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Syntheses of trisaccharide C–D–E and tetrasaccharide B–C–D–E fragments found in orthosomycins

Michel Trumtel*, Paolo Tavecchia†, Alain Veyrières, and Pierre Sinaÿ‡
Ecole Normale Supérieure, Laboratoire de Chimie, UA 1110, 24 Rue Lhomond, 75231 Paris 05 (France)

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ABSTRACT

1,5-Anhydro-3-*O*-benzyl-2,6-dideoxy-4-*O*-(3,4-di-*O*-benzyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-D-*arabino*-hex-1-enitol (**17**), which corresponds to the B–C fragment of various orthosomycins, was prepared from phenyl 2,3-di-*O*-benzyl-6-deoxy-4-*O*-(3,4-di-*O*-benzyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-1-thio-β-D-glucopyranoside (**16**) by reductive lithiation. The synthesis of **16** involved a stereoselective coupling of phenyl 2,3-di-*O*-benzyl-6-deoxy-1-thio-β-D-glucopyranoside (**9**) and 1,2-di-*O*-acetyl-3,4-di-*O*-benzyl-6-deoxy-β-D-glucopyranose (**14**) followed by deoxygenation at C-2′. Glycosylation of methyl 2-*O*-benzyl-6-deoxy-4-*O*-methyl-β-D-galactopyranoside (**25**) with 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl trichloroacetimidate, followed by deamination at C-2′, led stereospecifically to methyl 2-*O*-benzyl-6-deoxy-4-*O*-methyl-3-*O*-(3,4,6-tri-*O*-acetyl-2-deoxy-β-D-*arabino*-hexopyranosyl)-β-D-galactopyranoside (**26**). The 2-deoxy unit of **26** was then modified by consecutive axial introduction of a C-Me group at position 3′, protection of HO-3′, and deoxygenation at C-6′, in order to obtain methyl 3-*O*-(3-*O*-benzoyl-2,6-dideoxy-3-*C*-methyl-β-D-*arabino*-hexopyranosyl)-2-*O*-benzyl-6-deoxy-4-*O*-methyl-β-D-galactopyranoside (**39**), which corresponds to the D–E fragment of orthosomycins. A glycosyloxyselenation–oxidation–elimination sequence was performed on **39** and either 1,5-anhydro-3,4-di-*O*-benzyl-2,6-dideoxy-D-*arabino*-hex-1-enitol (**40**) or 1,5-anhydro-3-*O*-benzyl-2,6-dideoxy-4-*O*-(3,4-di-*O*-benzyl-2,6-dideoxy-β-D-*arabino*-hexopyranosyl)-D-*arabino*-hex-1-enitol (**17**) to give the C–D–E tri- and B–C–D–E tetrasaccharide fragments, respectively. Each fragment contained the spiro-ortholactone junction with an (*R*) configuration at the anomeric carbon atom of the C-unit.

INTRODUCTION

The orthosomycins[1], an oligosaccharide group of antibiotics, are characterized by the presence of one or two unique interglycoside spiro-ortholactone linkages that replace the usual acetalic junctions. Everninomicin C (**1**), D (**2**), and 2 (**3**), avilamycin A (**4**) and C (**5**), and curamycin A (**6**) are members of this group. We have reported[2] the synthesis of the C–D fragment and established the absolute configuration at C-16 in **1**–**6**. The spiro-ortholactone junction was constructed by glycosyloxyselenation[3] of a suitably protected glycal, oxidation at selenium, and *syn*-elimination of the resulting selenoxide[4]; intramolecular nucleophilic attack of the transient ketene acetal by the tertiary HO-3 of the D-unit provided the ortholactone corresponding to the natural product.

* Present address: F. Hoffmann-La Roche, 124 Grenzacherstrasse, CH-4002 Basel, Switzerland.
† Present address: Lepetit Research Center, via R. Lepetit 34, 21040 Gerenzano (VA), Italy.
‡ Author for correspondence.

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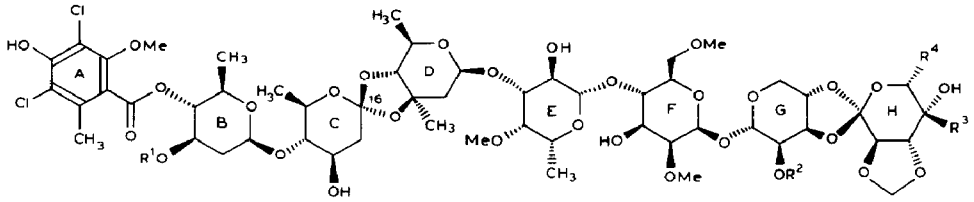
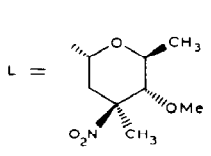


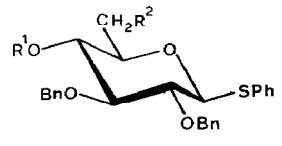


1 R^1 = L, R^2 = CH_3, R^3 = R^4 = H, Everninomicin C
2 R^1 = L, R^2 = CH_3, R^3 = (S)-$CH(OCH_3)CH_3$, R^4 = H, Everninomicin D
3 R^1 = R^4 = H, R^2 = CH_3, R^3 = (S)-$CH(OCH_3)CH_3$, Everninomicin 2
4 R^1 = H, R^2 = $COCH(CH_3)_2$, R^3 = $COCH_3$, R^4 = CH_3, Avilamycin A
5 R^1 = H, R^2 = $COCH(CH_3)_2$, R^3 = (S)-$CH(OH)CH_3$, R^4 = CH_3, Avilamycin C
6 R^1 = R^4 = H, R^2 = R^3 = $COCH_3$, Curamycin A

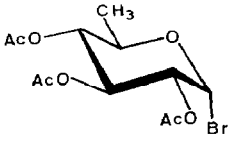
The development of a convenient preparation of pyranoid glycal derivatives from phenyl thioglycosides[5], together with that of two stereospecific syntheses of 2'-deoxy-β-disaccharides[6], made possible the extension of the selenium methodology to the preparation of larger fragments of orthosomycins. We now report the first synthesis of a protected B–C–D–E tetrasaccharide fragment.

RESULTS AND DISCUSSION

Synthesis of the B–C disaccharide fragment. — Two syntheses of this fragment have been reported[7,8], which allowed the preparation of a lactone that might be used for the elaboration of the spiro-ortholactone linkage according to a procedure described by Yoshimura and colleagues[9]. A key intermediate is the phenyl thioglycoside **16**, which can be converted into the corresponding glycal **17**. Therefore, phenyl 2,3-di-*O*-benzyl-6-



7 R^1 = H, R^2 = OH
8 R^1 = H, R^2 = I
9 R^1 = R^2 = H



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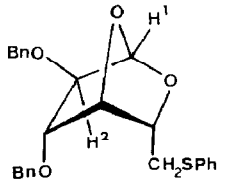

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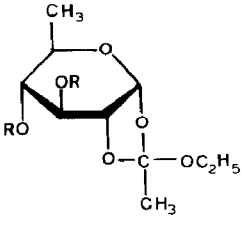
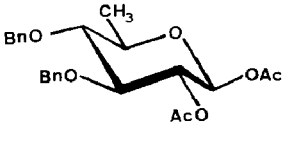


12 R = Ac
13 R = Bn



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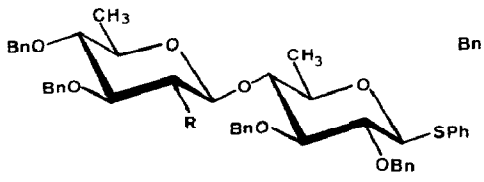
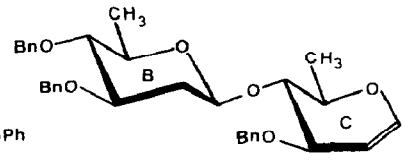
deoxy-1-thio-β-D-glucopyranoside (**9**) was selected as the precursor of the C unit and prepared (80% overall yield) from phenyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside by acid hydrolysis (→ **7**), conversion[11] into the 6-iodo derivative **8**, and hydrogenolysis (Pd–C) in the presence of diethylamine[12]. When **8** was treated with tributylstannane and *α,α'*-azobisisobutyronitrile in refluxing toluene, the reduction of the iodide function was not observed and 30% of 1,4-anhydro-2,3-di-*O*-benzyl-6-deoxy-6-phenylthio-α-D-glucopyranoside (**10**) was isolated. The ^{1}H-n.m.r. spectrum of **10** showed no coupling between H-1 and H-2, which is characteristic[13] of 1,4-anhydro sugar derivatives. The 1→6 migration of the phenylthio group occurred, presumably, *via* a 1,6-cyclic sulphonium species[14], and was followed by an intramolecular nucleophilic displacement.

2,3,4-Tri-*O*-acetyl-6-deoxy-α-D-glucopyranosyl bromide[15] (**11**) was converted into the 1,2-orthoacetate **12** by treatment with *N,N*-dimethylformamide diethyl acetal and tetrabutylammonium bromide[16]. The ^{1}H-n.m.r. spectrum of **12** indicated a 17:3 *exo,endo*-mixture and the major component was assumed to be the *exo*-orthoester[17]. Deacetylation of **12**, followed by benzylation, gave **13** which was reacted[6] with dry acetic acid to give the crystalline 1,2-*trans*-diacetate **14**.

The glycosylation of **9** by **14**, using trimethylsilyl trifluoromethanesulphonate as promoter, to give **15** and its conversion into the 2'-deoxy-β-disaccharide derivative **16** have been reported[6]. Reductive lithiation[5] of **16** afforded the crystalline glycal derivative **17** in excellent yield.



15 R = OAc
16 R = H



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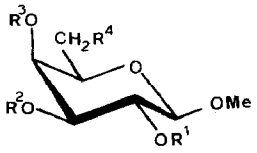
Synthesis of the D–E disaccharide fragment. — The required D–E fragment is the disaccharide methyl β-glycoside **39** that contains a 4-*O*-methyl-D-fucopyranoside (D-curacose) unit and a 2,6-dideoxy-3-*C*-methyl-β-D-*arabino*-hexopyranosyl (2-deoxy-D-evalose[1] or D-evermicose[18]) unit. The β configuration of the E unit was selected in order to mimic that present in the natural products (**1–6**). The E unit, as methyl 2-*O*-benzyl-6-deoxy-4-*O*-methyl-β-D-galactopyranoside (**25**), was synthesised from methyl 3,4-*O*-isopropylidene-β-D-galactopyranoside[19] (**18**). Treatment of **18** with triphenylphosphine, iodine, and imidazole[11] gave the 6-iodo derivative **19** (69%), hydrogenolysis (Pd–C) of which in the presence of diethylamine[12] afforded the 6-deoxy compound **20** in quantitative yield. Benzylation of **20** (→**21**) followed by acid hydrolysis gave known[20,21] syrupy **22**, the $[\alpha]_D^{20}$ value (+33°) of which accorded with that (+35.9°) recorded by Paulsen and Redlich[20] but was at variance with that (+213°) reported by Valente *et al.*[21].

