azido-5′-ene. Raney nickel-mediated desulphuration of the various 6,6′-dithio derivatives afforded methyl 6,6′-dideoxy-β-lactoside, and desulphuration of the 6′-bromo-6-thio derivatives could be accomplished without reductive dehalogenation to give methyl 6′-bromo-6,6′-dideoxylactoside.

INTRODUCTION

In studies of sucrose, we found that it is easy to span the 6,6′-positions with a single sulphur atom and to synthesis 6,6′-epithiosucrose and 6,6′-epidithiosucrose[1]. We now describe an extension of this work to lactose (**1**).

RESULTS AND DISCUSSION

Impure methyl β-lactoside (**3**) was synthesised in poor yield (35%) from the glycosyl bromide **2** by treatment with mercuric acetate in methanol[2]. When lead carbonate was used as the acid acceptor in the Koenigs–Knorr reaction, the yield of **3** was increased to 55% and the work-up procedure was simplified.

The syntheses of 6,6′-epithio- and -epidithio-sucroses[1] suggested that it may also be possible to obtain similar derivatives of lactose. Hence, **3** was treated with triphenylphosphine–carbon tetrabromide[3] in pyridine at 70°, but a monobromide **4** was obtained rather than the expected dibromide. The 250-MHz ^{1}H-n.m.r. spectrum of acetylated **4** (**5**) revealed four acetyl groups, and the remarkably small values for $J_{1',2'}$, $J_{2',3'}$, $J_{3',4'}$, and

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† Dedicated to Professor Grant Buchanan on the occasion of his 65th birthday.
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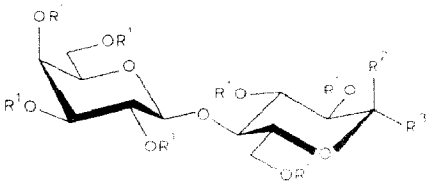
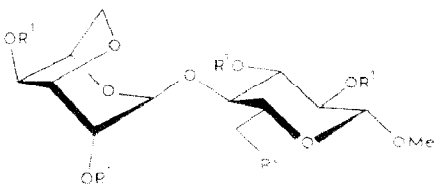


1 R = H, R^2,R^3 = H,O,H
2 R = Ac, R^2 = Br, R^3 = H
3 R = H, R^2 = H, R^3 = OH



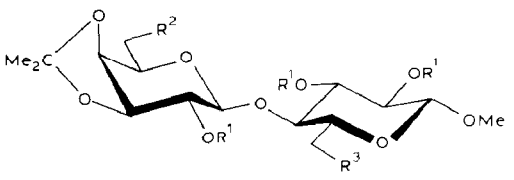
4 R^1 = H, R^2 = Br
5 R^1 = Ac, R^2 = Br
6 R^1 = Ac, R^2 = SCN
7 R^1 = Ac, R^2 = SAc
8 R^1 = Ac, R^2 = SCSNMe$_2$
9 R^1 = Ac, R^2 = SCSOR

$J_{4',5'}$, which were consistent with the $^1C_4$ conformation, indicated that **4** was the 6-bromo-6-deoxy-3′,6′-anhydride. The mass spectrum of **5** was in agreement with this conclusion, displaying peaks at *m/z* 229 and 323/325 (1:1 ratio) for the two fragments arising from the cleavage of each bond of the interglycosidic oxygen. The use of different proportions of the reagents and variation of the conditions did not prevent the formation of the 3′,6′-anhydride that presumably was facilitated by the axial 4-substituent and the orientation of the 1′-substituent which would favour a change to the $^1C_4$ conformation. The anhydride **4** was converted into the 6-thiocyanate **6**, the 6-thioacetate **7**, and the 6-*N*,*N*-dimethylaminothiocarbamate **8** by reaction with the appropriate nucleophile in *N*,*N*-dimethylformamide at 100°, followed by acetylation.

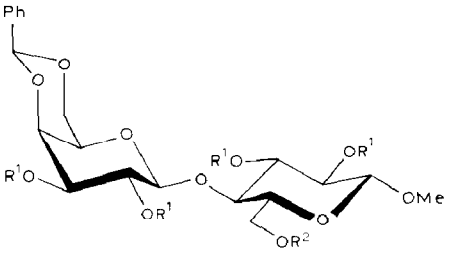
Thus, it appeared that temporary blocking of HO-3′ was necessary in order to preserve the 6′-bromo substituent, and this was achieved by conversion of **3** into the 3′,4′-*O*-isopropylidene derivative **10** by reaction with 2,2-dimethoxypropane catalysed by *p*-toluenesulphonic acid[4]. As anticipated, **10** reacted smoothly with triphenylphosphine–carbon tetrabromide in pyridine at 70° to give the 6,6′-dibromide **11** (61% after column chromatography). The spectroscopic data of the tetra-acetate (**12**) of **11** accorded with the structure. The isopropylidene group was removed from **11** by hydrolysis with Dowex 50 (H^+) resin to afford 6,6′-dibromo-6,6′-dideoxy-β-lactoside (**23**, 36% overall from **3**), which was isolated as the penta-acetate **24**.

Garegg and Samuelson[5] have described the use of triphenylphosphine–iodine–imidazole in toluene to replace primary hydroxyl groups by iodine. Application of this reaction to **10** afforded the 6,6′-dideoxy-6,6′-di-iodo derivative **13** (64%), which was characterised as the penta-acetate **14**. When this reaction was applied to methyl β-lactoside (**3**), a complex mixture of products was obtained. In contrast, treatment of **3** with sulphuryl chloride gave the 6,6′-dichloro-6,6′-dideoxy derivative in high yield[6]. In this reaction, the formation of an anhydride was prevented by the conversion of all the hydroxyl groups into chlorosulphate esters.

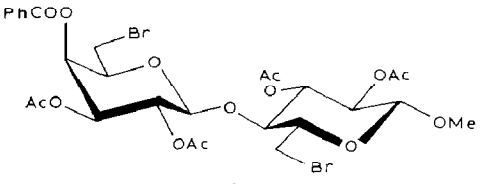
The synthesis of the 6,6′-dibromide **22** from methyl 4′,6′-*O*-benzylidene-β-lactoside[7] (**19**) was attempted by selective 6-bromination with triphenylphosphine–carbon tetrabromide, which gave the 6-bromide **20** (67%), followed by opening of the acetal ring with *N*-bromosuccinimide in carbon tetrachloride[8]. However, the latter reaction was unsuccessful because of the insolubility of **20** in carbon tetrachloride, but the



10 $R^1 = H, R^2 = R^3 = OH$
11 $R^1 = H, R^2 = R^3 = Br$
12 $R^1 = Ac, R^2 = R^3 = Br$
13 $R^1 = H, R^2 = R^3 = I$
14 $R^1 = Ac, R^2 = R^3 = I$
15 $R^1 = H, R^2 = R^3 = SCN$
16 $R^1 = Ac, R^2 = R^3 = SCN$
17 $R^1 = H, R^2 = Br, R^3 = SCSOEt$
18 $R^1 = Ac, R^2 = Br, R^3 = SCSOEt$



19 $R^1 = H, R^2 = OH$
20 $R^1 = H, R^2 = Br$
21 $R^1 = Ac, R^2 = Br$



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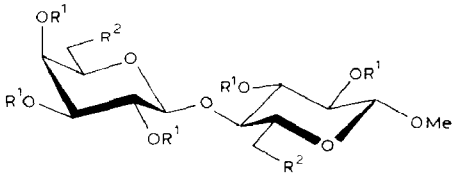
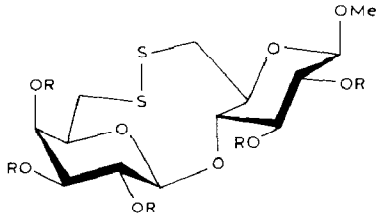


23 $R^1 = H, R^2 = Br$
24 $R^1 = Ac, R^2 = Br$
25 $R^1 = H, R^2 = I$
26 $R^1 = Ac, R^2 = I$
27 $R^1 = Ac, R^2 = SCN$
28 $R^1 = Ac, R^2 = SAc$
29 $R^1 = Ac, R^2 = SCSNMe_2$
30 $R^1 = H, R^2 = SCSNMe_2$



31 R = H
32 R = Ac
33 R=COPh

tetra-acetate (**21**) of **20** reacted smoothly to give the 4-*O*-benzoyl-6,6′-dibromo-6,6′-dideoxy derivative **22** (76%; 26% from **3**). *O*-Deacylation of **22** followed by acetylation afforded the penta-acetate **24** described above. The route to the 6,6′-dibromide via the 3′,4′-*O*-isopropylidene derivative was preferred for large-scale preparation.

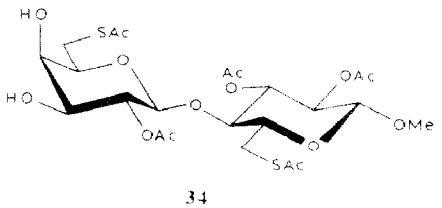
The construction of a 6,6′-epidithio bridge was then attempted as with sucrose[1]. When the 6,6′-dibromide **24** was heated with an excess of thiourea in *N*,*N*-dimethylformamide for 7 h, it was converted into products which were non-mobile in t.l.c. The mixture was then treated with sodium azide for 12 h, to give, after chromatography, 19% of methyl penta-*O*-acetyl-6,6′-epidithio-β-lactoside (**32**), the ^{1}H-n.m.r. spectrum of which indicated that both the rings adopted the usual $^4C_1$ conformations. As with 6,6′-epidithiosucrose[1], the broadening of the signals in the ^{1}H-n.m.r. spectrum due to the

hydrogens attached to the new 10-membered ring indicated that there was conformational instability. However, this broadening disappeared completely at 60° to give sharp signals. The mass spectrum of **32** contained a peak for M$^+$ at *m/z* 596 (0.8%). The epidisulphide could arise by hydrolysis of the first-formed bis-thiouronium salt, followed by oxidation to the disulphide. However, this sequence is improbable since, although the 6,6′-dithiolactoside presumably arose from the base-catalysed hydrolysis of other compounds (see below), none of these compounds formed the epidithio derivative.

