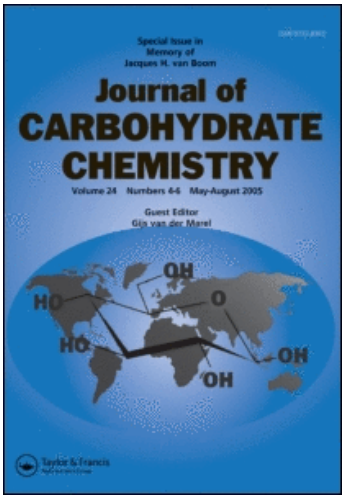

Journal of Carbohydrate Chemistry

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713617200

SYNTHETIC APPROACH TO TETRAHYDROFURAN UNITS AND FIVE-MEMBERED RING LACTONES FUSED TO HEXOPYRANOSIDES *

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Online publication date: 21 August 2002

To cite this Article Rauter, Amélia P. , Oliveira, Olga , Canda, Tana , Leroi, Estelle , Ferreira, Humberto , Ferreira, Maria J. and Ascenso, José A.(2002) 'SYNTHETIC APPROACH TO TETRAHYDROFURAN UNITS AND FIVE-MEMBERED RING LACTONES FUSED TO HEXOPYRANOSIDES *', Journal of Carbohydrate Chemistry, 21: 4, 257 — 273

To link to this Article: DOI: 10.1081/CAR-120013489

URL: http://dx.doi.org/10.1081/CAR-120013489

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JOURNAL OF CARBOHYDRATE CHEMISTRY
Vol. 21, No. 4, pp. 257–273, 2002

SYNTHETIC APPROACH TO TETRAHYDROFURAN UNITS AND FIVE-MEMBERED RING LACTONES FUSED TO HEXOPYRANOSIDES*

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ABSTRACT

A stereoselective synthesis of the miharamycin sugar moiety epimer at C-3′ was accomplished in high yield starting from an appropriate (*Z*)-Wittig product, synthesized by Wittig reaction of a 4,6-*O*-benzylidene protected hexopyranosid-3-ulose with [(ethoxycarbonyl)methylene]triphenylphosphorane followed by iodine promoted isomerisation of the (*E*)-Wittig product formed. Reduction of the (*Z*)-isomer obtained in quantitative yield, cyclisation and dihydroxylation with osmium tetroxide, gave the target molecule containing a *cis*-fused tetrahydrofuran ring in its structure. Synhesis of five-membered rings *trans*-fused to the hexopyranosidic units succeeded via two different synthetic pathways. Stereoselective Reformatsky reaction of a 2,6-di-*O*-pivaloyl protected hexopyranosid-3-ulose, followed by cyclisation with dimethylzinc gave a 3,4-*trans*-fused lactone. The approach using the reaction

*Dedicated to the 60th birthday of Prof. Joachim Thiem.

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DOI: 10.1081/CAR-120013489 0732-8303 (Print); 1532-2327 (Online)

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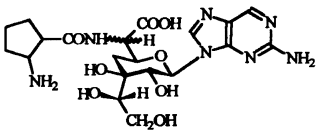
of 2,3-and 3,4-epoxides with the dianion of phenylselenoacetic acid led to low yield but novel phenylseleno derivatives of *trans*-fused five-membered rings, namely a phenylselenolactone 2,3-*trans*-fused to a 4,6-*O*-benzylidene-hexopyranoside and a phenylselenolactenol 3,4-*trans*-fused to a 6-*O*-pivaloyl-hexopyranoside.

INTRODUCTION

Synthesis of the sugar moieties of the antibiotics amipurymicin (**1**)[1] and miharamycin (**2**)[2,3] and the C-3′ epimer[3] have been previously reported. These two antibiotics are natural nucleosides isolated from *Streptomyces novoguineensis* nov. sp.[4] and are known to inhibit strongly *Pyricularia oryzae*, which produces the rice blast disease. In this paper we describe an efficient and high yield stereoselective synthesis of the miharamycin sugar moiety epimer **3** as well as the stereoselective approach to five-membered ring lactones fused to appropriate hexopyranosidic units, which can be regarded as precursors of novel miharamycin sugar analogues.