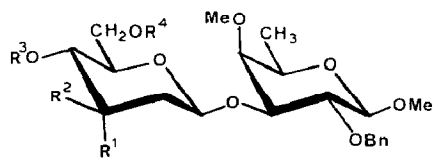


18 R^1 = H, R^2, R^3 = CMe_2 R^4 = OH
19 R^1 = H, R^2, R^3 = CMe_2, R^4 = I
20 R^1 = R^4 = H, R^2, R^3 = CMe_2
21 R^1 = Bn, R^2, R^3 = CMe_2, R^4 = H
22 R^1 = Bn, R^2 = R^3 = R^4 = H
23 R^1 = Bn, R^2 = p$MeOPhCH_2$, R^3 = R^4 = H
24 R^1 = Bn, R^2 = p$MeOPhCH_2$, R^3 = Me, R^4 = H
25 R^1 = Bn, R^2 = R^4 = H, R^3 = Me

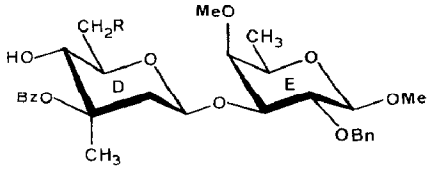
Reaction of the diol **22** with methyl iodide either in *N,N*-dimethylformamide in the presence of 1 equiv. of sodium hydride, or in toluene with silver silicate, gave mixtures of the 3- and 4-*O*-methyl derivatives in which the former preponderated. Protection of the HO-3 as the *p*-methoxybenzyl derivative (**23**) was achieved through a dibutyltin stannylene derivative[22], and *O*-methylation (→**24**) followed by treatment with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone[23] in dichloromethane–water gave the desired alcohol **25** (84% from **22**). The location of the *O*-methyl group was ascertained by the shift to lower field (δ 4.94, $J_{2,3}$ 10.5, $J_{3,4}$ 3.5 Hz) of the n.m.r. signal (δ 3.5–3.7) for H-3 when **25** was treated with trichloroacetyl isocyanate[24].

The glycosylation of **25** by 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl trichloroacetimidate and the conversion of the product into the 2'-deoxy compound **26** have been reported[6]. Deacetylation of **26** gave the crystalline disaccharide derivative **27**, the 2-deoxy-β-D-*arabino*-hexopyranosyl unit of which had to be transformed into a 2,6-dideoxy-3-*C*-methyl-β-D-*arabino*-hexopyranosyl moiety.

The 3'-keto derivative **29** was obtained (85% overall yield) by conversion of **27** into the 4',6'-*O*-benzylidene derivative **28**, followed by oxidation with pyridinium chlorochromate[25]. Treatment of **29** with methyl-lithium in ether afforded a nearly



26 R^1 = H, R^2 = OAc, R^3 = R^4 = Ac
27 R^1 = R^3 = R^4 = H, R^2 = OH
28 R^1 = H, R^2 = OH, R^3, R^4 = CHPh
29 R^1, R^2 = O, R^3, R^4 = CHPh
30 R^1 = OH, R^2 = Me, R^3, R^4 = CHPh
31 R^1 = Me, R^2 = OH, R^3, R^4 = CHPh
32 R^1, R^2 = CH_2, R^3, R^4 = CHPh
33 R^1 = R^2 = Me, R^3, R^4 = CHPh
34 R^1 = Me, R^2 = OBz, R^3, R^4 = CHPh



35 R = OH
36 R = Br
37 R = I
38 R = OCHO
39 R = H

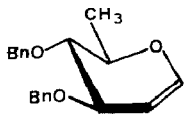
quantitative yield of a 1:1 mixture of 3′-*C*-methyl-*ribo* (**30**) and -*arabino* (**31**) derivatives. When performed in tetrahydrofuran or dimethoxymethane, the ratio **30**:**31** was 2.7 and 1.8, respectively. The *ribo* and *arabino* configurations of **30** and **31**, respectively, were assigned as follows. The axial HO-3′ of the *ribo* isomer **30** deshields the axial H-1′ which gives an n.m.r. signal at δ 5.27 in $CDCl_3$, whereas the H-1′ signal in the *arabino* derivative **31** appears at δ 4.92. The $\Delta\delta$ value (+0.35 p.p.m.) accords with the empirical rules established by Kotowycz and Lemieux[26]. In addition, the axial H-2′ and the hydroxyl proton of the *ribo*-isomer **30** are part of a planar zigzag (W arrangement)[26], which results in a $J_{2'a,OH}$ value of 2 Hz. Such an arrangement cannot be achieved with an equatorial HO-3′.

The lack of selectivity during similar reactions of a β-glycoside 3-ulose[27] is in sharp contrast with the behaviour[28,29] of an α-glycoside 3-ulose, where a 1,3-diaxial interaction hampers the axial approach of the organometallic reagent.

Diazomethane in ether quantitatively converted the ketone **29** into a mixture of epoxides which was immediately reduced with lithium aluminium hydride in tetrahydrofuran to give a mixture of **30** and **31**, in the ratio 11:1. No ring expansion was observed during the reaction with diazomethane[28].

An attempted Wittig olefination of **29** resulted in β-elimination and gave 89% of the alcohol **25**. A 3′-*C*-methylene compound **32** was obtained (90%) when **29** was treated with 1 equiv. of Tebbe's reagent[30] [(μ-chloro)(μ-methylene)bis(cyclopentadienyl)(dimethylaluminium)titanium]. When a large excess of reagent was used[31], 82% of the 3′-*C*-*gem*- dimethyl compound **33** was isolated. This example may represent a novel route to *gem*-dimethyl sugar derivatives. Epoxidation of **32** with 3-chloroperbenzoic acid in dichloromethane, followed by reduction with lithium aluminium hydride in tetrahydrofuran, gave almost exclusively the *ribo* compound **30**. Finally, mercuration–demercuration[2] of **32** gave 79% of a mixture of **30** and **31** in the ratio 1:2. The lack of selectivity in this reaction again resulted from the absence of directing influence such as that observed in α-glycosides[28]. Benzoylation of the tertiary alcohol **31** was achieved best (93% of isolated **32**) by treatment of the corresponding potassium alkoxide (prepared with potassium hydride in tetrahydrofuran) with benzoyl chloride at room temperature. Acidic methanolysis of **34** gave 84% of the diol **35** that did not react with the triphenylphosphine–iodine–imidazole system[11], but selectively gave a 6′-alkoxyphosphonium salt on treatment[32] with tris(dimethylamino)phosphine and tetrabromomethane in *N*,*N*-dimethylformamide at −45° and addition of potassium iodide to the mixture, and elevation of the temperature to 80° gave a mixture of the 6′-bromo (**36**) and 6′-iodo (**37**) derivatives which was converted into the desired 6′-deoxy derivative **39** (60% from **35**) by hydrogenolysis (Pd–C) in the presence of diethylamine. A small amount (5%) of the 6′-*O*-formyl derivative **38** was formed upon reaction of the intermediate phosphonium salt with *N*,*N*-dimethylformamide.

Synthesis of a protected C–D–E trisaccharide fragment. — 1,5-Anhydro-3,4-di-*O*-benzyl-2,6-dideoxy-D-*arabino*-hex-1-enitol[2] (3,4-di-*O*-benzyl-D-rhamnal, **40**) and the alcohol **39** were reacted using the phenylselenenyl chloride-mediated glycosylation procedure[3] to give the trisaccharide derivative **41** (34% from **39**) with a 1,2-*trans* diaxial



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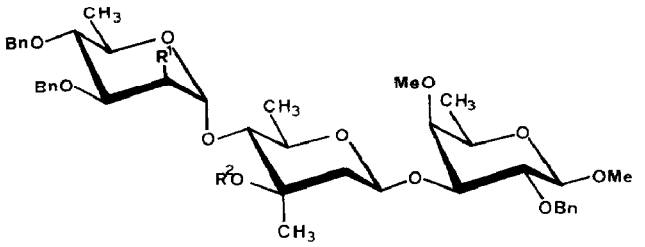
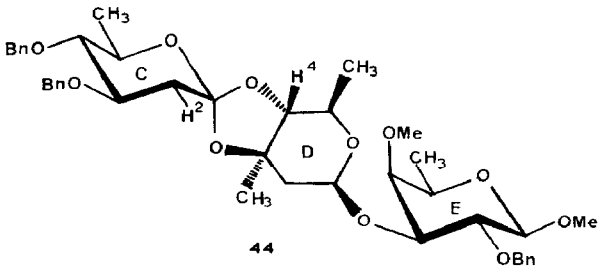


41 R^1 = SePh, R^2 = Bz
42 R^1 = SePh, R^2 = H
43 R^1 = SeOPh, R^2 = H



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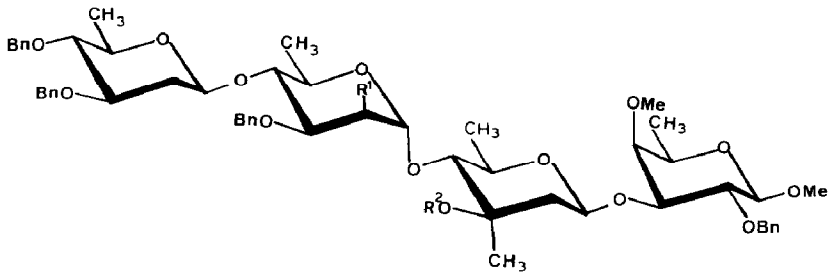
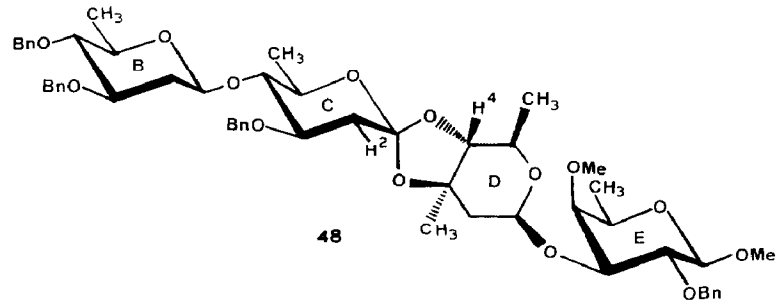
(1→4)-linkage, and 49% of **39** was recovered. The ^{1}H-n.m.r. spectrum of **41** contained signals at δ 5.52 (d, $J_{1,2}$ 2 Hz) and 4.02 (dd, $J_{2,3}$ 4.5 Hz) assigned to H-1 and H-2, respectively, of the C unit, thereby establishing the α-D-mannopyranosyl structure.

Compound **41** was debenzoylated (→**42**), then oxidized with sodium periodate in methanol–water to give, quantitatively, the selenoxide **43** as a mixture of diastereoisomers at selenium. Finally, when **43** was heated in a sealed tube for 18 h at 140° in 2:2:1 toluene–vinyl acetate–di-isopropylamine (vinyl derivatives[33] and secondary amines[34] are known to trap PhSeOH formed after elimination of the selenoxide), the spiro-ortholactone trisaccharide derivative **44** was obtained (76% from **41**). The excellent selectivity of this reaction was anticipated on the basis of previous results[2]. The ^{1}H-n.m.r. spectrum of **44** accorded with the structure, and the configuration of the spiro-center was deduced from the n.O.e. data, obtained by difference spectroscopy[35], which showed H-2*e*C and H-4D to be in close proximity.