Attempts were then made to prepare the 6,6′-dithiol directly, in the hope that it would oxidise spontaneously to the intramolecular disulphide. Thus, when the 6,6′-dibromide **24** was heated in *N,N*-dimethylformamide (95–100°) severally with potassium thiocyanate, potassium thioacetate, and sodium *N,N*-dimethyldithiocarbamate, it gave, after acetylation and chromatography, the 6,6′-dithiocyanate **27**, the bis-thioacetate **28**, and the bis-*N,N*-dimethyldithiocarbamate **29**, respectively, in good yields. Attempts to synthesise the epidithiolactoside **32** from **29** and **28** by treatment with sodium methoxide under mild conditions led only to *O*-deacetylation, but, under more forcing conditions, methyl 2,3,2′,4′-tetra-*O*-acetyl-6-*S*-acetyl-3′,6′-anhydro-6-thio-β-lactoside (**7**) and methyl 2,3,2′,4′-tetra-*O*-acetyl-3′,6′-anhydro-6-*S*-(*N,N*-dimethylaminothiocarbonyl)-6-thio-β-lactoside (**8**), were obtained after re-acetylation. Thus, the 6′-acylthio group had functioned as a leaving group rather than undergo deacylation.

In order to avoid the formation of 3′,6′-anhydro rings, the above reaction conditions were applied to the 3′,4′-*O*-isopropylidene-6,6′-dithiocyanate **15**, synthesised from **11**, but the epidithio derivative was not isolated. Instead, methyl 2,3,2′-tri-*O*-acetyl-6,6′-di-*S*-acetyl-6,6′-dithio-β-lactoside (**34**) was obtained, in which adventitious hydrolysis of the isopropylidene group occurred during the work-up procedure after acetylation. The structure of **34** was clear from the ^{1}H-n.m.r. spectrum and from the mass spectrum which contained a peak for (M$^+$ − OMe) at *m/z* 567 as well as two fragments at *m/z* 319 and 263 arising from the cleavage of the interglycosidic bond. It was clear that that the 6,6′-dithiolactoside had been formed, but had not cyclised to the 6,6′-epidithio derivative.

When 6,6′-dibromo-6,6′-dideoxysucrose was treated with potassium trithiocarbonate, it gave 6,6′-epithiosucrose[1]. However, when methyl 6,6′-dibromo-6,6′-dideoxy-



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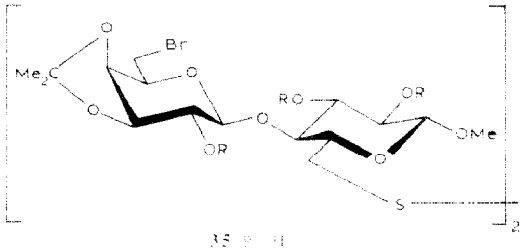
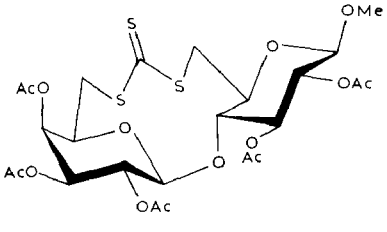


35 R = H
36 R = Ac

β-lactoside (**24**) was treated with potassium trithiocarbonate in various solvents, complex mixtures of products were formed which were not further investigated. However, when *N,N*-dimethylformamide was the solvent, the bridged 6,6′-trithiocarbonate **37** was isolated (33%). The n.m.r. spectrum of **37** was similar to that of **24** and the 6,6′-epidithiolactoside **32**, but free of the line broadening observed in the latter spectrum. The possibility that this cyclic trithiocarbonate could be dimeric cannot be discounted entirely on the spectroscopic evidence available.

A further possible route to the 6,6′-epithiolactoside was considered in which a thio group at one primary position would displace a bromine substituent at the other. Regioselective 6-substitution in **24** was anticipated to be straightforward[9] due to the unfavourable steric environment of the 6′-position because of the axial group at the 4-position. Thus, methyl 6′-bromo-6′-deoxy-6-*S*-ethoxythiocarbonyl-3′,4′-*O*-isopropylidene-6-thio-β-lactoside (**17**) was obtained in good yield from **11**. Such treatment of 6,6′-dibromosucrose led directly to 6,6′-epithiosucrose[1]. However, treatment of **17** with methoxide failed to give the 6,6′-epithio derivative, and acetylation of the products gave 25% of a crystalline compound that contained six acetyl groups and no ethoxy groups (^{1}H-n.m.r. data). The mass spectrum also revealed that the 6-bromo-6-deoxygalactosyl residue was intact [*m/z* 309, 307 (1:1 ratio)], and the product was identified as the dimeric disulphide **36**. Similarly, the 6,6′-dibromide **24** underwent selective reaction with potassium thioacetate, potassium *O*-ethyldithiocarbonate, and sodium *N,N*-dimethyldithiocarbamate in acetone or butanone to give the 6-thio derivatives **39**–**41**, respectively, in good yields. The structures of these derivatives were assigned unambiguously on the basis of n.m.r. and mass spectral data. This route to the 6,6′-epithiolactoside was not investigated thoroughly since **17** failed to give the intramolecular sulphide.

The failure to form the 6,6′-epithiolactoside was not surprising since molecular models revealed that linking the two primary positions by a sulphur atom led to unfavourable transannular interactions if the normal $^4C_1$ conformation of each ring was



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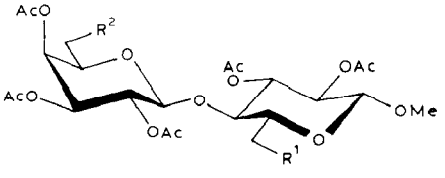
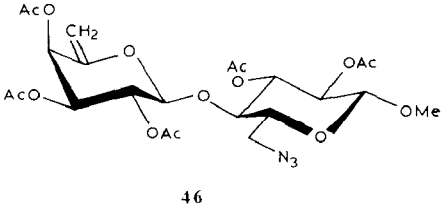


38 $R^1 = R^2 = Br$
39 $R^1 = SCN$, $R^2 = Br$
40 $R^1 = SCSOEt$, $R^2 = Br$
41 $R^1 = SCSNMe_2$, $R^2 = Br$
42 $R^1 = R^2 = H$
43 $R^1 = H$, $R^2 = Br$
44 $R^1 = N_3$, $R^2 = Br$
45 $R^1 = R^2 = N_3$



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maintained. However, if one ring is in the $^1C_4$ conformation, then spanning the 6,6′-positions should be relatively easy, because there are no major transannular interactions. Since such a change occurs in the galactopyranosyl ring to form the 3′,6′-anhydride **4**, it is puzzling that it fails to occur with the above compounds.

The 6,6′-dideoxylactoside **42** was prepared by desulphuration (Raney nickel) of the dithio derivatives **27**, **29**, and **37** in yields of 72–88%. When the 6′-bromo-6-thiocyanate **39** was treated with a limited quantity of Raney nickel in boiling ethanol for 30 min, selective desulphuration occurred to give the 6′-bromo-6,6′-dideoxylactoside **43** (38% after chromatography), but prolonged reaction afforded the 6,6′-dideoxylactoside **42** (70%).

Nucleophilic substitution of the 6,6′-dibromide **24** with azide in *N,N*-dimethylformamide gave, first, the 6-azido-6′-bromolactoside **44** (74%) and then a ~1:1 mixture of crystalline **45** and **46**, both of which were isolated by chromatography in yields of 34 and 36%, respectively. The component eluted first was a mono-azide with five acetyl groups, the ^{1}H-n.m.r. spectrum of which indicated that the glucopyranoside ring was unperturbed, but that the H-5′ resonance from the other ring was missing. Furthermore, the value of $J_{6a,6b}$ was only 1.3 Hz, indicative of a terminal double bond, thus identifying the compound as methyl 2,3-di-*O*-acetyl-6-azido-6-deoxy-4-*O*-(2,3,4-tri-*O*-acetyl-α-L-*arabino*-hex-5-enopyranosyl)-β-D-glucopyranoside (**46**). The other component was the anticipated 6,6′-diazide **45**. Elimination at a primary position to give **46** was unexpected, particularly with a strong nucleophile such as azide, although it is well established that displacement reactions at C-6 of galactosides are sterically unfavourable[9].

EXPERIMENTAL

Unless otherwise stated, n.m.r. spectra were measured with either a Nicolet NT-200 or Bruker WM-250 spectrometer, and mass spectra with a Kratos MS-25 spectrometer with a DS-50 data station. Unless otherwise stated, $[\alpha]_D$ values were measured at 18–20° on ~1% solutions in $CDCl_3$ with a Perkin Elmer 141 automatic polarimeter and a 10-cm cell. Melting points were measured on a Kofler hot-stage and are uncorrected.

Most reactions were optimised by monitoring by t.l.c. on silica gel (Merck, 5554), with detection by α-naphthol (10 g) in conc. sulphuric acid (50 mL) diluted to 1 L with 96% ethanol. Column chromatography was conducted on silica gel (Merck 7734).

Pyridine was dried over KOH pellets and *N,N*-dimethylformamide was dried over molecular sieve (type 4A).

Acetylations and benzoylations were carried out by dissolving the compound in 5–20 parts of dry pyridine, cooling the solution to <5°, then adding the acylating reagent (usually 2–10 mol. equiv.) and storing the mixture at room temperature. When the reaction was complete (t.l.c.), the mixture was poured into water, the product was extracted into chloroform or dichloromethane, the extract was dried ($MgSO_4$), and the solvent was evaporated.

Methyl 4-O-β-D-galactopyranosyl-β-D-glucopyranoside (methyl β-lactoside (**3**). — A suspension of hepta-*O*-acetylmaltosyl bromide[10] (**2**, 72 g) and lead carbonate (72 g) in methanol (300 mL) was stirred at room temperature for 4 days, when t.l.c. (ether) indicated that the reaction was complete. The mixture was filtered through Hyflo Supercel and the solvent was evaporated. The resulting syrup, which contained much inorganic material, was dissolved in chloroform, the solution was filtered, and the solvent was evaporated. The apparent pH of the solution of the resulting clear syrup in methanol (80 mL) was adjusted to 9 (Universal Indicator paper) by the addition of methanolic M sodium methoxide. A white solid crystallised out, and, after storage for 16 h at room temperature, the product was collected and recrystallised from aqueous ethanol to give **3** (27.5 g, 56% from **1**), m.p. 213–215° (dec.), $[\alpha]_D$ +3.6° (*c* 1.4, water); lit.[11] m.p. 206° (dec.), $[\alpha]_D$ +5.6°.

Methyl 4-O-(3,6-anhydro-β-D-galactopyranosyl)-6-bromo-6-deoxy-β-D-glucopyranoside (**4**). — Methyl β-lactoside (**3**; 1.5 g, 4.2 mmol) was dissolved in pyridine (45 mL) by heating at 80°. The solution was cooled rapidly to ~0° and triphenylphosphine (6.6 g, 25.3 mmol) was added portionwise. A solution of carbon tetrabromide (4.2 g, 12.65 mmol) in pyridine (10 mL) was added dropwise with stirring over 20 min and the mixture was heated at 70° for 2 h. T.l.c. (chloroform–methanol, 3:1) then revealed one major and several minor products. The mixture was cooled, methanol (10 mL) was added, the solvents were evaporated, and toluene was evaporated from the residue. Column chromatography (chloroform; and then chloroform–methanol, 20:1) gave the major component which crystallised and was recrystallised from ethanol to give **4** (0.8 g, 47%), m.p. 147–149°, $[\alpha]_D$ −59° (*c* 4.5, methanol) (Found: C, 39.0; H, 5.2. $C_{13}H_{21}BrO_9$ calc.: C, 38.9; H, 5.2%).