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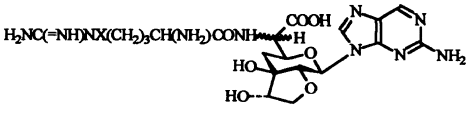
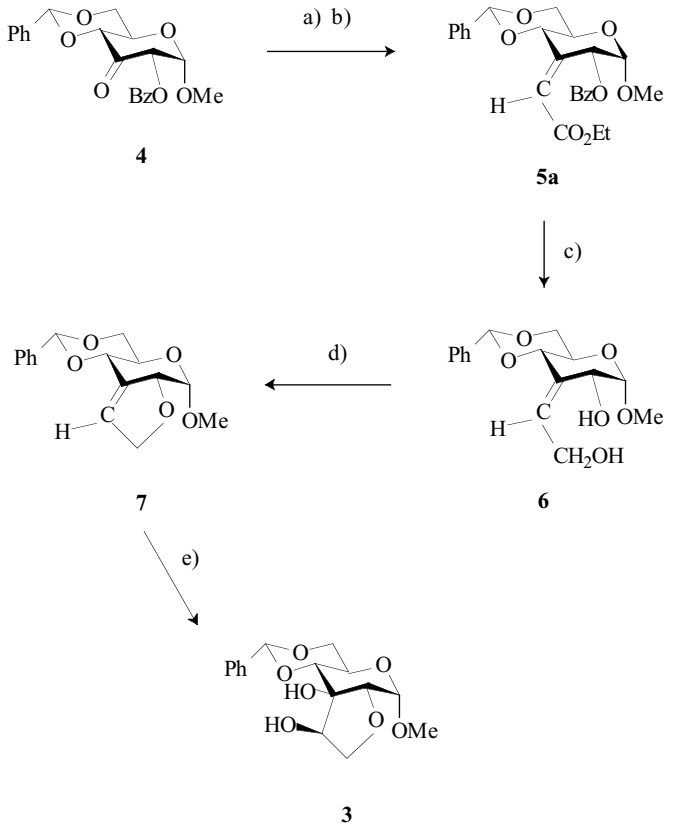


2 X = OH, H

RESULTS AND DISCUSSION

The preparation of **3** was first reported by a non-stereoselective procedure based on the Wittig reaction of methyl 2-*O*-benzoyl-4,6-*O*-benzylidene-α-D-*ribo*-hexopyranosid-3-ulose (**4**) with [(ethoxycarbonyl)methylene]triphenylphosphorane, leading to the mixture of the (*Z*/*E*)-isomers in 7:3 ratio, followed by osmylation of the Wittig products, reduction, and cyclisation with an overall yield of 16%.[3] A stereoselective method previously reported gave the target molecule **3** in 6% overall yield.[3]

Our stereoselective synthesis of **3** was initiated from the protected hexopyranuloside **4**. Wittig reaction of **4** with [(ethoxycarbonyl)methylene]triphenylphosphorane giving the expected mixture of the (*Z*/*E*)-isomers **5a**/**5b**[3] in quantitative yield, was followed by iodine promoted isomerisation of the (*E*)-isomer in dichloromethane[5] at rt for 24 h (Scheme 1) to give **5a**. Reduction of **5a** with lithium aluminum hydride in tetrahydrofuran at 0°C for 30 min and then at rt for 2.5 h gave the diol **6**, isolated in 90% yield. The olefinic proton in the ^{1}H NMR spectrum of **5a** appeared at δ 6.03 as a triplet, coupled with the hydroxymethyl group protons with J = 6.0 Hz. The resonances of these protons appeared as a multiplet at δ 3.94 − 3.66. The H-2 signal was displaced to a higher field (δ 4.40) compared with the corresponding signal of the Wittig product **5a** (δ 5.92), suggesting deprotection at position 2 under these reaction conditions. The ^{13}C NMR spectrum was also in agreement with the proposed structure with the signals of the olefinic carbons at δ 135.7 (C-3) and δ