Synthesis of a protected B–C–D–E tetrasaccharide fragment. — The disaccharide glycal **17** reacted with **39** in the presence of phenylselenenyl chloride and 2,4,6-trimethylpyridine in acetonitrile at room temperature for 45 h to give tetrasaccharide **45** (23% from **39**, 68% of which was recovered). The ^{1}H-n.m.r. spectrum of **45** contained signals at δ 5.56 (d, $J_{1,2}$ 4 Hz) and 4.10 (dd, $J_{2,3}$ 5.5 Hz) assigned to H-1 and H-2, respectively, of the C unit, which therefore has an α-D-mannopyranosyl configuration. Debenzoylation of **45** gave **46**, which was separated by column chromatography from a minor contaminant, possibly the isomeric tetrasaccharide with a *trans*-diequatorial new (1→4)-linkage. Oxidation of **46** with sodium periodate gave the selenoxide **47** as a mixture of diastereoisomers that was heated for 18 h at 140° in a sealed tube in 2:2:1



45 R^1 = SePh, R^2 = Bz
46 R^1 = SePh, R^2 = H
47 R^1 = SeOPh, R^2 = H



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toluene–vinyl acetate–di-isopropylamine to give the spiro-ortholactone tetrasaccharide derivative **48** (80%). Small amounts of **46** were also formed by reduction of **47** with phenylselenenic acid[36]. The excellent selectivity of this key reaction has been noted[2]. The ^{1}H-n.m.r. spectrum of **48** accorded with the structure, and n.O.e. data similar to those reported for **44** were observed.

The work now reported, together with previous work[2], augurs well for the total synthesis of orthosomycins. In view of the reported[37] efficiency of phenylselenenyl triflate compared with phenylselenenyl chloride in the glycosyloxyselenation step, this reagent is to be preferred.

EXPERIMENTAL

General methods. — Melting points were determined with a Büchi Model 510 capillary apparatus and are uncorrected. Optical rotations were measured at 20 $\pm 2°$ with a Perkin–Elmer Model 241 polarimeter. I.r. spectra were recorded with a Perkin–Elmer 599 spectrometer. C.i. (ammonia)-mass spectra were obtained with a Nermag R10-10 spectrometer. ^{1}H-N.m.r. spectra were recorded with a Cameca 250 and a Bruker AM-400 spectrometer for solutions in $CDCl_3$ or C_6D_6 (internal Me_4Si). Elemental analyses were performed at the University Pierre et Marie Curie (Paris VI). Reactions were monitored by t.l.c. on Silica Gel 60 F_{254} (Merck) and detection by charring with sulfuric acid. Flash-column chromatography[38] was performed on Silica Gel 60 (230–400 mesh, Merck).

Phenyl 2,3-di-O-benzyl-1-thio-β-D-glucopyranoside (**7**). — A suspension of phenyl 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside[10] (5.4 g, 10 mmol) in glacial acetic acid (60 mL) was heated at 100° until dissolution occurred. Water (40 mL) was added in portions with stirring at 100°, and the mixture was then heated for 30 min at 100°, cooled, and concentrated. The residue crystallized from dichloromethane–hexane to give **7** (4.07 g, 90%), m.p. 111–112°, $[\alpha]_D$ −25° (*c* 0.52, chloroform). ^{1}H-N.m.r. data (C_5D_5N): δ 7.82–7.11 (m, 15 H, 3 Ph), 5.25 and 5.09 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 5.22 (d, 1 H, $J_{1,2}$ 9.5 Hz, H-1), 5.02 and 4.92 (2 d, 2 H, J_{gem} 11 Hz, PhCH_2), 4.45–4.19 (m, 3 H, H-4,6a,6b), 3.98 (dd, 1 H, $J_{2,3} = J_{3,4}$ = 8.7 Hz, H-3), 3.83 (ddd, 1 H, $J_{4,5}$ 9.5, $J_{5,6a}$ 2, $J_{5,6b}$ 4.5 Hz, H-5), 3.73 (dd, 1 H, H-2).

Anal. Calc. for $C_{26}H_{28}O_5S$: C, 69.00; H, 6.24. Found: C, 68.92; H, 6.24.

Phenyl 2,3-di-O-benzyl-6-deoxy-6-iodo-1-thio-β-D-glucopyranoside (**8**). — A mixture of **7** (4.53 g, 10 mmol), triphenylphosphine (3.93 g, 15 mmol), imidazole (2.04 g, 30 mmol), and iodine (3.55 g, 14 mmol) in toluene (240 mL) was heated for 150 min at 70°. To the cooled mixture was added saturated aqueous sodium hydrogencarbonate (200 mL), followed, after stirring for 5 min, by 0.1 M sodium thiosulfate (5.3 mL). The mixture was stirred for 30 min and decanted, the water layer was extracted with ethyl acetate (2 × 25 mL), and the combined organic layers were dried and then concentrated. Column chromatography (5:1 hexane–ethyl acetate) of the residue gave **8** (5.06 g, 90%), m.p. 114–116° (from ethyl acetate–hexane), $[\alpha]_D$ −38° (*c* 1.15, chloroform). ^{1}H-N.m.r. data (C_6D_6): δ 7.88–7.04 (m, 15 H, 3 Ph), 5.00 and 4.65 (2 d, 2 H, J_{gem} 10.5 Hz, PhCH_2), 4.87 and 4.60 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.56 (d, 1 H, $J_{1,2}$ 9.5 Hz, H-1), 3.53–3.43 (m, 1 H, H-2), 3.38–3.25 (m, 3 H, H-3,4,6a), 3.13 (dd, 1 H, $J_{5,6b}$ 6, $J_{6a,6b}$ 10.5 Hz, H-6b), 2.65 (ddd, 1 H, $J_{4,5}$ 9, $J_{5,6a}$ 2.5 Hz, H-5), 1.86 (m, 1 H, HO-4).

Anal. Calc. for $C_{24}H_{27}IO_4S$: C, 55.52; H, 4.84. Found: C, 55.73; H, 4.88.

Phenyl 2,3-di-O-benzyl-6-deoxy-1-thio-β-D-glucopyranoside (**9**). — (*a*) A solution of **8** (5.62 g, 10 mmol) in ethyl acetate (140 mL) containing diethylamine (2.1 mL, 20 mmol) was hydrogenated at room temperature and atmospheric pressure in the presence of 10% Pd–C (0.34 g) for 18 h, then filtered, and concentrated to give **9** (4.37 g, 100%). An analytical sample of **9**, obtained by column chromatography (4:1 hexane–acetone), had m.p. 89–90° (from dichloromethane–hexane), $[\alpha]_D$ −31° (*c* 1.45, chloroform). ^{1}H-N.m.r. data (C_6D_6): 7.67–6.92 (m, 15 H, 3 Ph), 4.98 and 4.64 (2 d, 2 H, J_{gem} 10.5 Hz, PhCH_2), 4.85 and 4.60 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.61 (d, 1 H, $J_{1,2}$ 9.5 Hz, H-1), 3.49 (dd, 1 H, $J_{2,3}$ 8.5 Hz, H-2), 3.31 (dd, 1 H, $J_{3,4}$ 8.5 Hz, H-3), 3.13 (ddd, 1 H, $J_{4,5}$ 8.5, $J_{4,OH}$ 2 Hz, H-4), 3.05 (dq, 1 H, $J_{5,Me}$ 6 Hz, H-5), 1.78 (d, 1 H, HO-4), 1.26 (d, 3 H, H-6,6,6).

Anal. Calc. for $C_{26}H_{28}O_4S$: C, 71.53; H, 6.46. Found: C, 71.65; H, 6.55.

(*b*) A solution of **8** (562 mg, 1 mmol) in toluene (20 mL) was added dropwise to a refluxing solution of tributylstannane (0.28 mL, 1.06 mmol) and α,α′-azobisisobutyronitrile (16 mg) in toluene (20 mL). After boiling for 4 h under reflux, t.l.c. (6:1 hexane–acetone) showed traces of **9**, a major product (R_F 0.32), and several polar compounds. Column chromatography (6:1 hexane–ethyl acetate) gave 1,4-anhydro-2,3-di-*O*-benzyl-6-deoxy-6-phenylthio-α-D-glucopyranoside (**10**; 130 mg, 30%). ^{1}H-

N.m.r. data (C_6D_6): δ 7.38–7.01 (m, 15 H, 3 Ph), 5.60 (s, 1 H, H-1), 4.61 (dd, 1 H, $J_{3,4}$ 4.5, $J_{4,5}$ 3 Hz, H-4), 4.50 and 4.36 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.37 and 4.30 (2 d, 2 H, J_{gem} 12 Hz, PhCH_2), 4.37 (m, 1 H, H-5), 4.16 (m, 1 H, H-3), 3.85 (d, 1 H, $J_{2,3}$ 2.5 Hz, H-2), 3.72 (dd, 1 H, $J_{5,6a}$ 8.5, $J_{6a,6b}$ 13.5 Hz, H-6a), 3.62 (dd, 1 H, $J_{5,6b}$ 7 Hz, H-6b). Mass spectrum: m/z 452 (M^+ + 18), 435 (M^+ + 1).

1,2-Di-O-acetyl-3,4-di-O-benzyl-6-deoxy-β-D-glucopyranose (**14**). — *N,N*-Dimethylformamide diethyl acetal (2 mL, 12 mmol) was added under argon at room temperature to a solution of 2,3,4-tri-*O*-acetyl-6-deoxy-α-D-glucopyranosyl bromide[15] (**1**; 3.53 g, 10 mmol) and tetrabutylammonium bromide (3.22 g, 10 mmol) in dry 1,2-dichloroethane (35 mL) containing activated powdered molecular sieves (4 Å, 3 g). The mixture was heated for 160 min at 40°, more *N,N*-dimethylformamide diethyl acetal (0.5 mL, 3 mmol) was added, and stirring was continued for 90 min at 80°. T.l.c. (97:3 dichloromethane–acetone) then showed the complete conversion of **11** (R_F 0.56) into **12** (R_F 0.52). The mixture was cooled to room temperature, filtered, washed with water, dried ($MgSO_4$), and concentrated to dryness to give **12** (3.2 g, ~100%). ^{1}H-N.m.r. data ($CDCl_3$): δ 5.74 (d, 1 H, $J_{1,2}$ 5.5 Hz, H-1), 5.20 (dd, 1 H, $J_{2,3}$ 3.5, $J_{3,4}$ 3 Hz, H-3), 4.74 (ddd, 1 H, $J_{2,4}$ 0.5, $J_{4,5}$ 9.5 Hz, H-4), 4.34 (ddd, 1 H, H-2), 3.87 (dq, 1 H, $J_{5,Me}$ 6.5 Hz, H-5), 3.58 (q, 2 H, J 7 Hz, CH_3CH_2), 2.13 and 2.12 (2 s, each 3 H, 2 OAc), 1.74 (s, 3 H, CH_3C exo), 1.27 (d, 3 H, H-6,6,6), 1.20 (t, 3 H, CH_3CH_2).