Acetylation of **4** gave the tetra-acetate **5** (70%), m.p. 228–229° (from ethanol–light petroleum), $[\alpha]_D$ −56° (Found: C, 44.5; H, 5.1. $C_{21}H_{29}BrO_{13}$ calc.: C, 44.3; H, 5.1%). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.45 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.88 (dd, 1 H, $J_{2,3}$ 9.5, H-2), 5.22 (t, 1 H, $J_{3,4}$ 9.0, H-3), 4.29 (t, 1 H, $J_{4,5}$ 10.1 Hz, H-4), 3.84 (dd, 1 H, $J_{5,6a}$ ~3, $J_{6a,6b}$ 10.2 Hz, H-6a), 3.80 (m, 1 H, H-6b), 5.22 (d, 1 H, $J_{1',2'}$ 1.8 Hz, H-1'), 4.65 (s, 1 H, $J_{2',3'}$ 0 Hz, H-2'), 4.34 (d, 1 H, $J_{3',4'}$ 4.8 Hz, H-3'), 4.99 (t, 1 H, $J_{4',5'}$ 4.8 Hz, H-4'), 4.25 (ddd, 1 H, $J_{5',6'a}$ 1.8, $J_{5',6'b}$ 3.0 Hz, H-5'), 3.52 (s, 3 H, OMe), 2.14, 2.09, 2.05, 2.02 (4 s, 12 H, 4 Ac).

Methyl 2,3-di-O-acetyl-6-S-cyano-4-O-(2,4-di-O-acetyl-3,6-anhydro-β-D-galactopyranosyl)-6-thio-β-D-glucopyranoside (**6**). — A solution of **4** (0.5 g, 1.25 mmol) and potassium thiocyanate (0.5 g) in *N,N*-dimethylformamide (10 mL) was heated at 95–100° for 2 h, when t.l.c. (chloroform–methanol, 5:1) revealed one major product together with a faster-moving minor product. The mixture was cooled (ice-bath), and pyridine (5 mL) and acetic anhydride (1 mL) were added; after 16 h, t.l.c. revealed a single product. The mixture was poured into water, and the product was extracted with chloroform and purified by dry-pack[12] column chromatography (ether–light petroleum, 2:1) to give **6** (0.37 g, 73%), m.p. 168–170° (from ethanol–light petroleum), $[\alpha]_D$ −61° (Found: C, 48.35; H, 5.5; N, 2.55. $C_{22}H_{29}NO_{13}S$ calc.: C, 48.25; H, 5.3; N, 2.55%).

Methyl 2,3-di-O-acetyl-6-S-acetyl-4-O-(2,4-di-O-acetyl-3,6-anhydro-β-D-galactopyranosyl)-6-thio-β-D-glucopyranoside (**7**). — The above reaction of **4** was repeated,

but with potassium thioacetate for 30 min. The product crystallised and chromatography was not required. Compound **7** (0.45 g, 64%) had m.p. 221–223° (from ethanol), $[\alpha]_D$ −64° (Found: 49.0; H, 5.6. $C_{23}H_{32}O_{14}S$ calc.: C, 48.95; H, 5.65%). Mass spectrum: *m/z* 505 [0.1%, $(M^+ - OAc)$], 445 [0.1, $(M^+ - OAc - HOAc)$], 444 [0.3, $(M^+ - 2$ HOAc)], 319 (0.4, Glc*p*Ac_2SAcOMe$^+$), 229 (76.7, anhyd-Gal*p*Ac_3^+). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.39 (d, 1 H, $J_{1,2}$ 8.1 Hz, H-1), 4.86 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.20 (t, 1 H, $J_{3,4}$ 7.9 Hz, H-3), 3.65 (m, 2 H, H-4,5), 3.03 (dd, 1 H, $J_{5,6a} \sim 2$, $J_{6a,6b}$ 14.4 Hz, H-6a), 2.80 (m, 1 H, H-6b), 4.61 (s, 1 H, $J_{1',2'} \sim 0$ Hz, H-1'), 5.21 (d, 1 H, $J_{2',3'}$ 1.7 Hz, H-2'), 4.23 (m, 1 H, H-3'), 4.96 (d, 1 H, $J_{4',5'}$ 4.8 Hz, H-4'), 4.33 (dd, 1 H, $J_{5',6'a} \sim 3$, $J_{6'a,6'b}$ 12 Hz, H-6'a), 4.17 (dd, 1 H, $J_{5',6'b} \sim 2$ Hz, H-6'b), 3.49 (s, 3 H, OMe), 2.13, 2.09, 2.05, 2.02 (4 s, 12 H, 4 Ac), 2.21 (s, 3 H, SAc).

*Methyl 2,3-di-O-acetyl-4-O-(2,4-di-O-acetyl-3,6-anhydro-β-*D*-galactopyranosyl)-6-*S*-(N,N-dimethylaminothiocarbonyl)-6-thio-β-*D*-glucopyranoside* (**8**). — The above reaction was repeated, but with sodium *N,N*-dimethylaminodithiocarbamate for 30 min. Chromatography (ether–light petroleum, 3:2) of the product gave **8** (0.35 g, 58%), m.p. 223–225° (from ethanol), $[\alpha]_D$ −47° (Found: C, 47.55; H, 6.05; N, 2.2. $C_{24}H_{35}NO_{13}S_2$ calc.: C, 47.3; H, 5.75; N, 2.3%).

*Methyl 6-bromo-4-O-(6-bromo-6-deoxy-3,4-O-isopropylidene-β-*D*-galactopyranosyl)-6-deoxy-β-*D*-glucopyranoside* (**11**). — To an ice-cold solution of methyl 4-*O*-(3,4-*O*-isopropylidene-β-D-galactopyranosyl)-β-D-glucopyranoside[4] (**10**; 3.96 g, 10 mmol) in pyridine (200 mL) was added triphenylphosphine (10.48 g, 40 mmol) in small portions followed dropwise by a solution of carbon tetrabromide (6.64 g, 20 mmol) in pyridine (30 mL), and the mixture was then heated at 70° for 2 h. Methanol (30 mL) was added, the solvents were evaporated, and toluene was evaporated several times from the residue. Column chromatography (chloroform and then ether) of the resulting syrup and recrystallisation from ether gave **11** (3.2 g, 61%). When the ether solution was cooled rapidly, prisms of **11** were formed with m.p. 164–166°; when the solution was allowed to cool slowly, long needles formed with m.p. 130–131°, $[\alpha]_D$ +38° (*c* 2.1, methanol) (Found: C, 37.05; H, 4.95. $C_{16}H_{26}Br_2O_9$ calc.: C, 36.8; H, 5.0%).

Acetylation of **11** afforded the 2,3,2'-triacetate **12** (89%), m.p. 136–137° (from ethanol), $[\alpha]_D$ +6.3° (Found: C, 40.85; H, 5.05. $C_{22}H_{32}Br_2O_{12}$ calc.: C, 40.75; H, 4.95%). Mass spectrum: *m/z* 635, 633, 631 [0.2%, ratio 1:2:1, $(M^+ - Me)$], 325, 323 (2, ratio 1:1, Glc*p*Ac_2Br^+), 309, 307 (4.4, ratio, 1:1, Gal*p*$AcMe_2CBr^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.45 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1), 4.90 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.23 (dd, 1 H, $J_{3,4}$ 9.2 Hz, H-3), 3.84 (t, 1 H, $J_{4,5}$ 9.2 Hz, H-4), 3.76 (m, 1 H, H-5), 3.45–3.65 (m, 4 H, H-6a,6b,6'a,6'b), 4.55 (d, 1 H, $J_{1',2'}$ 7.5 Hz, H-1'), 4.89 (dd, 1 H, $J_{2',3'}$ 7.2 Hz, H-2'), 4.18 (dd, 1 H, $J_{3',4'}$ 5.7 Hz, H-3'), 4.34 (dd, 1 H, $J_{4',5'}$ 2.5 Hz, H-4'), 3.91 (td, 1 H, $J_{5',6'a} \approx J_{5',6'b} \approx$ 8 Hz, H-5'), 3.51 (s, 3 H, OMe), 2.13, 2.07, 2.05 (3 s, 9 H, 3 Ac), 1.55, 1.35 (2 s, 6 H, CMe_2).

*Methyl 2,3-di-O-acetyl-6-bromo-6-deoxy-4-O-(2,3,4-tri-O-acetyl-6-bromo-6-deoxy-β-*D*-galactopyranosyl)-β-*D*-glucopyranoside* (**24**). — (*a*) A solution of **11** (4.0 g, 7.7 mmol) in methanol (40 mL) was heated under reflux with Dowex-50W (H^+) resin for 2.5 h, then filtered, and the solvent was evaporated. The residual syrup was acetylated

with acetic anhydride (6 mL) and pyridine (30 mL) to give **24** (4.0 g, 75%), m.p. 183–185° (from ethanol), $[\alpha]_D$ −15° (Found: C, 40.3; H, 4.95. $C_{23}H_{32}Br_2O_{14}$ calc.: C, 39.9; H, 4.60%). Mass spectrum: *m/z* 325, 323 (4.4%, ratio 1:1, Glc*p*Ac_2Br^+), 353, 351 (5.2%, ratio 1:1, Gal*p*Ac_3Br^+). ^{1}H-N.m.r. data (250 MHz, $CDCl_3$): δ 4.46 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.90 (dd, 1 H, $J_{2,3}$ 9.3 Hz, H-2), 5.24 (dd, 1 H, $J_{3,4}$ 9.1 Hz, H-3), 3.88 (t, 1 H, $J_{4,5}$ 9.0 Hz, H-4), 3.55–3.8 (m, 3 H, H-5,6a,6b), 4.65 (d, 1 H, $J_{1',2'}$ 7.7 Hz, H-1'), 5.11 (dd, 1 H, $J_{2',3'}$ 10.2 Hz, H-2'), 5.01 (dd, 1 H, $J_{3',4'}$ 3.3 Hz, H-3'), 5.56 (dd, 1 H, $J_{4',5'}$ 1.5 Hz, H-4'), 3.85 (ddd, 1 H, $J_{5',6'a}$ 5.8, $J_{5',6'b}$ 8.0 Hz, H-5'), 3.37 (dd, 1 H, $J_{6'a,6'b}$ 10.2 Hz, H-6'a), 3.27 (dd, 1 H, H-6'b), 3.51 (s, 3 H, OMe), 2.18, 2.10, 1.98 (3 s, 9 H, 3 Ac), 2.06 (s, 6 H, 2 Ac).