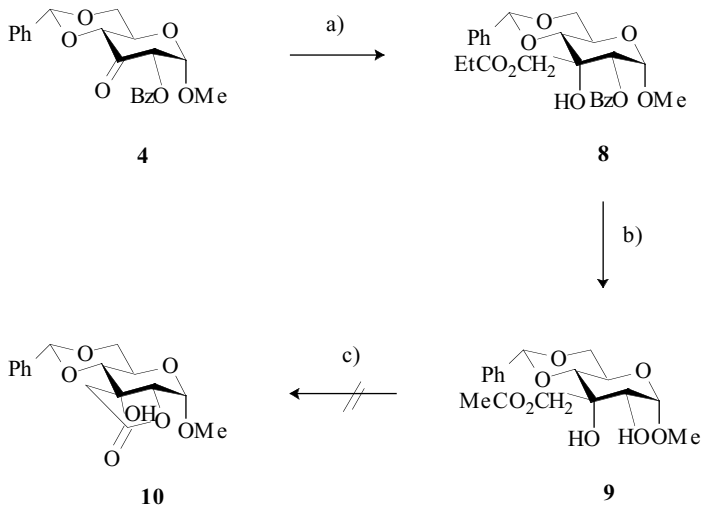


4 **5a** **6** **7** **3**

Scheme 1. a) $Ph_3P{=}CHCO_2Et$, $CHCl_3$, Δ, 5.5 h, *Z*/*E* (7/3), η = 100%; b) I_2, CH_2Cl_2, rt, 24 h, η = 100%; c) $LiAlH_4$, THF, 0°C, 0.5 h, rt, 2.5 h, η = 90%; d) DEAD, Ph_3P, $CHCl_3$, molecular sieves 4 Å, 5°C, 6.5 h, η = 88%; e) OsO_4, Py, rt, 3 h, η = 80%.

115.3 (C-3′), and the signal of C-3″ at δ 30.2, respectively, (confirmed by DEPT). Cyclisation with diethyl azodicarboxylate/triphenylphosphine in chloroform in the presence of 4 Å molecular sieves at 5°C for 6.5 h under argon gave **7** in 88% yield. The target molecule **3** was synthesized in 80% yield by dihydroxylation of **7** with osmium tetroxide in pyridine at rt during 3 h. This stereoselective pathway is the most efficient procedure described to date to prepare **3**, with an overall yield of 63% starting from the ketosugar **4**.

In order to obtain novel miharamycin sugar analogues, we investigated the formation of other five-membered rings fused to positions 2,3 or 3,4 of the hexopyranosidic moiety. Application of the Reformatsky reaction to ketosugar **4** with ethyl bromoacetate in tetrahydrofuran in the presence of activated zinc gave **8** as a single isomer (Scheme 2). The expected configuration of **8** at C-3 was confirmed by NOESY, with correlations of the CH_2-3′ protons with H-2, H-4, H-6a and H-6e. Treatment of **8** with potassium carbonate in methanol at rt afforded the partially protected derivative **9** in 93% yield. Deprotection at position 2 was confirmed by the chemical shift of H-2 (δ



4 **8** **10** **9**

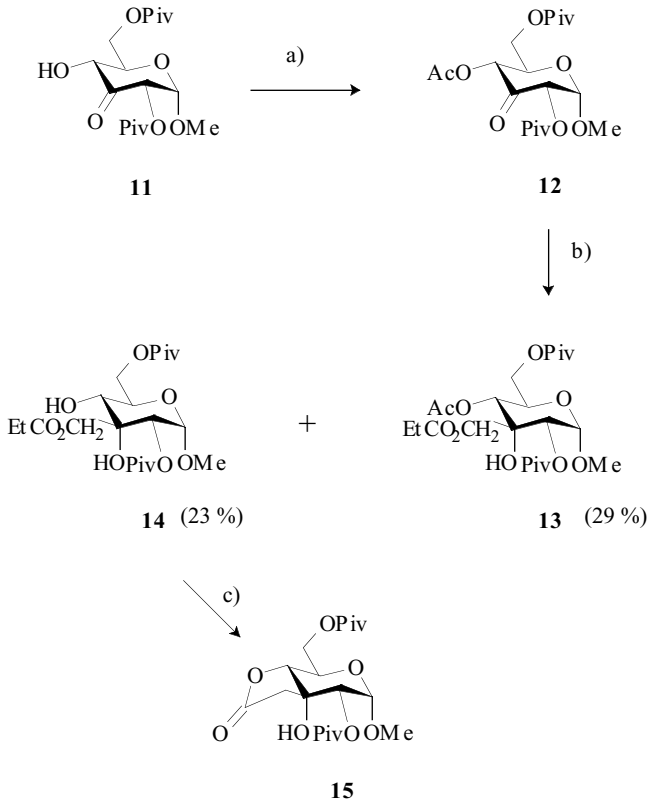
Scheme 2. a) $BrCH_2CO_2Et$, Zn, THF, Δ, η = 71%; b) K_2CO_3, MeOH, rt, η = 93%; c) Me_2Zn, THF, rt.

3.62), which appeared at higher field in comparison to the H-2 signal of **8** (δ 5.60). Attempts to cyclise **9** with dimethylzinc in tetrahydrofuran at rt[6] failed and the lactone **10** was not detected by TLC.