A solution of **12** (3.2 g) in dry methanol (100 mL) was treated with methanolic M sodium methoxide (10 mL) for 1 h at room temperature, then concentrated, and toluene was evaporated several times from the residue. To a solution of the residue in dry *N,N*-dimethylformamide (30 mL) at 0° was added sodium hydride (1.6 g, of a 60% dispersion in oil). The mixture was stirred for 1 h at room temperature, cooled to 0°, benzyl bromide (4 mL, 34 mmol) was added, and stirring was continued for 1 h at room temperature. Methanol was added to decompose the excess of sodium hydride, the mixture was concentrated, and a solution of the residue in dichloromethane was washed with water and then concentrated. Column chromatography (97:2:1 toluene–ethyl acetate–triethylamine) of the residue removed benzyl methyl ether, but failed to give an analytical sample of **13** (3.3 g, 80%). ^{1}H-N.m.r. ($CDCl_3$): δ 7.42–7.25 (m, 10 H, 2 Ph), 5.69 (d, 1 H, $J_{1,2}$ 5.5 Hz, H-1), 4.73 and 4.46 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.62 (m, 2 H, PhCH_2), 4.42 (ddd, 1 H, $J_{2,3}$ 3.5, $J_{2,4}$ 0.5 Hz, H-2), 3.85 (dd, 1 H, $J_{3,4}$ 4 Hz, H-3), 3.75 (dq, 1 H, $J_{4,5}$ 9, $J_{5,Me}$ 6 Hz, H-5), 3.62–3.49 (m, 2 H, CH_3CH_2), 3.26 (ddd, 1 H, H-4), 1.66 (s, 3 H, CH_3C exo), 1.28 (d, 3 H, H-6,6,6), 1.19 (t, 3 H, CH_3CH_2). Mass spectrum: m/z 432 (M^+ + 18), 369 (M^+ − OEt).

Compound **13** (3.3 g) was treated with glacial acetic acid (40 mL) for 1 h at room temperature, as described[6], to give **14** (3.14 g, 92%).

Methyl 6-deoxy-6-iodo-3,4-O-isopropylidene-β-D-galactopyranoside (**19**). — A mixture of methyl 3,4-*O*-isopropylidene-β-D-galactopyranoside[19] (**18**; 2.34 g, 10 mmol), triphenylphosphine (3.93 g, 15 mmol), imidazole (2.04 g, 30 mmol), and iodine (3.55 g, 14 mmol) in toluene (240 mL) was heated for 5 h at 75°, then worked-up as described for the preparation of **8**. Column chromatography (2:1 hexane–ethyl acetate) of the product gave **19** (2.37 g, 69%), m.p. 122° (from di-isopropyl ether), $[\alpha]_D$ +31° (*c* 1.1,

chloroform). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.32 (dd, 1 H, $J_{3,4}$ 5.5, $J_{4,5}$ 2.5 Hz, H-4), 4.09 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 4.09 (dd, 1 H, $J_{2,3}$ 7.5 Hz, H-3), 3.92 (ddd, $J_{5,6a}$ 7.5, $J_{5,6b}$ 6.5 Hz, H-5), 3.59 (s, 3 H, OMe), 3.54 (m, 1 H, H-2), 3.43 (m, 2 H, H-6a,6b), 2.48 (bd, 1 H, OH), 1.51 and 1.35 (2 s, each 3 H, CMe_2).

Anal. Calc. for $C_{10}H_{17}IO_5$: C, 34.89; H, 4.98. Found: C, 34.94; H, 5.02.

*Methyl 6-deoxy-3,4-O-isopropylidene-β-*D*-galactopyranoside* (**20**). — A solution of **19** (3.44 g, 10 mmol) in 1:1 hexane–ethyl acetate (140 mL) containing diethylamine (2.1 mL, 20 mmol) was hydrogenated at room temperature and atmospheric pressure in the presence of 10% Pd–C (0.34 g) for 19 h. The mixture was filtered through Celite and concentrated, and the residue was crystallized from di-isopropyl ether to give **20** (1.96 g, 90%), m.p. 40–50° (sublimation), $[\alpha]_D$ +24° (*c* 1, chloroform); lit.[20] m.p. 64–66°, $[\alpha]_D$ +24.5° (*c* 0.96, chloroform); lit.[21] m.p. 56–58°, $[\alpha]_D$ +16° (chloroform). ^{1}H-N.m.r. data ($CDCl_3$): δ 4.12–3.99 (m, 3 H, H-1,3,4), 3.87 (m, 1 H, $J_{4,5}$ 2, $J_{5,Me}$ 6.5 Hz, H-5), 3.54 (s, 3 H, OMe), 3.52 (m, 1 H, H-2), 2.60 (d, 1 H, OH), 1.53 and 1.36 (2 s, each 3 H, CMe_2), 1.42 (d, 3 H, H-6,6,6).

*Methyl 2-O-benzyl-6-deoxy-β-*D*-galactopyranoside* (**22**). — A solution of **20** (2.18 g, 10 mmol) in *N,N*-dimethylformamide (7 mL) was treated at 0° with sodium hydride (0.8 g of a 60% dispersion in oil, 20 mmol). The mixture was stirred for 30 min at room temperature, cooled to 0°, benzyl bromide (1.8 mL, 15 mmol) was added, and the mixture was stirred at room temperature for 2 h. Methanol was added to decompose the excess of hydride, the mixture was concentrated, and a solution of the residue in dichloromethane was washed with water, dried ($MgSO_4$), and concentrated. A portion of crude **21** was purified by column chromatography (4:1 hexane–acetone). ^{1}H-N.m.r. data ($CDCl_3$): δ 7.42–7.19 (m, 5 H, Ph), 4.82 and 4.75 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.18 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 4.12 (dd, 1 H, $J_{2,3}$ 7, $J_{3,4}$ 5.5 Hz, H-3), 3.97 (dd, 1 H, $J_{4,5}$ 2.5 Hz, H-4), 3.81 (m, 1 H, $J_{5,Me}$ 6.5 Hz, H-5), 3.53 (s, 3 H, OMe), 3.36 (dd, 1 H, H-2), 1.40 (d, 3 H, H-6,6,6), 1.36 and 1.33 (2 s, each 3 H, CMe_2).

A solution of the bulk of the crude **21** in aqueous 60% acetic acid (20 mL) was heated for 2 h at 90°, then cooled, and concentrated. Column chromatography (7:3 hexane–acetone) of the residue gave **22** (1.95 g, 73%), $[\alpha]_D$ +33° (*c* 1, chloroform); lit.[20] +35.9° (*c* 0.75, chloroform); lit.[21] +213° (chloroform). ^{1}H-N.m.r. data ($CDCl_3$): δ 7.39–7.21 (m, 5 H, Ph), 4.90 and 4.66 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.21 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 3.63 (dd, 1 H, $J_{3,4}$ 3.5, $J_{4,5}$ 0.5 Hz, H-4), 3.56 (dd, 1 H, $J_{2,3}$ 9.5 Hz, H-3), 3.52 (s, 3 H, OMe), 3.42 (dd, 1 H, H-2), 3.09 (bd, 2 H, 2 OH), 1.30 (d, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6).

*Methyl 2-O-benzyl-6-deoxy-3-O-p-methoxybenzyl-4-O-methyl-β-*D*-galactopyranoside* (**24**). — A mixture of **22** (2.68 g, 10 mmol) and dibutyltin oxide (3.00 g, 12 mmol) in dry acetonitrile (50 mL) was heated for 4 h under reflux in the presence of activated powdered molecular sieves (4 Å, 6 g), then cooled to 0° under argon. Tetrabutylammonium iodide (3.69 g, 10 mmol) and *p*-methoxybenzyl bromide[39] (1.7 mL, 11.8 mmol) were added, and the mixture was allowed to reach room temperature, then, after 1 h, filtered through Celite, and concentrated. Column chromatography (3:1 hexane–acetone) of the residue gave **23** (3.69 g, 95%), isolated as an oil. A solution of **23** (3.69 g) in dry tetrahydrofuran (40 mL) was treated at 0° with sodium hydride (760 mg of a 60%

dispersion in oil, 19 mmol). The mixture was stirred for 1 h at room temperature under argon, methyl iodide (2.4 mL, 39 mmol) was added, and the mixture was heated for 30 min at 40°, then cooled at 0°. Methanol was added to decompose the excess of sodium hydride, the solution was concentrated, and a solution of the residue in dichloromethane was washed with saturated aqueous ammonium chloride and then water, dried ($MgSO_4$), and concentrated to dryness. T.l.c. (3:1 hexane–acetone) showed the residue (3.80 g, ~100%) to be pure enough to be used in the following step. An analytical sample of **24**, obtained by column chromatography (4:1 hexane–acetone), had m.p. 60–61° (from hexane), $[\alpha]_D$ +3° (*c* 1.05, chloroform). ^{1}H-N.m.r. data ($CDCl_3$): δ 7.48–6.90 (m, 9 H, aromatic), 4.91 and 4.76 (2 d, 2 H, J_{gem} 11 Hz, PhCH_2), 4.75 and 4.68 (2 d, 2 H, J_{gem} 12 Hz, PhCH_2), 4.23 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 3.83, 3.64, and 3.55 (3 s, each 3 H, 3 OMe), 3.68 (dd, 1 H, $J_{2,3}$ 10 Hz, H-2), 3.47 (dd, 1 H, $J_{3,4}$ 3 Hz, H-3), 3.47 (m, 1 H, H-5), 3.27 (dd, 1 H, $J_{4,5}$ 0.5 Hz, H-4), 1.31 (d, 3 H, $J_{5,Me}$ 6.3 Hz, H-6,6,6).

Anal. Calc. for $C_{23}H_{30}O_6$: C, 68.62; H, 7.52. Found: C, 68.70; H, 7.51.

*Methyl 2-O-benzyl-6-deoxy-4-O-methyl-β-*D*-galactopyranoside* (**25**). — To a solution of **24** (4 g, 10 mmol) in 18:1 dichloromethane–water (40 mL) was added 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (2.27 g, 10 mmol). The mixture was stirred for 2 h at room temperature, then filtered, and decanted. The organic layer was washed with saturated aqueous sodium hydrogencarbonate, dried ($MgSO_4$), and concentrated. Column chromatography (4:1 hexane–acetone) of the residue gave **25** (2.48 g, 88%), m.p. 109–110° (from di-isopropyl ether), $[\alpha]_D$ +14° (*c* 1, chloroform). ^{1}H-N.m.r. data ($CDCl_3$): δ 7.48–7.28 (m, 5 H, Ph), 4.98 and 4.69 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.23 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 3.71–3.51 (m, 2 H, H-3,5), 3.62 and 3.55 (2 s, each 3 H, 2 OMe), 3.46 (dd, 1 H, $J_{2,3}$ 10 Hz, H-2), 3.31 (dd, 1 H, $J_{3,4}$ 3, $J_{4,5}$ 0.5 Hz, H-4), 2.41 (bd, 1 H, OH), 1.34 (d, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6); ^{1}H ($CDCl_3$ + CCl_3CONCO)[24], δ 8.38 (bd, 1 H, NH), 7.43–7.27 (m, 5 H, Ph), 4.94 (dd, 1 H, $J_{2,3}$ 10.5, $J_{3,4}$ 3.5 Hz, H-3), 4.92 and 4.64 (2 d, 2 H, J_{gem} 12 Hz, PhCH_2), 4.34 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 3.69 (dd, 1 H, H-2), 3.69–3.45 (m, 2 H, H-4,5), 3.58 and 3.54 (2 s, each 3 H, 2 OMe), 1.34 (s, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6).