(*b*) The acetal **11** (1.2 g, 2.3 mmol) was stirred vigorously with aqueous 90% trifluoroacetic acid (2.5 mL) for 10 min, ether (20 mL) was added, and the precipitated solid was collected and acetylated to give **24** (1.25 g, 78%).

*Methyl 4-O-(4,6-O-benzylidene-β-*D*-galactopyranosyl)-6-bromo-6-deoxy-β-*D*-glucopyranoside* (**20**). — To an ice-cold solution of methyl 4-*O*-(4,6-*O*-benzylidene-β-D-galactopyranosyl)-β-D-glucopyranoside[13] (**19**; 4.44 g, 10 mmol) in pyridine (200 mL) was added slowly triphenylphosphine (10.48 g, 40 mmol) followed by a solution of carbon tetrabromide (6.5 g, 19.58 mmol) in pyridine (50 mL). The mixture was then heated at 70° for 1 h, methanol (25 mL) was added, the solvent was evaporated, and toluene was evaporated several times from the residue. Column chromatography (chloroform; then chloroform–methanol, 10:1) gave **20** (3.4 g, 67%), m.p. 164–166° (from ethanol), $[\alpha]_D$ −18° (*c* 1, water) (Found: C, 47.3; H, 6.1. $C_{20}H_{27}BrO_{10}$ calc.: C, 47.35; H, 5.35%).

Acetylation of **20** afforded the 2,3,2',3'-tetra-acetate **21** (90%), m.p. 246–248° (from ethanol), $[\alpha]_D$ +29° (Found: C, 47.95; H, 5.2. $C_{28}H_{35}BrO_{14}$ calc.: C, 49.8; H, 5.2%). Mass spectrum: *m/z* 676, 674 (0.2%, ratio 1:1, M^+), 335 (6.2, Gal*p*Ac_2PhCH^+), 325, 323 (0.2%, ratio 1:1, Glc*p*Ac_2BrOMe^+). ^{1}H-N.m.r. data (250 MHz, $CDCl_3$): δ 4.48 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1), 4.92 (dd, 1 H, $J_{2,3}$ 8.1 Hz, H-2), 5.24 (t, 1 H, $J_{3,4}$ 9.1 Hz, H-3), 3.83 (t, 1 H, $J_{4,5}$ ~9 Hz, H-4), 3.48 (m, 1 H, H-5), 3.78 (dd, 1 H, $J_{5,6a}$ ~5, $J_{6a,6b}$ ~11 Hz, H-6a), 3.59 (dd, 1 H, $J_{5,6b}$ ~3 Hz, H-6b), 4.65 (d, 1 H, $J_{1',2'}$ 7.9 Hz, H-1'), 5.27 (dd, 1 H, $J_{2',3'}$ 10.3 Hz, H-2'), 4.93 (dd, 1 H, $J_{3',4'}$ 3.2 Hz, H-3'), 4.33 (m, 1 H, H-4'), 3.49 (m, 1 H, H-5'), 4.30 (dd, 1 H, $J_{5',6'a}$ ~2, $J_{6'a,6'b}$ 12.7 Hz, H-6'a), 4.04 (dd, 1 H, $J_{5',6'b}$ ~ 2 Hz, H-6'b), 3.51 (s, 3 H, OMe), 2.09 (s, 3 H, Ac), 2.05 (s, 9 H, 3 Ac), 5.47 (s, 1 H, C*H*Ph), 7.3–7.5 (m, 5 H, Ph).

*Methyl 2,3-di-*O*-acetyl-6-bromo-6-deoxy-4-*O*-(2,3-di-*O*-acetyl-4-*O*-benzoyl-6-bromo-6-deoxy-β-*D*-galactopyranosyl)-β-*D*-glucopyranoside* (**22**). — A mixture of **20** (3.0 g, 4.44 mmol), *N*-bromosuccinimide (1 g, 5.62 mmol), barium carbonate (3 g, 15.23 mmol), and carbon tetrachloride (90 mL) was stirred and heated under reflux for 2.5 h, then filtered through Hyflo Supercel, and the solvent was evaporated. The syrupy residue, which crystallised, was recrystallised from ethanol to give **22** (2.5 g, 75%), m.p. 100–102°, $[\alpha]_D$ +7.2° (*c* 3.6, chloroform)(Found C, 44.6; H, 4.45. $C_{28}H_{34}Br_2O_{14}$ calc.: C, 44.55; H, 4.5%). Mass spectrum: *m/z* 728, 726, 724 [10%, ratio 1:2:1, $(M^+ + 1 - OMe)$], 637, 635, 633 [12.4, ratio 1:2:1, $(M^+ - OMe - OAc)$], 415, 413 (23.6, ratio 1:1, Gal*p*-Ac_2BzBr^+), 325, 323 (12.1, ratio 1:1, Glc*p*Ac_2BrOMe^+). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.48 (d, 1 H, $J_{1,2}$ 7.8 Hz, H-1), 4.93 (dd, 1 H, $J_{2,3}$ 9.3 Hz, H-2), 5.28 (t, 1 H, $J_{3,4}$ 9.1 Hz, H-3),

3.91 (t, 1 H, $J_{4,5}$ 9.0 Hz, H-4), 3.77 (m, 1 H, H-5), 3.56–3.98 (m, 2 H, H-6a,6b), 4.75 (d, 1 H, $J_{1',2'}$ 7.4 Hz, H-1'), 5.21 (dd, 1 H, $J_{2',3'}$ 10.4 Hz, H-2'), 5.13 (dd, 1 H, $J_{3',4'}$ 3.1 Hz, H-3'), 5.82 (dd, 1 H, $J_{4',5'}$ 0.7 Hz, H-4'), 3.97 (td, 1 H, $J_{5',6'a}$ 6.9 $J_{5',6'b}$ 7.9 Hz, H-5'), 3.40 (dd, 1 H, $J_{6'a,6'b}$ 11.0 Hz, H-6'a), 3.34 (dd, 1 H, H-6'b), 3.52 (s, 3 H, OMe), 2.10, 2.06, 2.05, 1.95 (4 s, 12 H, 4 Ac), 7.5–8.1 (m, 5 H, Ph).

O-Deacetylation of **22** with methanolic sodium methoxide at room temperature gave the 6,6'-dibromide **23**, which crystallised directly and was acetylated to give the penta-acetate **24** (59%).

*Methyl 6-deoxy-4-O-(6-deoxy-6-iodo-3,4-O-isopropylidene-β-*D*-galactopyranosyl)-6-iodo-β-*D*-glucopyranoside* (**13**). — A mixture of **10** (1.0 g, 2.53 mmol), toluene (25 mL), imidazole (1.6 g, 23.5 mmol), resublimed iodine (2 g, 7.9 mmol), and triphenylphosphine (2.1 g, 8 mmol) was heated at 80° for 2.5 h, and the solvents were then evaporated. Column chromatography (chloroform, and then ether) of the residue gave **13** (0.55 g, 35%), m.p. 164–165° (from ether), $[\alpha]_D$ +40° (Found: C, 31.1; H, 4.2. $C_{16}H_{26}I_2O_9$ calc.: C, 31.15; H, 4.2%).

*Methyl 6-deoxy-4-O-(6-deoxy-6-iodo-β-*D*-galactopyranosyl)-6-iodo-β-*D*-glucopyranoside* (**25**). — A solution of **13** (0.4 g) in methanol (5 mL) was heated under reflux in the presence of Dowex 50W-X8 (H^+) resin (2 g) for 2.5 h, then filtered, and the solvent was evaporated. The residue was recrystallised from ethanol to give **25** (0.25 g, 67%) as long needles, m.p. 148° (dec.), $[\alpha]_D$ +30° (*c* 1, water) (Found: C, 27.1; H, 3.8. $C_{13}H_{22}I_2O_9$ calc.: C, 27.1; H, 3.8%).

Acetylation of **25** afforded the 2,3,2',3',4'-penta-acetate **26** (92%), m.p. 179–180° (from ethanol), $[\alpha]_D$ +2° (Found: C, 35.15; H, 4.0. $C_{23}H_{32}I_2O_{14}$ calc.: C, 35.1; H, 4.05%). Mass spectrum: *m/z* 659 (2.4%, $M^+ - I$), 599 [1.6, $(M^+ - I - HOAc)$], 399 (21, Gal*p*Ac_3I^+), 371 (4.3, Glc*p*Ac_2OMeI^+). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.46 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.91 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.24 (t, 1 H, $J_{3,4}$ 9.3 Hz, H-3), 3.73 (t, 1 H, $J_{4,5}$ 9.1 Hz, H-4), 3.3 (m, 2 H, H-5,6b), 3.60 (m, 1 H, H-6a), 4.64 (d, 1 H, $J_{1',2'}$ 7.7 Hz, H-1'), 5.09 (dd, 1 H, $J_{2',3'}$ 10.4 Hz, H-2'), 5.00 (dd, 1 H, $J_{3',4'}$ 3.3 Hz, H-3'), 5.57 (dd, 1 H, $J_{4',5'}$ 1.3 Hz, H-4'), 3.84 (ddd, 1 H, $J_{5',6'a}$ 7.0, $J_{5',6'b}$ 7.7 Hz, H-5'), 3.17 (dd, 1 H, $J_{6'a,6'b}$ 10.0 Hz, H-6'a), 3.10 (dd, 1 H, H-6'b), 3.53 (s, 3 H, OMe), 2.18, 2.17, 2.11, 2.05, 1.98 (5 s, 15 H, 5 Ac).