The ketosugar **12** (Scheme 3), whose conformation is less rigid than that of **4**, was synthesized in 93% yield by acetylation of **11**[1] with acetic anhydride in pyridine at rt for 16 h. It was then used as the starting material for the Reformatsky reaction with ethyl bromoacetate to give product **13** isolated only in 29% yield. The deacetylated compound **14** was also obtained (23%), probably formed during the work up of the reaction mixture. NOESY spectra of **13** and of **14** showed in both cases correlation between CH_2-3′ and H-2, H-4 and the pivaloyl protons at position 6, thus confirming the expected configuration at C-3. Cyclisation of **14** with dimethylzinc in tetrahydrofuran at rt for 48 h gave the lactone **15** in 83% yield. The carbonyl group of the five-membered ring lactone was confirmed by the band at 1780 cm^{-1} in its IR spectrum and by the signal at δ 173.4 in its ^{13}C NMR spectrum. The CH_2-3′ ^{13}C signal appeared at δ 37.3, while the two protons were observed as a singlet at δ 2.75. The ^{13}C and ^{1}H NMR signals due to the ethoxy group were absent, implying also the proposed lactonisation.

In an attempt to make the five-membered lactone **17**, the α-acetoxyketosugar **12** (Scheme 4) was treated with the bulky base lithium bis(trimethylsilyl)amide.[7] Lactone **17** was not formed but rather deacetylation occurred giving **11**[1] in 67% yield. A second product **16** (33% yield) was also formed via tautomerisation, pivaloyl migration and dehydration.

The reaction of the lithium salt of phenylselenoacetic acid with an epoxide to build a five-membered ring lactone was previously used to prepare butenolides linked to furanosidic systems by a C—C bond.[8,9] This method, reported by J. Font and coworkers,[10] was now used in order to synthesize five-membered ring lactones fused to the hexopyranosidic unit in positions 3,4 or 2,3. The oxirane ring was built at positions



Scheme 3. a) Ac_2O, Py, rt, 16 h, $\eta = 93\%$; b) $BrCH_2CO_2Et$, Zn, THF, Δ; c) Me_2Zn, THF, rt, 48 h, $\eta = 83\%$.

3,4 by three different approaches (Scheme 5). The synthesis of **19** was first accomplished by treatment of methyl 2,6-di-*O*-pivaloyl-α-D-glucopyranoside[11] (**18**) with diethyl azodicarboxylate and triphenylphosphine in benzene at 80°C for 48 h to give the epoxide **19** in 26% yield. Reaction of **18** with triiodoimidazole/triphenylphosphine[12] in toluene at 90°C for 7 h afforded the olefin **20** in 62% yield, which was then treated with 3-chloroperbenzoic acid/sodium acetate in dichloromethane[13] at rt for 40 h to also give the epoxide **19** (29% yield, based on the reacted alkene, recovered in 46% yield). Another procedure was also investigated in which the diol **18** was treated with benzyltriethylammonium bromide (TEBA) in 50% aqueous sodium hydroxide and dichloromethane, followed by addition of tosyl chloride[14] to give epoxide **21** in 88% yield. When **21** was treated with the dianion of phenylselenoacetic acid, the enol **22** was isolated in 8% yield and the deprotected epoxide **23** was obtained in 33% yield. The ^{13}C NMR spectrum of the lactenol **22** showed the olefinic quaternary carbons at δ 145.5 and δ 144.9, and also the signals corresponding to the presence of the phenyl group, thus confirming the structure of the phenylselenoenol. Additional spectral assignments for **22** and **23** (see Experimental) are in agreement with the proposed structures.

The synthesis of the phenylselenolactone **28** (Scheme 6), which possesses the expected *trans*-fused lactone ring, was initiated from the diol **24**. Mesylation of **24**[15]