Anal. Calc. for $C_{15}H_{22}O_5$: C, 63.79; H, 7.86. Found: C, 63.54; H, 7.74.

*Methyl 2-O-benzyl-6-deoxy-3-O-(2-deoxy-β-*D*-arabino-hexopyranosyl)-4-O-methyl-β-*D*-galactopyranoside* (**27**). — A solution of **26** (ref. 6) (555 mg, 1 mmol) in dry methanol (10 mL) was treated for 90 min at room temperature with methanolic M sodium methoxide (1 mL). T.l.c. (3:3:1 2-propanol–ethyl acetate–water) then showed the reaction to be complete. The mixture was neutralized with Amberlite IR-120 (H^+) resin, filtered, and concentrated to dryness to give **27** (416 mg, 97%). An analytical sample, obtained by column chromatography (3:2 acetone–chloroform), had m.p. 155–157° (from dichloromethane–hexane), $[\alpha]_D$ −25° (*c* 1.1, chloroform). ^{1}H-N.m.r. data (C_5D_5N): δ 7.63–7.20 (m, 5 H, Ph), 5.28 (dd, 1 H, $J_{1',2'e}$ 2, $J_{1',2'a}$ 10 Hz, H-1'), 5.05 and 4.80 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.57 (dd, 1 H, $J_{5',6'a}$ 2.5, $J_{6'a,6'b}$ 12 Hz, H-6'a), 4.42 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 4.37 (dd, 1 H, $J_{5',6'b}$ 6 Hz, H-6'b), 4.20–3.92 (m, 4 H), 3.80 (ddd, 1 H, $J_{4',5'}$ 12 Hz, H-5'), 3.68 and 3.52 (2 s, each 3 H, 2 OMe), 3.65 (dd, 1 H, $J_{3,4}$ 3.5, $J_{4,5}$ 0.5 Hz, H-4), 3.52 (m, 1 H), 2.70 (ddd, 1 H, $J_{2'e,3'}$ 5, $J_{2'e,2'a}$ 12.5 Hz, H-2'*e*), 2.16 (ddd, 1 H, $J_{2'a,3'}$ 9.5 Hz, H-2'*a*), 1.22 (d, 1 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6). Mass spectrum: *m/z* 446 (M^+ + 18).

Anal. Calc. for $C_{21}H_{32}O_9$: C, 58.87; H, 7.53. Found: C, 58.82; H, 7.47.

*Methyl-2-O-benzyl-3-O-(4,6-O-benzylidene-2-deoxy-β-*D-arabino-*hexopyranosyl)-6-deoxy-4-O-methyl-β-*D-*galactopyranoside* (**28**). — A mixture of **27** (428 mg, 1 mmol), *α,α*-dimethoxytoluene (0.2 mL, 1.3 mmol), and (±)-camphor-10-sulfonic acid (23 mg, 0.1 mmol) in dry *N,N*-dimethylformamide (12 mL) was heated for 3 h at 80° under vacuum (~7 kPa), then cooled to room temperature, neutralized with triethylamine, and concentrated at 40° at ~100 Pa. Column chromatography (24:1 chloroform–acetone) of the residue gave **28** (496 mg, 96%), m.p. 204–205° (from hexane–acetone), $[\alpha]_D$ −33° (*c* 0.9, chloroform). ^{1}H.N.m.r. data ($CDCl_3$): *δ* 7.61–7.33 (m, 10 H, 2 Ph), 5.59 (s, 1 H, PhC*H*), 4.96 and 4.66 (2 d, 2 H, J_{gem} 11 Hz, PhCH_2), 4.90 (dd,1 H, $J_{1',2'e}$ 2, $J_{1',2'a}$ 9.5 Hz, H-1′), 4.33 (dd, 1 H, $J_{5',6'a}$ 5, $J_{6'a,6'b}$ 10.5 Hz, H-6′a), 4.26 (d, 1 H, $J_{1,2}$ 7 Hz, H-1), 3.80 (dd, 1 H, $J_{5',6'b}$ 10.5 Hz, H-6′b), 3.64 and 3.59 (2 s, each 3 H, 2 OMe), 3.46 (dd, 1 H, $J_{4',5'}$ 9.5 Hz, H-4′), 3.37 (dd, 1 H, $J_{3,4}$ 3, $J_{4,5}$ 0.5 Hz, H-4), 3.32 (ddd, 1 H, H-5′), 2.56 (s, 1 H, OH), 2.30 (ddd, 1 H, $J_{2'e,3'}$ 5.5, $J_{2'e,2'a}$ 13 Hz, H-2′*e*), 1.71 (ddd, 1 H, $J_{2'a,3'}$ 11.5 Hz, H-2′*a*), 1.33 (d, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6).

Anal. Calc. for $C_{28}H_{36}O_9$: C, 65.10; H, 7.02. Found: C, 64.84; H, 6.99.

*Methyl 2-O-benzyl-3-O-(4,6-O-benzylidene-2-deoxy-β-*D-erythro-*hexopyranosyl-3-ulose)-6-deoxy-4-O-methyl-β-*D-*galactopyranoside* (**29**). — A solution of **28** (517 mg, 1 mmol) in dry dichloromethane (15 mL) was stirred for 1 h at room temperature under argon in the presence of activated powdered molecular sieves (4 Å, 1 g). Pyridinium chlorochromate (323 mg, 1.5 mmol) was then added and the mixture was stirred at room temperature under argon. After 2 h, t.l.c. (47:3 chloroform–acetone) revealed a new compound (R_F 0.51 with streaking) and **28** (R_F 0.15). More pyridinium chlorochromate (323 mg, 1.5 mmol) was added and stirring was continued for 90 min. The mixture was poured directly on to the top of a column of silica gel, and **29** (458 mg, 89%), eluted with 99:1 chloroform–acetone, had m.p. 205–207° (from dichloromethane–hexane), $[\alpha]_D$ 0° (*c* 1, chloroform); ν_{max} 1740 cm^{-1} (C=O). ^{1}H-N.m.r. data ($CDCl_3$): *δ* 7.57–7.29 (m, 10 H, 2 Ph), 5.59 (s, 1 H, PhC*H*), 5.12 (dd, 1 H, $J_{1',2'e}$ 3.5, $J_{1',2'a}$ 9 Hz, H-1′), 4.88 and 4.58 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.43 (dd, 1 H, $J_{5',6'a}$ 5, $J_{6'a,6'b}$ 10.5 Hz, H-6′a), 4.29 (dd, 1 H, $J_{2'a,4'}$ 1, $J_{4',5'}$ 10 Hz, H-4′), 4.22 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 3.88 (dd, 1 H, $J_{5',6'b}$ 10 Hz, H-6′b), 3.74 (dd, 1 H, $J_{2,3}$ 10.5, $J_{3,4}$ 3 Hz, H-3), 3.61 and 3.54 (2 s, each 3 H, 2 OMe), 3.36 (dd, 1 H, $J_{4,5}$ 0.5 Hz, H-4), 2.79 (dd, 1 H, $J_{2'e,2'a}$ 15 Hz, H-2′*e*), 2.67 (ddd, 1 H, H-2′*a*), 1.31 (d, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6).

Anal. Calc. for $C_{28}H_{34}O_9$: C, 65.36; H, 6.66. Found: C, 65.35; H, 6.68.

*Methyl 2-O-benzyl-3-O-(4,6-O-benzylidene-2,3-dideoxy-3-C-methylene-β-*D-erythro-*hexopyranosyl)-6-deoxy-4-O-methyl-β-*D-*galactopyranoside* (**32**). — To a solution of **29** (515 mg, 1 mmol) in dry tetrahydrofuran (25 mL) at −40° was added under argon 0.8M Tebbe's reagent[30] in toluene (1.3 mL) [prepared from titanocene dichloride (249 mg, 1 mmol) and trimethylaluminium (216 mg, 3 mmol)]. T.l.c. (24:1 chloroform–acetone) showed the immediate disappearance of **29** (R_F 0.33) and the formation of **32** (R_F 0.48). The mixture was allowed to attain −15°, then diluted with tetrahydrofuran (20 mL), treated dropwise with 4M sodium hydroxide (0.8 mL), and filtered through Celite. The insoluble material was thoroughly washed with ether, and the combined

filtrate and washings were concentrated. Column chromatography (9:1 toluene–ethyl acetate) of the residue gave **32** (461 mg, 90%), m.p. 181–182° (from dichloromethane–hexane), $[\alpha]_D$ +3° (*c* 0.9, chloroform). ^{1}H-N.m.r. data (C_6D_6): δ 7.77–7.14 (m, 10 H, 2 Ph), 5.46 (s, 1 H, PhC*H*), 5.38 and 4.86 (2 d, 2 H, J_{gem} 2 Hz, CH_2=), 5.11 and 4.65 (2 d, 2 H, J_{gem} 12 Hz, PhCH_2), 4.93 (dd, 1 H, $J_{1',2'e}$ 2.5, $J_{1',2'a}$ 9.5 Hz, H-1'), 4.24 (d, 1 H, $J_{1,2}$ 8 Hz, H-1), 4.22 (dd, 1 H, $J_{5',6'a}$ 5, $J_{6'a,6'b}$ 10 Hz, H-6'a), 4.01 (dd, 1 H, $J_{2,3}$ 10 Hz, H-2), 3.78 (d, 1 H, $J_{4',5'}$ 9.5 Hz, H-4'), 3.70 (dd, 1 H, $J_{3,4}$ 3 Hz, H-3), 3.63 and 3.43 (2 s, each 3 H, 2 OMe), 3.63 (m, 1 H, H-5'), 3.32 (dd, 1 H, $J_{5',6'b}$ 5 Hz, H-6'b), 3.27 (dd, 1 H, $J_{4,5}$ 0.5 Hz, H-4), 3.19 (dq, 1 H, $J_{5,Me}$ 6.5 Hz, H-5), 2.64 (dd, 1 H, $J_{2'e,2'a}$ 13.5 Hz, H-2'*e*), 2.44 (dd, 1 H, H-2'*a*), 1.24 (d, 3 H, H-6,6,6). Mass spectrum: *m/z* 530 (M^+ + 18), 282 (**25**$^+$).

Anal. Calc. for $C_{29}H_{36}O_8$: C, 67.95; H, 7.08. Found: C, 68.06; H, 6.92.