*Methyl 2,3-di-O-acetyl-6-S-cyano-6-thio-4-O-(2,3,4-tri-O-acetyl-6-S-cyano-6-thio-β-*D*-galactopyranosyl)-β-*D*-glucopyranoside* (**27**). — A mixture of the dibromolactoside **24** (1 g), excess of potassium thiocyanate (1 g), and *N*,*N*-dimethylformamide (10 mL) was heated at 95–100° for 5 h, and then poured into ice–water. The solid was collected and purified by column chromatography (ether–light petroleum, 3:1) to give **27** as needles (0.5 g, 53%). Recrystallisation from ethanol gave material with m.p. 123–124°, $[\alpha]_D$ +7°, ν_{max} 2150 cm^{-1} (CN) (Found: C, 46.4; H, 5.75; N, 4.15. $C_{25}H_{32}N_2O_{14}S_2$ calc.: C, 46.3; H, 4.9; N, 4.3%). Mass spectrum: *m/z* 617 [0.2%, $(M^+ - OMe)$], 530 [0.3, $(M^+ - 2\ OAc)$], 330 (6.8, Gal*p*Ac_3SCN^+), 302 (3.8, Glc*p*$Ac_2OMeSCN^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.49 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.93 (dd, 1 H, $J_{2,3}$ 9.3 Hz, H-2), 5.32 (t, 1 H, $J_{3,4}$ 9.1 Hz, H-3), 3.80 (t, 1 H, $J_{4,5}$ 9.1 Hz, H-4), 3.88 (ddd, 1 H, $J_{5,6a}$ 2.2, $J_{5,6b}$ 9.1 Hz, H-5), 3.55 (dd, 1 H, $J_{6a,6b}$ 13.5 Hz, H-6a), 3.04 (dd, 1 H, H-6b), 4.68 (d, 1 H, $J_{1',2'}$ 7.3 Hz, H-1'), 5.15 (dd, 1 H, $J_{2',3'}$ 10.4 Hz, H-2'), 5.05 (dd, 1 H,

$J_{3',4'}$ 3.3 Hz, H-3'), 5.45 (dd, 1 H, $J_{4',5'}$ 1.3 Hz, H-4'), 3.98 (ddd, 1 H, $J_{5',6'a} = J_{5',6'b} = 7.9$ Hz, H-5'), 3.15 (dd, 1 H, $J_{6'a,6'b}$ 13.5 Hz, H-6'a), 3.07 (dd, 1 H, H-6'b), 3.55 (s, 3 H, OMe), 2.19, 2.09, 2.07, 2.06, 1.99 (5 s, 15 H, 5 Ac).

Methyl 2,3-di-O-*acetyl-6*-S-*acetyl-6-thio-4*-O-*(2,3,4-tri*-O-*acetyl-6*-S-*acetyl-6-thio-β*-D-*galactopyranosyl)-β*-D-*glucopyranoside* (**28**). — A mixture of **24** (1 g), excess of potassium thioacetate (1 g), and *N,N*-dimethylformamide (10 mL) was heated at 95–100° for 30 min and then poured into ice–water. The brown solid was collected and purified by column chromatography (ether–light petroleum 2:1) to give **28** as a syrup (0.75 g, 76%), $[\alpha]_D$ +14° (Found: C, 47.4; H, 5.4. $C_{27}H_{38}O_{16}S_2$ calc.: C, 47.5; H, 5.55%). Mass spectrum: *m/z* 651 [0.1%, $(M^+ - OCH_3)$], 579 [0.7, $(M^+ - AcOH - Ac)$], 347 (6.4, Gal*p*Ac_3SAc^+), 319 (2.7, Glc*p*$Ac_2OMeSAc^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.36 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.91 (dd, 1 H, $J_{2,3}$ 9.7 Hz, H-2), 5.17 (dd, 1 H, $J_{3,4}$ 8.4 Hz, H-3), 3.66 (t, 1 H, $J_{4,5}$ 9.0 Hz, H-4), 3.5–3.6 (m, 2 H, H-5,6a), 2.97 (dd, 1 H, $J_{5,6b}$ 5.5, $J_{6a,6b}$ 14.0 Hz, H-6b), 4.54 (d, 1 H, $J_{1',2'}$ 7.7 Hz, H-1'), 5.10 (dd, 1 H, $J_{2',3'}$ 10.0 Hz, H-2'), 4.96 (dd, 1 H, $J_{3',4'}$ 3.7 Hz, H-3'), 5.38 (dd, 1 H, $J_{4',5'}$ 1.1 Hz, H-4'), 3.66 (ddd, 1 H, $J_{5',6'a} = J_{5',6'b} = 7.0$ Hz, H-5'), 3.08 (dd, 1 H, $J_{6'a,6'b}$ 14.0 Hz, H-6'a), 3.00 (dd, 1 H, H-6'b), 3.48 (s, 3 H, OMe), 2.17, 2.10, 2.07, 2.05, 1.96 (5 s, 15 H, 5 Ac), 2.36, 2.35 (2 s, 6 H, 2 Ac).

Methyl 2,3-di-O-*acetyl-6*-S-(N,N-*dimethylaminothiocarbonyl)-6-thio-4*-O-*[2,3,4-tri*-O-*acetyl-6*-S-(N,N-*dimethylaminothiocarbonyl)-6-thio-β*-D-*galactopyranosyl]-β*-D-*glucopyranoside* (**29**). — A mixture of **24** (2 g), excess of sodium *N,N*-dimethylaminodithiocarbamate (2 g), and *N,N*-dimethylformamide (20 mL) was heated at 95–100° for 2 h, then poured into ice–water. The solid was collected, purified by column chromatography (ether–light petroleum, 3:1), and crystallised from ether–light petroleum to give **29** (1.8 g, 81%), m.p. 99–101°, $[\alpha]_D$ −12.6° (Found: C, 44.7; H, 5.95; N, 3.65. $C_{29}H_{44}N_2O_{14}S_4$ calc.: C, 45.1; H, 5.7; N, 3.65%). Mass spectrum: *m/z* 653 [0.3%, $(M^+ - AcOH - OAc)$], 652 [1.1, $(M^+ - 2AcOH)$], 392 (13.7, Gal*p*$Ac_3SCSNMe_2^+$), 364 (1.2, Glc*p*$Ac_2OMeSCSNMe_2^+$). ^{1}H-N.m.r data ($CDCl_3$: δ 4.37 (d, 1 H, $J_{1,2}$ 7.7 Hz, H-1), 4.94 (dd, 1 H, $J_{2,3}$ 10.0 Hz, H-2), 5.18 (dd, 1 H, $J_{3,4}$ 9.7 Hz, H-3), 3.83 (dd, 1 H, $J_{4,5}$ 8.4 Hz, H-4), 3.78 (m, 1 H, H-5), 3.3–3.5 (m, 4 H, H-6a,6b,6'a,6'b), 4.61 (d, 1 H, $J_{1',2'}$ 7.3 Hz, H-1'), 5.08 (dd, 1 H, $J_{2',3'}$ 10.0 Hz, H-2'), 4.98 (dd, 1 H, $J_{3',4'}$ 3.3 Hz, H-3'), 5.44 (dd, 1 H, $J_{4',5'}$ 1.1 Hz, H-4'), 3.95 (m, 1 H, H-5'), 3.49 (s, 3 H, OMe), 2.17, 2.10, 2.08, 2.05, 1.96 (5 s, 15 H, 5 Ac), 3.56 (s, 6 H, NMe_2), 3.42, 3.39 (2 s, 6 H, NMe_2).

O-Deacetylation of **29** gave methyl 6-*S*-(*N,N*-dimethylaminothiocarbonyl)-4-*O*-[6-*S*-(*N,N*-dimethylaminothiocarbonyl)-6-thio-β-D-galactopyranosyl]-6-thio-β-D-glucopyranoside (**30**, 92%) as a powdery solid from ethanol; m.p. 131–133°, $[\alpha]_D$ +66° (*c* 1, methanol) (Found: C, 39.9; H, 6.05; N, 4.7. $C_{19}H_{34}N_2O_9S_4$ calc.: C, 40.55; H, 6.05; N, 5.0%).

Re-acetylation of **30** afforded **29** in high yield.

Methyl 2,3,2',3',4'-penta-O-*acetyl-6,6'-epidithio-β-lactoside* (**32**). — A mixture of **24** (3 g), thiourea (3 g), and *N,N*-dimethylformamide (20 mL) was stirred and heated at 95–100° for 7 h, when t.l.c. (ether) revealed the absence of **24** and the presence of product(s) which were non-mobile. Sodium azide (2 g) was added to the mixture and heating was continued for 12 h. The mixture was then poured into water, and the

precipitate was collected, washed with water, dried, and purified on a dry-packed[12] column, using ether–light petroleum (2:1). The product crystallised from ethanol to give **32** (0.5 g, 19%), m.p. 218–220°, $[\alpha]_D$ +82° (Found: C, 46.3; H, 5.85. $C_{23}H_{32}O_{14}S_2$ calc.: C, 46.3; H, 5.35%). Mass spectrum: *m/z* 597 [0.3%, $(M^+ + 1)$], 596 (0.8, M^+). ^{1}H-N.m.r. data ($CDCl_3$, 60°): δ 4.40 (d, 1 H, $J_{1,2}$ 8.1 Hz, H-1), 4.88 (dd, 1 H, $J_{2,3}$ 9.1 Hz, H-2), 5.38 (t, 1 H, $J_{3,4}$ 9.3 Hz, H-3), 4.03 (dd, 1 H, $J_{4,5}$ 10.1 Hz, H-4), 3.70 (ddd, 1 H, H-5), 2.93 (dd, 1 H, $J_{5,6a}$ 3.0, $J_{6a,6b}$ 14.5 Hz, H-6a), 2.65 (dd, 1 H, $J_{5,6b}$ 9.5 Hz, H-6b), 4.81 (d, 1 H, $J_{1',2'}$ 7.2 Hz, H-1'), 5.13 (dd, 1 H, $J_{2',3'}$ 10.2 Hz, H-2'), 5.02 (dd, 1 H, $J_{3',4'}$ 3.2 Hz, H-3'), 5.28 (dd, 1 H, $J_{4',5'}$ 1.1 Hz, H-4'), 4.7 (ddd, 1 H, $J_{5',6'a}$ 5.7, $J_{5',6'b}$ 10.4 Hz, H-5'), 3.73 (dd, 1 H, $J_{6'a,6'b}$ 13.1 Hz, H-6'a), 2.50 (dd, 1 H, H-6'b), 3.47 (s, 3 H, OMe), 2.16, 1.99, 1.95 (3 s, 9 H, 3 Ac), 2.02 (s, 6 H, 2 Ac).

O-Deacetylation of **32** with sodium methoxide afforded highly crystalline methyl 6,6'-epidithio-β-lactoside (**31**, ~100%), m.p. >250° (from aqueous alcohol), $[\alpha]_D$ +132° (*c* 1, water) (Found: C, 40.05; H, 5.65. $C_{13}H_{22}O_9S_2$ calc.: C, 40.4; H, 5.7%).

Benzoylation of **31** afforded the 2,3,2',3',4'-pentabenzoate **33** (85%), m.p. 145–147° (from 2-propanol), $[\alpha]_D$ +274° (Found: C, 63.4; H, 4.55. $C_{58}H_{42}O_{14}S_2$ calc.: 63.55; H, 4.65%).

*Methyl 6-S-cyano-4-O-(6-S-cyano-3,4-O-isopropylidene-6-thio-β-*D*-galactopyranosyl)-6-thio-β-*D*-glucopyranoside* (**15**). — A mixture of dibromolactoside **11** (2 g), excess of potassium thiocyanate (2 g), and *N,N*-dimethylformamide (20 mL) was heated at 95–100° for 72 h, then cooled, and treated overnight with acetic anhydride (5 mL) and pyridine (15 mL). The solvents were evaporated and the residue was purified by column chromatography (chloroform; then chloroform–methanol, 20:1) to give syrupy **15** (1.6 g, 87%), $[\alpha]_D$ +74° (*c* 1, methanol) (Found: C, 45.05; H, 5.55; N, 5.35. $C_{18}H_{26}N_2O_9S_2$ calc.: C, 45.2; H, 5.45; N, 5.85%).

Acetylation of **15** furnished the 2,3,2'-triacetate **16** (73%), m.p. 130–131° (from 2-propanol), $[\alpha]_D$ +23° (Found: C, 47.5; H, 5.3; N, 4.95. $C_{24}H_{32}N_2O_{12}S_2$ calc.: C, 47.7; H, 5.3; N, 4.65%). Mass spectrum: *m/z* 486 [0.1%, $(M^+ - 2\ OAc)$], 485 [0.1, $(M^+ - HOAc - OAc)$], 302 (5.2, Glc*p*Ac$_2$SCNOMe$^+$), 286 (12.5, Gal*p*AcCMe$_2$SCN$^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.47 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1), 4.92 (dd, 1 H, $J_{2,3}$ 9.4 Hz, H-2), 5.28 (t, 1 H, $J_{3,4}$ 9.2 Hz, H-3), 3.81 (dd, 1 H, $J_{4,5}$ 8.5 Hz, H-4), 3.83 (m, 1 H, H-5), 3.57 (dd, 1 H, $J_{5,6a}$ ~3, $J_{6a,6b}$ 13.5 Hz, H-6a), 3.14 (dd, 1 H, $J_{5,6b}$ 8.5 Hz, H-6b), 4.62 (d, 1 H, $J_{1',2'}$ 7.9 Hz, H-1'), 4.90 (m, 1 H, H-2'), 4.25–4.33 (m, 2 H, H-3',4'), 4.03 (ddd, 1 H, $J_{5',6'a}$ ~2, $J_{5',6'a}$ ~7 Hz, H-5'), 3.27 (m, 2 H, H-6'a,6'b), 3.47 (s, 3 H, OMe), 2.16, 1.99, 1.95 (3 s, 9 H, 3 Ac), 2.02 (s, 6 H, 2 Ac), 1.54, 1.34 (2 s, 6 H, Me_2C).

Attempts to form a 6,6'-epidithio linkage. — (*a*) *From* **15**. A mixture of **15** and methanolic 0.1M sodium methoxide (5 mL) was heated under reflux for 24 h, then neutralised with Amberlite IR-120 (H^+) resin, and the solvent was evaporated. The residue was acetylated to give methyl 2,3-di-*O*-acetyl-4-*O*-(2-*O*-acetyl-6-*S*-acetyl-6-thio-β-D-galactopyranosyl)-6-*S*-acetyl-6-thio-β-D-glucopyranoside (**34**; 0.2 g, 53%) as a syrup, $[\alpha]_D$ +3.6° (*c* 0.5, methanol) (Found: C, 46.3; H, 5.45. $C_{32}H_{34}O_{14}S_2$ calc.: C, 46.15; H, 5.7%).

Mass spectrum: *m/z* 567 [0.1%, ($M^+ - OMe$)], 319 (0.4, Glc*p*Ac_2SAcOMe$^+$), 263 (0.1, Gal*p*AcSAc$^+$). ^{1}H-N.m.r. data (250 MHz, $CDCl_3$): δ 4.37 (d, 1 H, $J_{1,2}$ 8.1 Hz, H-1), 4.91 (dd, 1 H, $J_{2,3}$ 9.8 Hz, H-2), 5.16 (t, 1 H, $J_{3,4}$ 9.4 Hz, H-3), 3.82 (t, 1 H, $J_{4,5}$ 9.3 Hz, H-4), 2.6–3.7 (m, 7 H, H-3′,5,5′,6a,6′a,6b,6′b), 4.46 (d, 1 H, $J_{1',2'}$ 7.8 Hz, H-1′), 4.84 (dd, 1 H, $J_{2',3'}$ 9.9 Hz, H-2′), 4.06 (d, 1 H, $J_{4',5'}$ ~3, $J_{4',5'}$ ~1.5 Hz, H-4′), 3.48 (s, 3 H, OMe), 2.23, 2.19 (s, 6 H, 2 SAc), 2.14 (s, 3 H, Ac), 2.09 (2 s, 6 H, 2 Ac), 1.54, 1.34 (2 s, 6 H, Me_2C).

(*b*) *From* **28**. A solution of **28** (1.2 g) in methanolic 0.12M sodium methoxide (15 mL) was heated under reflux for 5 h, then treated with Amberlite IR-120 (H^+) resin, and filtered, and the solvent was evaporated. The syrupy residue was acetylated to give **7** (0.7 g, 71%), m.p. 221–223° (from ethanol), $[\alpha]_D$ −61°, identical to the compound described above.

*Methyl-4-*O*-(6-bromo-6-deoxy-3,4-*O*-isopropylidene-β-*D*-galactopyranosyl)-6-*S*-ethoxythiocarbonyl-6-thio-β-*D*-glucopyranoside* (**17**). — A mixture of **11** (4 g), ethyl potassium xanthate (4 g), and acetone (40 mL) was heated under reflux for 1 h, when t.l.c. (chloroform–methanol, 12:1) revealed one major and several minor products, and a little **11**. The mixture was then filtered through Hyflo supercel and the solvent was evaporated. Column chromatography (light petroleum–ethyl acetate, 3:2, then 1:1) of the residue afforded an impure product which was again chromatographed, using a short column and the same solvents, to give **17** (0.95 g, 22%), $[\alpha]_D$ +50° (Found: C, 39.9; H, 5.5. $C_{19}H_{31}BrO_{10}S_2$ calc.: C, 40.5; H, 5.5%).

Acetylation of **17** gave the syrupy 2,3,2′-triacetate **18** (80%), $[\alpha]_D$ +4.8° (Found: C, 43.1; H, 5.3. $C_{25}H_{37}BrO_{13}S_2$ calc.: C, 43.5; H, 5.35%). Mass spectrum: 365 (0.1%, Glc*p*Ac_2SCSOEtOMe$^+$), 309,307 (10.9, 1:1 ratio, Gal*p*AcBr$^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.36 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1), 4.88 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.20 (t, 1 H, $J_{3,4}$ 9.5 Hz, H-3), 3.72 (m, 2 H, H-4,5), 3.81 (dd, 1 H, $J_{5,6a}$ ~2, $J_{6a,6b}$ ~13.7 Hz, H-6a), 3.30 (m, 1 H, H-6b), 4.49 (d, 1 H, $J_{1',2'}$ 7.5 Hz, H-1′), 4.90 (dd, 1 H, $J_{2',3'}$ 7.1 Hz, H-2′), 3.25 (dd, 1 H, $J_{3',4'}$ 5.6 Hz, H-3′), 4.32 (dd, 1 H, $J_{4',5'}$ 1.9 Hz, H-4′), 3.92 (td, 1 H, $J_{5',6'a}$ 7.5, $J_{5',6'b}$ 7.0 Hz, H-5′), 3.60 (dd, 1 H, $J_{6'a,6'b}$ 10.0 Hz, H-6′a), 3.47 (dd, 1 H, H-6′b), 3.49 (s, 3 H, OMe), 2.10, 2.06, 2.04 (3 s, 9 H, 3 Ac), 1.55, 1.34 (2 s, 6 H, CMe_2), 1.43 and 4.67 (t and q, 5 H, Et).

*Selective displacement reactions of methyl 2,3-di-*O*-acetyl-6-bromo-6-deoxy-4-*O*-(2,3,4-tri-*O*-acetyl-6-bromo-6-deoxy-β-*D*-galactopyranosyl)-β-*D*-glucopyranoside* (**24**). — (*a*) A solution of **24** (1.4 g) and potassium thioacetate (0.23 g) in acetone was heated under reflux for 45 min, after which t.l.c. (ether–light petroleum, 9:1) revealed some **24** and a little of the 6,6′-di(thioacetate). The solvent was evaporated and column chromatography [ether–light petroleum, 1:1) of the residue gave **24** (0.15 g, 11%), followed by methyl 2,3-di-*O*-acetyl-6-*S*-acetyl-6-thio-4-*O*-(2,3,4-tri-*O*-acetyl-6-bromo-6-deoxy-β-D-galactopyranosyl)-β-D-glucopyranoside (**38**; 0.76 g, 55%), m.p. 127–128° (from ethanol), $[\alpha]_D$ +2.1° (Found: C, 44.05; H, 4.95. $C_{25}H_{35}BrO_{15}S$ calc.: C, 43.65; H, 5.1%). Mass spectrum: *m/z* 585, 583 [0.1%, ratio 1:1, ($M^+ - AcOH - Ac$)], 353, 351 (9.2, 1:1 ratio, Gal*p*Ac_3Br$^+$), 319 (1.8, Glc*p*Ac_2SAcOMe$^+$). ^{1}H-N.m.r. data (250 MHz, $CDCl_3$): δ 4.36 (d, 1 H, $J_{1,2}$ 7.7 Hz, H-1), 4.88 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.18 (t, 1 H, $J_{3,4}$ 9.1 Hz, H-3), 3.68 (t, 1 H, $J_{4,5}$ 8.8 Hz, H-4), 3.55 (m, 2 H, H-5,6a), 2.99 (dd, 1 H, $J_{5,6b}$ 8.0, $J_{6a,6b}$ 13.5 Hz, H-6b), 4.57 (d, 1 H, $J_{1',2'}$ 7.3 Hz, H-1′), 5.13 (dd, 1 H, $J_{2',3'}$ 10.6 Hz, H-2′), 5.02 (dd, 1 H,

$J_{3',4'}$ 3.3 Hz, H-3'), 5.54 (dd, 1 H, $J_{4',5'}$ 1.1 Hz, H-4'), 3.86 (t, 1 H, $J_{5',6'a} \approx J_{5',6'b} \approx 7$ Hz, H-5'), 3.36 (dd, 1 H, $J_{6'a,6'b}$ 10.6 Hz, H-6'a), 3.29 (dd, 1 H, H-6'b), 3.47 (s, 3 H, OMe), 2.17, 2.10, 2.05, 2.04, 1.98 (5 s, 15 H, 5 Ac), 2.37 (s, 3 H, SAc).