With >2 equiv. of Tebbe's reagent, methyl 2-*O*-benzyl-3-*O*-(4,6-*O*-benzylidene-2,3-dideoxy-3,3-di-*C*-methyl-*β*-D-*erythro*-hexopyranosyl)-6-deoxy-4-*O*-methyl-*β*-D-galactopyranoside (**33**) was isolated (82%), $[\alpha]_D$ −44° (*c* 0.23, chloroform). ^{1}H-N.m.r. data ($CDCl_3$): δ 7.57–7.30 (m, 10 H, 2 Ph), 5.56 (s, 1 H, PhC*H*), 5.02 (dd, 1 H, $J_{1',2'e}$ 2.5, $J_{1',2'a}$ 10 Hz, H-1'), 4.94 and 4.65 (2 d, 2 H, J_{gem} 11 Hz, PhCH_2), 4.28 (dd, 1 H, $J_{5',6'a}$ 4.5, $J_{6'a,6'b}$ 10 Hz, H-6'a), 4.24 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 3.79–3.51 (m, 5 H, H-2,3,5,5',6'b), 3.63 and 3.57 (2 s, each 3 H, 2 OMe), 3.36 (dd, 1 H, $J_{3,4}$ 3, $J_{4,5}$ 0.5 Hz, H-4), 3.31 (d, 1 H, $J_{4',5'}$ 9 Hz, H-4'), 1.78 (dd, 1 H, $J_{2'e,2'a}$ 14 Hz, H-2'*e*), 1.56 (dd, 1 H, H-2'*a*), 1.32 (d, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6), 1.08 and 1.02 (2 s, each 3 H, CMe_2). Mass spectrum: *m/z* 546 (M^+ + 18).

Anal. Calc. for $C_{30}H_{40}O_8$: C, 68.16; H, 7.63. Found: C, 68.07; H, 7.42.

*Methyl 2-O-benzyl-3-O-(4,6-O-benzylidene-2-deoxy-3-C-methyl-β-*D-ribo- *and -β-*D-arabino-*hexopyranosyl)-6-deoxy-4-O-methyl-β-*D-*galactopyranoside* (**30** *and* **31**). — (*a*) To a solution of **29** (515 mg, 1 mmol) in dry ether (60 mL) at −78° under argon was added 1.6M methyl-lithium in ether (2 mL), and the mixture was allowed to reach room temperature slowly. T.l.c. (97:3 chloroform–acetone) then showed two new compounds (R_F 0.10 and 0.24) and no **29** (R_F 0.29). The mixture was poured into cold saturated aqueous ammonium chloride and decanted, the water layer was extracted with ether, and the combined organic layers were dried ($MgSO_4$) and concentrated. Column chromatography of the residue, first with 4:1 hexane–acetone, gave **30** (265 mg, 50%), $[\alpha]_D$ −22° (*c* 0.65, chloroform). ^{1}H-N.m.r. data ($CDCl_3$): δ 7.60–7.22 (m, 10 H, 2 Ph), 5.66 (s, 1 H, PhC*H*), 5.27 (dd, 1 H, $J_{1',2'e}$ 2, $J_{1',2'a}$ 9.5 Hz, H-1'), 4.89 and 4.71 (2 d, 2 H, J_{gem} 11 Hz, PhCH_2), 4.34 (dd, 1 H, $J_{5',6'a}$ 4.5, $J_{6'a,6'b}$ 10 Hz, H-6'a), 4.25 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 3.92 (ddd, 1 H, $J_{4',5'}$ 9, $J_{5',6'b}$ 10 Hz, H-5'), 3.78 (dd, 1 H, H-6'b), 3.73 (dd, 1 H, $J_{2,3}$ 10, $J_{3,4}$ 3 Hz, H-3), 3.62 and 3.57 (2 s, each 3 H, 2 OMe), 3.44 (d, 1 H, H-4'), 3.38 (dd, 1 H, $J_{4,5}$ 0.5 Hz, H-4), 2.17 (dd, 1 H, $J_{2'e,2'a}$ 14 Hz, H-2'*e*), 1.97 (d, 1 H, $J_{2'a,OH}$ 2 Hz, OH), 1.67 (ddd, 1 H, H-2'*a*), 1.34 (s, 3 H, CMe), 1.32 (d, 3 H, $J_{5,Me}$ 6 Hz, H-6,6,6). Mass spectrum: *m/z* 548 (M^+ + 18).

Anal. Calc. for $C_{29}H_{38}O_9 \cdot 0.5H_2O$: C, 64.55; H, 7.28. Found: C, 64.37; H, 7.35.

Elution with 3:1 hexane–acetone then gave **31** (255 mg, 48%), $[\alpha]_D$ −25° (*c* 0.93, chloroform). ^{1}H-N.m.r. data (C_6D_6): δ 7.66–7.14 (m, 10 H, 2 Ph), 5.36 (s, 1 H, PhC*H*), 5.09 and 4.54 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.96 (dd, 1 H, $J_{1',2'e}$ 3, $J_{1',2'a}$ 10 Hz, H-1'), 4.28 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 4.22 (dd, 1 H, $J_{5',6'a}$ 5, $J_{6'a,6'b}$ 10.5 Hz, H-6'a), 4.01 (dd, 1 H,

$J_{2,3}$ 10 Hz, H-2), 3.78 (dd, 1 H, $J_{3,4}$ 3 Hz, H-3), 3.61 and 3.42 (2 s, each 3 H, 2 OMe), 3.28 (dd, 1 H, $J_{4,5}$ 0.5 Hz, H-4), 3.21 (m, 1 H, H-5'), 2.17 (dd, 1 H, $J_{2'e,2'a}$ 13 Hz, H-2'*e*), 2.05 (dd, 1 H, H-2'*a*), 1.24 (d, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6), 1.10 (s, 3 H, CMe). Mass spectrum: *m/z* 548 ($M^+ + 18$).

Anal. Calc. for $C_{29}H_{38}O_9 \cdot H_2O$: C, 63.49; H, 7.35. Found: C, 63.13; H, 7.39.

(*b*) 0.3M Diazomethane in ether (5 mL, prepared from *N*-nitroso-*N*-methyl-4-toluenesulfonamide) was added dropwise at 0° to a solution of **29** (515 mg, 1 mmol) in aqueous 95% ethanol. The mixture was brought to room temperature and left for a few hours until the yellow colour disappeared. T.l.c. (19:1 toluene–methanol) then showed complete conversion of **29** (R_F 0.28) into a mixture of epoxides (R_F 0.35). The solution was concentrated to dryness and a solution of the residue in dry tetrahydrofuran (70 mL) was treated at room temperature under argon with lithium aluminium hydride (95 mg, 2.5 mmol) for 15 min. The mixture was cooled to 0°, ethyl acetate and then water were added to decompose the excess of hydride, the organic solvents were evaporated, and the aqueous residue was extracted with dichloromethane. The extract was washed with water until neutral, then dried ($MgSO_4$), and concentrated. Column chromatography (4:1 hexane–acetone) of the residue gave **30** (450 mg, 85%) and **31** (41 mg, 8%).

(*c*) A solution of **32** (513 mg, 1 mmol) in 3:1 tetrahydrofuran–water (35 mL) was treated at room temperature with mercury(II) acetate (351 mg, 1.1 mmol) for 14 h. Water (20 mL) was added and the mixture was stirred for a further 2 h. T.l.c. (24:1 chloroform–acetone) then showed only material at R_F 0 (**32** has R_F 0.55). 3M Sodium hydroxide (2.8 mL) and then 0.5M sodium borohydride in 3M sodium hydroxide (4.5 mL) were added. The mixture was stirred for 10 min at room temperature, then filtered through Celite, washed with aqueous ammonium chloride and then water, dried ($MgSO_4$), and concentrated. Column chromatography (4:1 hexane–acetone) of the residue gave **30** (135 mg, 25%) and **31** (284 mg, 54%).

Methyl 3-O-(3-O-benzoyl-4,6-O-benzylidene-2-deoxy-3-C-methyl-β-D-arabino-hexopyranosyl)-2-O-benzyl-6-deoxy-4-O-methyl-β-D-galactopyranoside (**34**). — To a solution of **31** (531 mg, 1 mmol) in dry tetrahydrofuran (45 mL) at −10° under argon was added potassium hydride (400 mg of a 20% dispersion in oil, 2 mmol). The mixture was stirred for 1 h at room temperature, benzoyl chloride (0.14 mL, 1.2 mmol) was added, and more benzoyl chloride (0.08, 0.2, and 0.2 mL) was added after 15, 30, and 45 min, respectively. T.l.c. (3:1 hexane–acetone) then showed a new compound (R_F 0.33) and traces of **31** (R_F 0.19). The mixture was diluted with tetrahydrofuran, then cooled to −50°. Methanol was added to decompose the excess of potassium hydride, followed by saturated aqueous ammonium chloride. The mixture was brought to room temperature, the organic solvents were evaporated, the aqueous residue was extracted with dichloromethane, and the extract was washed with water, dried ($MgSO_4$), and concentrated. Column chromatography (4:1 hexane–acetone) of the residue gave **34** (590 mg, 93%), m.p. 130–131° (from hexane), $[\alpha]_D$ −40° (*c* 0.95, chloroform). ^{1}H-N.m.r. data ($CDCl_3$): δ 8.10–7.22 (m, 15 H, 3 Ph), 5.72 (s, 1 H, PhC*H*), 4.99 (dd, 1 H, $J_{1',2'e}$ 2, $J_{1',2'a}$ 10 Hz, H-1'), 4.97 and 4.65 (2 d, 2 H, J_{gem} 11 Hz, PhCH_2), 4.36 (dd, 1 H, $J_{5',6'a}$ 5, $J_{6'a,6'b}$ 10.5 Hz, H-6'a), 4.26 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 4.13 (d, 1 H, $J_{4',5'}$ 9.5 Hz, H-4'), 3.85 (dd, 1 H,

$J_{5',6'b}$ 10 Hz, H-6'b), 3.77 (dd, 1 H, $J_{2,3}$ 10, $J_{3,4}$ 3 Hz, H-3), 3.68 (dd, 1 H, H-2), 3.64–3.46 (m, 2 H, H-5,5'), 3.61 and 3.59 (2 s, each 3 H, 2 OMe), 3.34 (dd, 1 H, $J_{4,5}$ 0.5 Hz, H-4), 3.16 (dd, 1 H, $J_{2'e,2'a}$ 13 Hz, H-2'*e*), 2.19 (dd, 1 H, H-2'*a*), 1.70 (s, 3 H, CMe), 1.32 (d, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6). Mass spectrum: *m/z* 652 ($M^+ + 18$).

Anal. Calc. for $C_{36}H_{42}O_{10}$: C, 68.12; H, 6.67. Found: C, 67.95; H, 6.71.

*Methyl 3-O-(3-O-benzoyl-2,6-dideoxy-3-C-methyl-β-*D-arabino-*hexopyranosyl)-2-O-benzyl-6-deoxy-4-O-methyl-β-*D-*galactopyranoside* (**39**). — A solution of **34** (635 mg, 1 mmol) and (±)-camphor-10-sulfonic acid (23 mg, 0.1 mmol) in 1:1 chloroform–methanol (85 mL) was left for 75 h at room temperature under argon, then neutralized with triethylamine, and concentrated. Column chromatography (17:3 chloroform–acetone) of the residue gave **34** (63 mg, 10%), then **35** (459 mg, 84%). ^{1}H-N.m.r. data ($CDCl_3$): δ 8.11–7.30 (m, 10 H, 2 Ph), 5.32 (s, 1 H, OH), 5.01 and 4.66 (2 d, 2 H, J_{gem} 11 Hz, PhCH_2), 4.92 (dd, 1 H, $J_{1',2'e}$ 2, $J_{1',2'a}$ 10 Hz, H-1'), 4.28 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 3.78 (dd, 1 H, $J_{2,3}$ 10, $J_{3,4}$ 3 Hz, H-3), 3.69 (dd, 1 H, H-2), 3.64 and 3.60 (2 s, each 3 H, 2 OMe), 2.43 (dd, 1 H, $J_{2'e,2'a}$ 13.5 Hz, H-2'*e*), 2.04 (ddd, 1 H, $J_{2'a,4'}$ 1 Hz, H-2'*a*), 1.50 (s, 3 H, CMe), 1.35 (d, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6). Mass spectrum: *m/z* 564 ($M^+ + 18$).