(*b*) A mixture of **24** (1.4 g), potassium thiocyanate (0.8 g), and butanone (15 mL) was heated under reflux for 8 h, and the solvent was then evaporated. Column chromatography (ether–light petroleum, 3:2) of the residue gave methyl 2,3-di-*O*-acetyl-6-*S*-cyano-6-thio-4-*O*-(2,3,4-tri-*O*-acetyl-6-bromo-6-deoxy-β-D-galactopyranosyl)-β-D-glucopyranoside (**39**; 1.1 g, 81%), m.p. 102–104° (from ethanol), $[\alpha]_D$ −7.8° (Found: C, 43.5; H, 4.7; N, 1.95. $C_{24}H_{32}BrNO_{14}S$ calc.: C, 43.0; H, 4.8; N, 2.1%). Mass spectrum: *m/z* 672, 670 (0.2%, ratio 1:1, $M^+ + 1$), 353, 351 (19.4, 1:1 ratio, Gal*p*Ac$_3$Br$^+$), 302 (12.3, Glc*p*Ac$_2$SCNOMe$^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.47 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.93 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.30 (t, 1 H, $J_{3,4}$ 9.1 Hz, H-3), 3.77 (t, 1 H, $J_{4,5}$ 9.5 Hz, H-4), 3.5 (m, 2 H, H-5,6a), 3.10 (dd, 1 H, $J_{5,6b}$ 8.0, $J_{6a,6b}$ 13.5 Hz, H-6b), 4.61 (d, 1 H, $J_{1',2'}$ 7.7 Hz, H-1'), 5.12 (dd, 1 H, $J_{2',3'}$ 10.6 Hz, H-2'), 5.01 (dd, 1 H, $J_{3',4'}$ 3.3 Hz, H-3'), 5.51 (dd, 1 H, $J_{4',5'}$ 1.1 Hz, H-4'), 3.90 (m, 1 H, H-5'), 3.41 (dd, 1 H, $J_{5',6'a} \sim 8$, $J_{6'a,6'b}$ 10.6 Hz, H-6'a), 3.29 (dd, 1 H, $J_{5',6'b} \sim 8$ Hz, H-6'b), 3.54 (s, 3 H, OMe), 2.18, 2.09, 2.06, 2.05, 1.98 (5 s, 15 H, 5 Ac).

(*c*) A mixture of **24** (2 g), potassium ethyl xanthate (2 g), and acetone (40 mL) was heated under reflux for 20 min. The reaction was then complete (t.l.c.) and the solvent was evaporated. Column chromatography (ether–light petroleum, 2:1) of the residue gave methyl 2,3-di-*O*-acetyl-6-*S*-ethoxythiocarbonyl-6-thio-4-*O*-(2,3,4-tri-*O*-acetyl-6-bromo-6-deoxy-β-D-galactopyranosyl)-β-D-glucopyranoside (**40**; 1.5 g, 71%), m.p. 156–157° (from ethanol), $[\alpha]_D$ +1.6° (Found: C, 42.85; H, 5.05. $C_{25}H_{35}BrO_{15}S_2$ calc.: C, 42.55; H, 5.05%). Mass spectrum: *m/z* 353, 351 (11.6%, 1:1 ratio, Gal*p*Ac$_3$Br$^+$), 365 (0.4, Glc*p*Ac$_2$SCSOEtOMe$^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.61 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.89 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.21 (t, 1 H, $J_{3,4}$ 8.8 Hz, H-3), 3.7–3.8 (m, 3 H, H-4,5,6a), 3.30 (m, 1 H, H-6b), 4.37 (d, 1 H, $J_{1',2'}$ 7.7 Hz, H-1'), 5.13 (dd, 1 H, $J_{2',3'}$ 10.2 Hz, H-2'), 5.00 (dd, 1 H, $J_{3',4'}$ 3.9 Hz, H-3'), 5.54 (dd, 1 H, $J_{4',5'}$ 1.1 Hz, H-4'), 3.87 (m, 1 H, H-5'), 3.37 (dd, 1 H, $J_{5',6'a}$ 7.0, $J_{6'a,6'b}$ 10.2 Hz, H-6'a), 3.28 (dd, 1 H, $J_{5',6'b}$ 7.7 Hz, H-6'b), 3.47 (s, 3 H, OMe), 2.18, 2.06, 2.05, 2.04, 1.98 (5 s, 15 H, 5 Ac), 1.65, 4.68 (t and q, 5 H, Et).

(*d*) A mixture of **24** (1 g), sodium *N*,*N*-dimethylaminodithiocarbamate (0.6 g), and acetone (20 mL) was heated under reflux for 20 min. The reaction was then complete (t.l.c.) and the solvent was evaporated. Column chromatography (ether–light petroleum, 2:1) of the residue gave methyl 2,3-di-*O*-acetyl-6-*S*-(*N*,*N*-dimethylaminothiocarbonyl)-6-thio-4-*O*-(2,3,4-tri-*O*-acetyl-6-bromo-6-deoxy-β-D-galactopyranosyl)-β-D-glucopyranoside (**41**; 0.9 g, 85%), isolated as a syrup, $[\alpha]_D$ −1.0° (Found: C, 42.75; H, 5.3; N, 1.8. $C_{26}H_{38}BrNO_{14}S_2$ calc.: C, 42.6; H, 5.2; N, 1.9%). Mass spectrum: *m/z* 353, 351 (11.0, 1:1 ratio, Gal*p*Ac$_3$Br$^+$), 364 (0.8, Glc*p*Ac$_2$SCSNMe$_2$OMe$^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.63 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.90 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.18 (t, 1 H, $J_{3,4}$ 9.5 Hz, H-3), 3.8–4.0 (m, 4 H, H-4,5,5',6a), 4.68 (d, 1 H, $J_{1',2'}$ 7.7 Hz, H-1'), 5.1 (dd, 1 H, $J_{2',3'}$ 10.4 Hz, H-2'), 5.01 (dd, 1 H, $J_{3',4'}$ 3.3 Hz, H-3'), 5.53 (dd, 1 H, $J_{4',5'} \sim 1$ Hz, H-4'), 3.38 (dd, 1 H, $J_{5',6'a}$ 7.0, $J_{6'a,6'b}$ 10.2 Hz, H-6'a), 3.29 (dd, 1 H, $J_{5',6'b}$ 8.0 Hz, H-6'b), 3.48 (s, 3 H, OMe), 2.17, 2.11, 2.05, 2.04, 1.97 (5 s, 15 H, 5 Ac), 3.36, 3.22 (2 s, 6 H, CMe_2).

Attempted formation of methyl 6,6'-epithio-β-lactoside. — A solution of **17** (0.7 g) in methanolic 0.1M sodium methoxide (15 mL) was stored overnight at room temperature, then neutralised with Amberlite IR-120 (H^+) resin, and the solvent was evaporated. Column chromatography (ethyl acetate–light petroleum, 6:1) gave bis[methyl 4-*O*-(6-bromo-6-deoxy-3,4-*O*-isopropylidene-β-D-galactopyranosyl)-β-D-glucopyranosid-6-yl] disulphide (**35**; 0.3 g, 51%), m.p. 128–130° (from ethanol), $[\alpha]_D$ +127° (Found: C, 39.85; H, 5.35. $C_{32}H_{52}Br_2O_{18}S_2$ calc.: C, 40.5; H, 5.5%).

Acetylation of **35** provided the 2,2,3,3,2',2'-hexa-acetate **36** (66%), m.p. 108–110°, $[\alpha]_D$ +25° (Found C, 43.15; H, 5.15. $C_{44}H_{64}Br_2O_{24}S_2$ calc.: C, 44.0; H, 5.35%). Mass spectrum: *m/z* 309, 307 (11.8%, 1:1 ratio, Gal*p*AcBr$^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.39 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.89 (dd, 1 H, $J_{2,3}$ 9.6 Hz, H-2), 5.21 (t, 1 H, $J_{3,4}$ 8.9 Hz, H-3), 3.73 (m, 2 H, H-4,5), 3.29 (dd, 1 H, $J_{5,6a}$ 2.0, $J_{6a,6b}$ 6.8 Hz, H-6a), 2.99 (dd, 1 H, $J_{6a,6b}$ 13.9 Hz, H-6b), 4.49 (d, 1 H, $J_{1',2'}$ 7.5 Hz, H-1'), 4.88 (dd, 1 H, $J_{2',3'}$ 6.7 Hz, H-2'), 4.18 (dd, 1 H, $J_{3',4'}$ 5.6 Hz, H-3'), 4.32 (dd, 1 H, $J_{4',5'}$ 2.0 Hz, H-4'), 3.95 (td, 1 H, $J_{5',6'a} = J_{5',6'b} = 4.8$ Hz, H-5'), 3.60 (dd, 1 H, $J_{6'a,6'b}$ 10.3 Hz, H-6'a), 3.51 (dd, 1 H, H-6'b), 3.50 (s, 3 H, OMe), 2.12, 2.06, 2.05 (3 s, 9 H, 3 Ac), 1.98, 1.34 (2 s, 6 H, CMe_2).

Methyl 2,3,2',3',4'-penta-O-*acetyl-6,6'-dithio-6,6'*-S,S-*thiocarbonyl-β-lactoside* (**37**). — A solution of **24** (1 g) and potassium trithiocarbonate (0.85 g) in *N,N*-dimethylformamide (10 mL) was heated at 95–100° for 1 h, when t.l.c. (ether–light petroleum, 9:1) indicated that the reaction was complete. The reaction mixture was poured into water and the product was extracted with chloroform. Column chromatography of the impure product (ether–light petroleum, 2:1) gave **37** (0.3 g, 35%) as needles from ethanol; m.p. 182–183°, $[\alpha]_D$ −2.2° (Found: C, 45.3; H, 5.3. $C_{24}H_{32}O_{14}S_3$ calc.: C, 45.0; H, 5.0%). Mass spectrum: *m/z* 609 [0.1%, (M$^+$ −OMe)], 549 [0.1, (M$^+$ −OMe−HOAc)]. ^{1}H-N.m.r. data ($CDCl_3$): δ 4.42 (d, 1 H, $J_{1,2}$ 0.0 Hz, H-1), 4.88 (dd, 1 H, $J_{2,3}$ 0.0 Hz, H-2), 5.21 (t, 1 H, $J_{3,4}$ 0.0 Hz, H-3), 3.90 (t, 1 H, $J_{4,5}$ 0.0 Hz, H-4), 3.55 (ddd, 1 H, $J_{5,6a}$ 0.0, $J_{5,6b}$ 0.0 Hz, H-5), 3.03 (1 H), 2.70 (2 H), 2.50 (1 H), (3 m, H-6a,6'a,6b,6'b), 4.58 (d, 1 H, $J_{1',2'}$ 0.0 Hz, H-1'), 5.10 (dd, 1 H, $J_{2',3'}$ 0.0 Hz, H-2'), 5.00 (dd, 1 H, $J_{3',4'}$ 0.0 Hz, H-3'), 5.50 (dd, 1 H, $J_{4',5'}$ 0.0 Hz, H-4'), 3.66 (t, 1 H, $J_{5',6'a}$ 0.0, $J_{5',6'b}$ 0.0 Hz, H-5'), 3.51 (s, 3 H, OMe), 2.17, 2.06, 1.98 (3 s, 9 H, 3 Ac), 2.05 (s, 6 H, 2 Ac).

Methyl 2,3,2',3',4'-penta-O-*acetyl-6,6'-dideoxy-β-lactoside* (**42**). — Raney nickel (~4 g) was added to a solution of **27** (0.2 g), and the mixture was heated under reflux for 30 min, when t.l.c. (ether) indicated that the reaction was complete. The mixture was filtered through Hyflo-supercel and the solvent was evaporated to give **42** (0.12 g, 73%), m.p. 170–171° (from ethanol), $[\alpha]_D$ −25° (Found: C, 51.85; H, 6.1. $C_{23}H_{34}O_{14}$ calc.: C, 51.7; H, 6.35%).

Mass spectrum: *m/z* 503 [0.2%, (M$^+$ −OMe)], 443 [0.1, (M$^+$ −OMe−HOAc)], 273 (15.1, deoxyGal*p*Ac$_3^+$), 245 (3.6, deoxyGlc*p*Ac$_2$OMe$^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.36 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.87 (dd, 1 H, $J_{2,3}$ 9.7 Hz, H-2), 5.10 (t, 1 H, $J_{3,4}$ 9.5 Hz, H-3), 3.37–3.52 (m, 2 H, H-4,5), 1.34 (d, 1 H, $J_{5,6}$ 6.5 Hz, H-6), 4.51 (d, 1 H, $J_{1',2'}$ 7.6 Hz, H-1'), 5.10 (dd, 1 H, $J_{2',3'}$ 10.3 Hz, H-2'), 4.97 (dd, 1 H, $J_{3',4'}$ 3.4 Hz, H-3'), 5.19 (dd, 1 H, $J_{4',5'}$ 1.0 Hz, H-4'), 3.75 (dt, 1 H, $J_{5',6'}$ 6.3 Hz, H-5'), 1.19 (d, 1 H, H-6'a), 3.48 (s, 3 H, OMe), 2.17, 2.05, 2.04, 2.03, 1.97 (5 s, 15 H, 5 Ac).

This procedure was also applied to the other 6,6'-dithio derivatives, **28**–**30** and **37**, to give **42** in yields of 65, 72, 78, and 88%, respectively.

*Methyl 2,3,2',3',4'-penta-*O*-acetyl-6'-bromo-6,6'-dideoxy-β-*lactoside (**43**). — Compound **39** (0.2 g) was desulphurised with Raney nickel (0.2 g) for 30 min as described above. Column chromatography (ether–light petroleum, 1:1) of the syrupy product gave, first, **43** (0.07 g, 38%), m.p. 113–115° (from ethanol), $[\alpha]_D$ −22° (Found: C, 45.0; H, 5.8. $C_{23}H_{33}BrO_{14}$ calc.: C, 45.0; H, 5.4%). Mass spectrum: *m/z* 353, 351 (3.1%, ratio 1:1, Gal*p*BrAc$_3^+$), 245 (2.1, deoxyGlc*p*Ac$_2$OMe$^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.36 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.88 (dd, 1 H, $J_{2,3}$ 9.7 Hz, H-2), 5.15 (t, 1 H, $J_{3,4}$ 9.2 Hz, H-3), 3.4–3.5 (m, 2 H, H-4,5), 1.35 (d, 1 H, $J_{5,6}$ 6.5 Hz, H-6), 4.56 (d, 1 H, $J_{1',2'}$ 7.5 Hz, H-1'), 5.12 (dd, 1 H, $J_{2',3'}$ 10.4 Hz, H-2'), 5.00 (dd, 1 H, $J_{3',4'}$ 3.3 Hz, H-3'), 5.55 (dd, 1 H, $J_{4',5'}$ 1.1 Hz, H-4'), 3.84 (dt, 1 H, $J_{5',6'a} \approx J_{5',6'b} \approx 7$ Hz, H-5'), 3.32 (m, 2 H, H-6'a,6'b), 3.48 (s, 3 H, OMe), 2.17, 1.98 (2 s, 6 H, 2 Ac), 2.05 (s, 9 H, 3 Ac).

Further elution afforded the 6,6'-dideoxy derivative **42** (0.1 g, 6%).

When the reaction time of this reaction was lengthened to 45 min, only **42** (70%) was obtained.

Reaction of the 6,6'-dibromide **24** *with sodium azide.* — (*a*) A mixture of **24** (2.0 g), sodium azide (2 g), and *N*,*N*-dimethylformamide (15 mL) was heated at 100° with stirring for 30 min. The solid obtained on pouring the mixture into ice–water was collected and crystallised from ethanol to give methyl 2,3,2',3',4'-penta-*O*-acetyl-6-azido-6'-bromo-6,6'-dideoxy-β-lactoside (**44**; 1.4 g, 74%), m.p. 88–90°, $[\alpha]_D$ +8.4° (Found: C, 41.85; H, 4.8; N, 6.8. $C_{23}H_{32}BrN_3O_{14}$ calc.: C, 42.2; H, 4.9; N, 6.4%). Mass spectrum: *m/z* 353, 351 (9.6%, ratio 1:1, Gal*p*BrAc$_3^+$), 286 (4.5, Glc*p*Ac$_2$N$_3$OMe$^+$). ^{1}H-N.m.r data ($CDCl_3$): δ 4.44 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1), 4.91 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.22 (t, 1 H, $J_{3,4}$ 9.2 Hz, H-3), 3.84 (t, 1 H, $J_{4,5}$ 9.4 Hz, H-4), 3.64 (m, 1 H, H-5), 3.6–3.4 (m, 4 H, H-6a,6'a,6b,6'b), 4.53 (d, 1 H, $J_{1',2'}$ 7.4 Hz, H-1'), 5.09 (dd, 1 H, $J_{2',3'}$ 10.4 Hz, H-2'), 4.99 (dd, 1 H, $J_{3',4'}$ 3.2 Hz, H-3'), 5.55 (dd, 1 H, $J_{4',5'}$ 1.0 Hz, H-4'), 3.84 (m, 1 H, H-5'), 3.50 (s, 3 H, OMe), 2.17, 1.98 (2 s, 6 H, 2 Ac), 2.06 (s, 9 H, 3 Ac).

(*b*) The above reaction was repeated for 24 h, when t.l.c. (ether–light petroleum, 6:1) revealed two products in roughly equal proportions. The mixture was then poured into ice–water and the precipitate collected. Column chromatography (ether–light petroleum, 1:1) gave, first, methyl 2,3-di-*O*-acetyl-6-azido-6-deoxy-4-*O*-(2,3,4-tri-*O*-acetyl-α-L-*arabino*-hex-5-enopyranosyl)-β-D-glucopyranoside (**46**; 0.6 g, 36%), m.p. 147–149° (from ethanol), $[\alpha]_D$ −9.8° (Found: C, 57.6; H, 5.35; N, 7.2. $C_{25}H_{31}N_3O_{14}$ calc.: C, 48.15; H, 5.4; N, 7.35%). Mass spectrum: *m/z* 542 [1.5%, (M$^+$ − OMe)], 514 [0.4, (M$^+$ − OAc)], 286 (3.6, Glc*p*Ac$_2$N$_3$OMe$^+$), 271 (Gal*p*-5-eneAc$_3^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.45 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1), 4.93 (dd, 1 H, $J_{2,3}$ 9.7 Hz, H-2), 5.22 (t, 1 H, $J_{3,4}$ 9.3 Hz, H-3), 3.83 (t, 1 H, $J_{4,5}$ 9.3 Hz, H-4), 3.61 (m, 1 H, H-5), 3.54 (dd, 1 H, $J_{5,6a}$ 2.3, $J_{6a,6b}$ 14.0 Hz, H-6a), 3.41 (dd, 1 H, $J_{5,6b}$ 3.8, H-6b), 4.67 (d, 1 H, $J_{1',2'}$ 5.9 Hz, H-1'), 5.20 (dd, 1 H, $J_{2',3'}$ 9.0 Hz, H-2'), 5.02 (dd, 1 H, $J_{3',4'}$ 3.5 Hz, H-3'), 5.63 (d, 1 H, H-4'), 4.88 (d, 1 H, $J_{6'a,6'b}$ 1.3 Hz, H-6'a), 4.72 (d, 1 H, H-6'b), 3.51 (s, 3 H, OMe), 2.12, 2.09, 2.06, 2.02, 2.00 (5 s, 15 H, 5 Ac).

Further elution of the column afforded methyl 2,3-di-*O*-acetyl-6-azido-6-deoxy-

4-*O*-(2,3,4-tri-*O*-acetyl-6-azido-6-deoxy-β-D-galactopyranosyl)-β-D-glucopyranoside (**45**; 0.6 g, 34%), m.p. 127–129° (from ethanol), $[\alpha]_D$ +2.3° (Found: C, 44.7; H, 5.2; N, 13.3. $C_{23}H_{32}N_6O_{14}$ calc.: C, 44.8; H, 5.2; N, 13.6%). Mass spectrum: *m/z* 617 [0.1%, $(M^+ + 1)$], 616 (0.2, M^+), 314 (59.0, Gal*p*$Ac_3N_3^+$), 286 (12.2, Glc*p*$Ac_2N_3^+$). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.44 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1), 4.91 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-2), 5.21 (t, 1 H, $J_{3,4}$ 9.3 Hz, H-3), 3.85 (t, 1 H, $J_{4,5}$ 9.4 Hz, H-4), 3.61 (ddd, 1 H, $J_{5,6a}$ 2.0, $J_{5,6b}$ 4.9 Hz, H-5), 3.56 (dd, 1 H, $J_{6a,6b}$ 13.5 Hz, H-6a), 3.38 (dd, 1 H, H-6b), 4.54 (d, 1 H, $J_{1',2'}$ 7.5 Hz, H-1′), 5.09 (dd, 1 H, $J_{2',3'}$ 10.4 Hz, H-2′), 4.98 (dd, 1 H, $J_{3',4'}$ 3.1 Hz, H-3′), 5.36 (dd, 1 H, $J_{4',5'}$ 0.9 Hz, H-4′), 3.74 (t, 1 H, $J_{5',6'a} = J_{5',6'b} = 6.7$ Hz, H-5′), 3.48 (dd, 1 H, $J_{6'a,6'b}$ 13.3 Hz, H-6′a), 3.27 (dd, 1 H, H-6′b), 3.50 (s, 3 H, OMe), 2.17, 2.05, 1.97 (3 s, 9 H, 3 Ac), 2.06 (s, 6 H, 2 Ac).

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