To a solution of **35** (273 mg, 0.5 mmol) and tetrabromomethane (332 mg, 1 mmol) in dry *N,N*-dimethylformamide (15 mL) under argon at −45° was added tris(dimethylamino)phosphine (0.18 mL, 1 mmol). The mixture was allowed to reach room temperature, potassium iodide (332 mg, 2 mmol) was added, and the mixture was heated overnight at 80°, then cooled, and concentrated. A solution of the residue in dichloromethane was washed with water, dried ($MgSO_4$), and concentrated. Column chromatography (17:3 toluene–ethyl acetate) of the residue gave, first, a mixture of **36** and **37** (196 mg).

A small portion of this mixture was chromatographed again to give **36**. ^{1}H-N.m.r. data ($CDCl_3$): δ 8.03–7.22 (m, 10 H, 2 Ph), 5.25 (d, 1 H, $J_{4',OH}$ 0.7 Hz, HO-4'), 4.93 and 4.63 (2 d, 2 H, J_{gem} 11 Hz, PhCH_2), 4.82 (dd, 1 H, $J_{1',2'e}$ 1.7, $J_{1',2'a}$ 9.6 Hz, H-1'), 4.23 (d, 1 H, $J_{1,2}$ 7.2 Hz, H-1), 3.88–3.35 (m, 8 H, H-2,3,4,5,4',5',6'a,6'b), 3.62 and 3.55 (2 s, each 3 H, 2 OMe), 2.40 (dd, 1 H, $J_{2'e,2'a}$ 13 Hz, H-2'*e*), 2.07 (dd, 1 H, H-2'*a*), 1.52 (s, 3 H, CMe), 1.33 (d, 3 H, $J_{5,Me}$ 6.3 Hz, H-6,6,6). Mass spectrum: *m/z* 627 and 628 ($M^+ + 18$).

The iodo derivative **37** was eluted next. ^{1}H-N.m.r. data ($CDCl_3$): δ 8.11–7.32 (m, 10 H, 2 Ph), 5.32 (d, 1 H, $J_{4',OH}$ 0.7 Hz, HO-4'), 4.98 and 4.67 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.86 (dd, 1 H, $J_{1',2'e}$ 2, $J_{1',2'a}$ 10 Hz, H-1'), 4.28 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 3.85–3.12 (m, 8 H, H-2,3,4,5,4',5',6'a,6'b), 3.67 and 3.59 (2 s, each 3 H, 2 OMe), 2.43 (dd, 1 H, $J_{2'e,2'a}$ 13 Hz, H-2'*e*), 2.10 (dd, 1 H, H-2'*a*), 1.55 (s, 3 H, CMe), 1.34 (d, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6). Mass spectrum: *m/z* 674 ($M^+ + 18$).

The reaction also gave the 6'-*O*-formyl derivative (**38**; 15 mg, 5%). ^{1}H-N.m.r. data ($CDCl_3$): δ 8.12 (s, 1 H, CHO), 8.04–7.23 (m, 10 H, 2 Ph), 5.20 (d, 1 H, $J_{4',OH}$ 0.7 Hz, HO-4'), 4.95 and 4.62 (2 d, 2 H, J_{gem} 11 Hz, PhCH_2), 4.82 (dd, 1 H, $J_{1',2'e}$ 1.7, $J_{1',2'a}$ 9.7 Hz, H-1'), 4.63 (dd, 1 H, $J_{5',6'a}$ 2.3, $J_{6'a,6'b}$ 11.6 Hz, H-6'a), 4.42 (dd, 1 H, $J_{5',6'b}$ 5 Hz, H-6'b), 4.23 (d, 1 H, $J_{1,2}$ 7.1 Hz, H-1), 3.85 (d, 1 H, $J_{4',5'}$ 9.6 Hz, H-4'), 3.72 (dd, 1 H, $J_{2,3}$ 9.9, $J_{3,4}$ 3 Hz, H-3), 3.59 and 3.56 (2 s, each 3 H, 2 OMe), 3.45 (ddd, 1 H, H-5'), 3.36 (d, 1 H, H-4), 2.41 (dd, 1 H, $J_{2'e,2'a}$ 13.1 Hz, H-2'*e*), 2.05 (dd, 1 H, H-2'*a*), 1.52 (s, 3 H, CMe), 1.33 (d, 3 H, $J_{5,Me}$ 6.4 Hz, H-6,6,6). Mass spectrum: *m/z* 592 ($M^+ + 18$).

Unchanged **35** (27 mg, 10%) was recovered. A solution of the mixture (196 mg) of **36** and **37** in 1:1 hexane–ethyl acetate (15 mL) containing diethylamine (60 μL) was hydrogenated at room temperature and atmospheric pressure in the presence of 10% Pd–C (20 mg). After 6 h, t.l.c. (17:3 toluene–ethyl acetate) showed only one compound (R_F 0.10) and no **36** or **37** (R_F 0.25). The mixture was filtered through Celite, then concentrated to give **39** (159 mg, 60% overall yield). An analytical sample of **39**, obtained by column chromatography (17:3 toluene–ethyl acetate), had $[\alpha]_D$ +26° (*c* 0.63, chloroform). ^{1}H-N.m.r. data ($CDCl_3$): δ 8.11–7.32 (m, 10 H, 2 Ph), 5.10 (d, 1 H, $J_{4',OH}$ 0.7 Hz, HO-4'), 4.98 and 4.67 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.83 (dd, 1 H, $J_{1',2'e}$ 2, $J_{1',2'a}$ 10 Hz, H-1'), 4.28 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 3.77 (dd, 1 H, $J_{2,3}$ 10, $J_{3,4}$ 3 Hz, H-3), 3.73–3.54 (m, 2 H, H-5,4'), 3.67 (dd, 1 H, H-2), 3.65 and 3.59 (2 s, each 3 H, 2 OMe), 3.42 (dd, 1 H, $J_{4,5}$ 0.5 Hz, H-4), 3.35 (dq, 1 H, $J_{4',5'}$ 9, $J_{5',Me}$ 6 Hz, H-5'), 2.45 (dd, 1 H, $J_{2'e,2'a}$ 13 Hz, H-2'*e*), 2.06 (ddd, 1 H, $J_{2'a,4'}$ 0.5 Hz, H-2'*a*), 1.52 (s, 3 H, CMe), 1.39 (d, 3 H, H-6',6',6'), 1.34 (d, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6). Mass spectrum: *m/z* 548 (M^+ + 18).

Anal. Calc. for $C_{29}H_{38}O_9$: C, 65.64; H, 7.22. Found: C, 65.92; H, 7.33.

Methyl O-*(3,4-di-*O*-benzyl-2,6-dideoxy-2-phenylseleno-α-*D*-mannopyranosyl)-(1→4)-*O*-(3-*O*-benzoyl-2,6-dideoxy-3-*C*-methyl-β-*D*-arabino-hexopyranosyl)-(1→3)-2-*O*-benzyl-6-deoxy-4-*O*-methyl-β-*D*-galactopyranoside* (**41**). — To an ice-cooled mixture of **39** (53 mg, 0.1 mmol) and 1,5-anhydro-3,4-di-*O*-benzyl-2,6-dideoxy-D-*arabino*-hex-1-enitol[2] (**40**; 50 mg, 0.16 mmol) in dry acetonitrile (0.2 mL) were added, successively under argon, phenylselenenyl chloride (46 mg, 0.24 mmol) and then, after 5 min, 2,4,6-trimethylpyridine (32 μL, 0.24 mmol). The mixture was stirred at room temperature for 24 h. T.l.c. (9:1 toluene–ethyl acetate) then showed the disappearance of **40** (R_F 0.65) and the formation of a major compound (R_F 0.28); large amounts of **39** (R_F 0.12) were still present. The mixture was diluted with dichloromethane, washed with ice-cold water, dried ($MgSO_4$), and concentrated. Column chromatography (9:1 toluene–ethyl acetate twice, then 97:3 carbon tetrachloride–acetone) gave **41** (34 mg, 34%), $[\alpha]_D$ +1° (*c* 0.2, chloroform). ^{1}H-N.m.r. data ($CDCl_3$): δ 8.01–6.86 (m, 25 H, 5 Ph), 5.52 (d, 1 H, $J_{1,2}$ 2 Hz, H-1C), 4.90 and 4.60 (2 d, 2 H, J_{gem} 11 Hz, PhCH_2), 4.88 and 4.62 (2 d, 2 H, J_{gem} 10.7 Hz, PhCH_2), 4.70 (dd, 1 H, $J_{1,2e}$ 1.7, $J_{1,2a}$ 9.7 Hz, H-1D), 4.49 and 4.42 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.20 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1E), 4.02 (dd, 1 H, $J_{2,3}$ 4.5, $J_{3,4}$ 8.5 Hz, H-3C), 3.74 (dd, 1 H, H-2C), 3.72 (d, 1 H, $J_{4,5}$ 9.5 Hz, H-4D), 3.66 (dd, 1 H, $J_{2,3}$ 10, $J_{3,4}$ 3 Hz, H-3E), 3.60 (dd, 1 H, H-2E), 3.55 and 3.54 (2 s, each 3 H, 2 OMe), 3.31 (d, 1 H, H-4E), 3.11 (dd, 1 H, $J_{2e,2a}$ 13 Hz, H-2*e*D), 1.90 (dd, 1 H, H-2*a*D), 1.57 (s, 3 H, CMe), 1.35 and 1.29 (3 d, 9 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6C,D,E). Mass spectrum: *m/z* 593 [($C_{33}H_{37}O_5Se^+$ + 1), CD fragment with loss of benzoic acid].

Anal. Calc. for $C_{55}H_{64}O_{12}Se$: C, 66.32; H, 6.48. Found: C, 66.36; H, 6.53.

Unchanged **39** (26 mg, 49%) was also recovered.

Methyl O-*[3,4-di-*O*-benzyl-2,6-dideoxy-1(*R*)-*D*-arabino-hexopyranosylidene]-(1→3,4)-*O*-(2,6-dideoxy-3-*C*-methyl-β-*D*-arabino-hexopyranosyl)-(1→3)-2-*O*-benzyl-6-deoxy-4-*O*-methyl-β-*D*-galactopyranoside* (**44**). — Sodium (a few mg) was added to a solution of **41** (10 mg, 10 μmol) in dry methanol (4 mL), and the solution was left for 18 h at room temperature under argon. T.l.c. (95:5 chloroform–acetone) then showed a

complete conversion of **41** (R_F 0.63) into **42** (R_F 0.25). The mixture was diluted with methanol, neutralized with Amberlite IR-120 (H^+) resin, filtered, and concentrated to give **42** (9 mg, 100%). Mass spectrum: *m/z* 909 ($M^+ + 18$), 892 ($M^+ + 1$).

A solution of **42** (9 mg) in 12:7:2 methanol–dichloromethane–water (3 mL) was treated for 2 h at room temperature with sodium periodate (49 mg, 0.23 mmol) and sodium hydrogencarbonate (14 mg, 0.17 mmol). T.l.c. (9:1 chloroform–acetone) then showed the reaction to be complete. The mixture was concentrated, and a solution of the residue in dichloromethane was washed with water, dried ($MgSO_4$), and concentrated to give **43** (9 mg, 100%). Mass spectrum: *m/z* 908 ($M^+ + 1$), 891 ($M^+ - 16$), 736 (**44**$^+ + 1$).

A solution of **43** (9 mg) in 2:2:1 toluene–vinyl acetate–di-isopropylamine (4.5 mL) was heated in a sealed glass tube for 18 h at 140°, then concentrated. Column chromatography (84:15:1 hexane–acetone–triethylamine) of the residue gave **44** (5.6 mg, 76%). ^{1}H-N.m.r. data (C_6D_6): δ 7.33–7.04 (m, 15 H, 3 Ph), 5.05 (dd, 1 H, $J_{1,2e}$ 2.7, $J_{1,2a}$ 9.2 Hz, H-1D), 5.04 and 4.51 (2 d, 2 H, J_{gem} 11.2 Hz, PhCH_2), 4.94 and 4.53 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.43 and 4.36 (2 d, 2 H, J_{gem} 11.7 Hz, PhCH_2), 4.25 (d, 1 H, $J_{1,2}$ 7.7 Hz, H-1E), 4.07 (dq, 1 H, $J_{4,5}$ 9.5, $J_{5,Me}$ 6.2 Hz, H-5C), 4.03 (ddd, 1 H, $J_{2e,3}$ 5, $J_{2a,3}$ 11.5, $J_{3,4}$ 9.2 Hz, H-3C), 3.97 (dd, 1 H, $J_{2,3}$ 9.7 Hz, H-2E), 3.75 (dd, 1 H, $J_{3,4}$ 3 Hz, H-3E), 3.61 and 3.40 (2 s, each 3 H, 2 OMe), 3.58–3.49 (m, 2 H, H-4D,5D), 3.34 (dd, 1 H, $J_{4,5}$ 0.5 Hz, H-4E), 3.22 (dq, 1 H, $J_{5,Me}$ 6.5 Hz, H-5E), 3.17 (dd, 1 H, H-4C), 2.41 (dd, 1 H, $J_{2e,2a}$ 12 Hz, H-2*e*C), 2.32 (dd, 1 H, $J_{2e,2a}$ 11.7 Hz, H-2*e*D), 2.04 (dd, 1 H, H-2*a*D), 2.03 (dd, 1 H, H-2*a*C), 1.34 (d, 3 H, $J_{5,Me}$ 5.6 Hz, H-6,6,6D), 1.33 (d, 3 H, H-6,6,6C), 1.29 (s, 3 H, CMe), 1.24 (d, 3 H, H-6,6,6E). Mass spectrum: *m/z* 753 ($M^+ + 18$), 736 ($M^+ + 1$).

Compound **42** (1.8 mg, 20%) was eluted next.

Methyl O-*(3,4-di*-O-*benzyl-2,6-dideoxy-β*-D-arabino-*hexopyranosyl)-(1→4)*-O-*(3*-O-*benzyl-2,6-dideoxy-2-phenylseleno-α*-D-*mannopyranosyl)-(1→4)*-O-*(3*-O-*benzoyl-2,6-dideoxy-3*-C-*methyl-β*-D-arabino-*hexopyranosyl)-(1→3)-2*-O-*benzyl-6-deoxy-4*-O-*methyl-β*-D-*galactopyranoside* (**45**). — To an ice-cooled mixture of **17** (76 mg, 0.14 mmol) and **39** (53 mg, 0.1 mmol) in dry acetonitrile (0.17 mL) under argon were added phenylselenenyl chloride (40 mg, 0.21 mmol) and 2,4,6-trimethylpyridine (28 μL, 0.21 mmol). The mixture was stirred for 45 h at room temperature. T.l.c. (9:1 carbon tetrachloride–acetone) then showed the disappearance of **17** (R_F 0.72) and the formation of a major compound (R_F 0.47); **39** was still present (R_F 0.28). The mixture was worked-up as described for **41**. Column chromatography (93:7 carbon tetrachloride–acetone) of the product gave **45** (28 mg, 23%), $[\alpha]_D$ +12° (*c* 1, chloroform). ^{1}H-N.m.r. data ($CDCl_3$): δ 7.99–6.92 (m, 30 H, 6 Ph), 5.56 (d, 1 H, $J_{1,2}$ 4 Hz, H-1C), 4.93 and 4.61 (2 d, 2 H, J_{gem} 10.7 Hz, PhCH_2), 4.88 and 4.64 (2 d, 2 H, J_{gem} 11 Hz, PhCH_2), 4.72 (dd, 1 H, $J_{1,2e}$ 1.5, $J_{1,2a}$ 10 Hz, H-1D), 4.67 and 4.50 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.65 (dd, 1 H, $J_{1,2e}$ 2, $J_{1,2a}$ 10 Hz, H-1B), 4.60 and 4.59 (2 d, 2 H, J_{gem} 12 Hz, PhCH_2), 4.20 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1E), 4.10 (dd, 1 H, $J_{2,3}$ 5.5 Hz, H-2C), 3.83 (dd, 1 H, $J_{3,4}$ 8.5 Hz, H-3C), 3.79 (d, 1 H, $J_{4,5}$ 9.5 Hz, H-4D), 3.67 (dd, 1 H, $J_{2,3}$ 10, $J_{3,4}$ 3 Hz, H-3E), 3.60 (dd, 1 H, H-2E), 3.56 and 3.54 (2 s, each 3 H, 2 OMe), 3.32 (d, 1 H, H-4E), 3.14 (dd, 1 H, $J_{2e,2a}$ 12.7 Hz, H-2*e*D), 3.10 (dd, 1 H, $J_{3,4} = J_{4,5} = 9$ Hz, H-4B), 2.34 (ddd, 1 H, $J_{2e,2a}$ 12, $J_{2e,3}$ 5 Hz, H-2*e*B), 1.91 (dd, 1 H, H-2*a*D), 1.56 (ddd, 1 H, $J_{2a,3}$ 10 Hz, H-2*a*B), 1.44 (s, 3 H, CMe), 1.34, 1.31, 1.29,

and 1.25 (4 d, each 3 H, $J_{5,Me}$ 6 Hz, H-6,6,6B,C,D,E). Mass spectrum: *m/z* 1234 (M^+ + 18), 1216 (M^+ + 1), 1112 (M^+ − PhCO), 813 [($C_{46}H_{53}O_8Se^+$ + 1), BCD fragment with loss of benzoic acid].

Anal. Calc. for $C_{68}H_{80}O_{15}Se$: C, 67.15; H, 6.63. Found: C, 67.14; H, 6.80.

Unchanged **39** (36 mg, 68%) was eluted next.

Methyl O-*(3,4-di-*O*-benzyl-2,6-dideoxy-β-*D-arabino-*hexopyranosyl)-(1→4)-*O-*[3-*O*-*benzyl-2,6-dideoxy-1(R)-*D-arabino-*hexopyranosylidene]-(1→3,4)-*O-*(2,6-dideoxy-3-*C*-methyl-β-*D-arabino-*hexopyranosyl)-(1→3)-2-*O*-*benzyl-6-deoxy-4-*O*-methyl-β-*D-*galactopyranoside* (**48**). — Sodium (a few mg) was added to a solution of **45** (12 mg, 10 μmol) in 2:1 methanol–dichloromethane (3 mL), and the mixture was left for 94 h at room temperature under argon. After the usual work-up, column chromatography (4:1 hexane–acetone) of the product gave **46** (8.9 mg, 80%). Mass spectrum: *m/z* 1130 (M^+ + 18), 1113 (M^+ + 1).

Compound **46** (8.9 mg) was oxidized, as described for **42**, to give **47** (9 mg, ~100%), R_f 0.34 (95:5 chloroform–methanol). Mass spectrum: *m/z* 955 (**48**$^+$ + 1), 456 ($C_{26}H_{30}O_6^+$ + 18), and 426 [($C_{22}H_{32}O_7^+$ + 18), corresponding to the BC and DE fragments, respectively].

A solution of **47** (9 mg) in 2:2:1 toluene–vinyl acetate–di-isopropylamine (8 mL) was heated in a sealed glass tube for 18 h at 140°, then concentrated. Column chromatography (84:15:1 hexane–acetone–triethylamine) of the residue gave **48** (6 mg, 80%). ^{1}H-N.m.r. data (C_6D_6): δ 7.47–7.07 (m, 20 H, 4 Ph), 5.05 (dd, 1 H, $J_{1,2e}$ 2.7, $J_{1,2a}$ 9 Hz, H-1D), 5.04 and 4.51 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.92 and 4.52 (2 d, 2 H, J_{gem} 11.5 Hz, PhCH_2), 4.84 and 4.54 (2 d, 2 H, J_{gem} 11.7 Hz, PhCH_2), 4.53 (dd, 1 H, $J_{1,2e}$ 2, $J_{1,2a}$ 10 Hz, H-1B), 4.45 and 4.37 (2 d, 2 H, J_{gem} 12 Hz, PhCH_2), 4.25 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1E), 4.14–3.95 (m, 3 H, H-3C,5C,2E), 3.75 (dd, 1 H, $J_{2,3}$ 10, $J_{3,4}$ 3 Hz, H-3E), 3.61 and 3.40 (2 s, each 3 H, 2 OMe), 3.58–3.38 (m, 3 H, H-3B,4C,5D), 3.49 (d, 1 H, $J_{4,5}$ 9.5 Hz, H-4D), 3.34 (d, 1 H, H-4E), 3.26–3.18 (m, 2 H, H-5B,E), 3.08 (dd, 1 H, $J_{3,4} = J_{4,5}$ = 9 Hz, H-4B), 2.42 (dd, 1 H, $J_{2e,2a}$ 12.5, $J_{2e,3}$ 5 Hz, H-2*e*C), 2.31 (dd, 1 H, $J_{2e,2a}$ 12 Hz, H-2*e*D), 2.27 (ddd, 1 H, $J_{2e,2a}$ 12.5, $J_{2e,3}$ 5 Hz, H-2*e*B), 2.10 (dd, 1 H, $J_{2a,3}$ 12 Hz, H-2*a*C), 2.03 (dd, 1 H, H-2*a*D), 1.77 (ddd, 1 H, $J_{2a,3}$ 12 Hz, H-2*a*B), 1.35 (d, 3 H, $J_{5,Me}$ 6.5 Hz, H-6,6,6C), 1.32 (d, 3 H, $J_{5,Me}$ 6 Hz, H-6,6,6D), 1.31 (s, 3 H, CMe), 1.28 and 1.24 (2 d, each 3 H, H-6,6,6B,E). Mass spectrum: *m/z* 955 (M^+ + 1).

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