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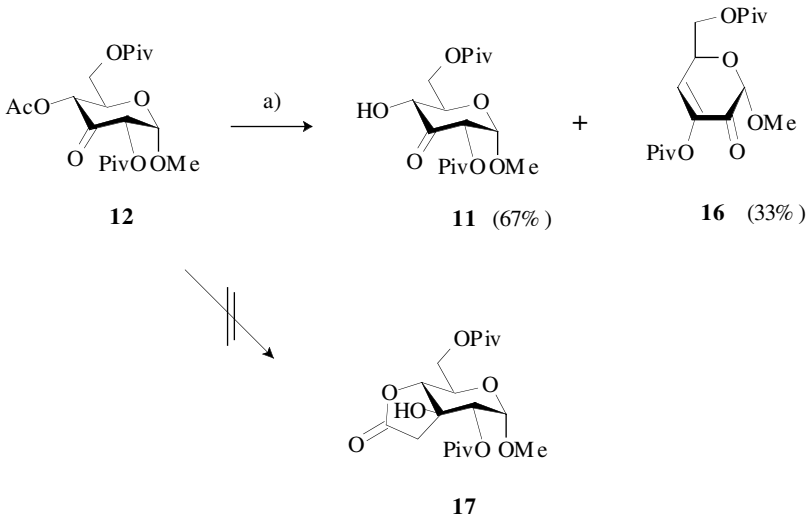
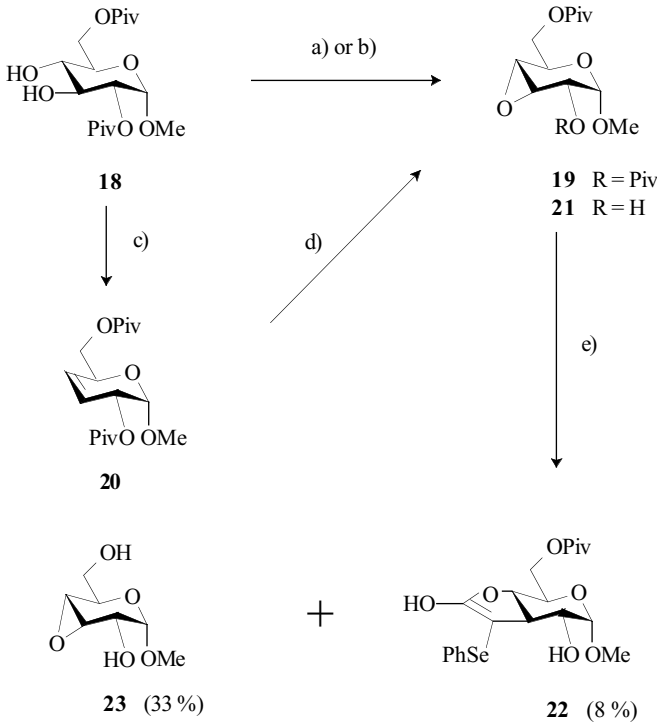


12 **11** (67%) **16** (33%) **17**

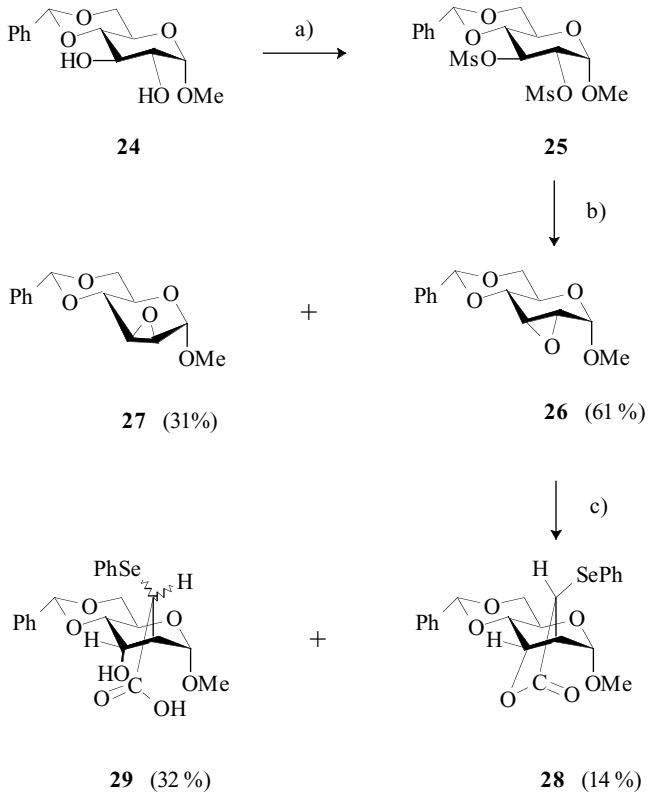
Scheme 4. a) $(Me_3Si)_2NLi$, THF, −78°C, 1.5 h; HCl 2N, rt.



18 **19** R = Piv **21** R = H **20** **23** (33%) **22** (8%)

Scheme 5. a) DEAD, Ph_3P, PhH, 80°C, 48 h, η = 26%; b) TEBA, NaOH 50%, r 15 min, CH_2Cl_2, TsCl, rt, 20 min, η = 88%; c) Triiodoimidazole, Ph_3P, toluene, 90°C, 7 h, η = 62%; d) *m*-CPBA, NaOAc, CH_2Cl_2, rt, 40 h, η = 29%; e) $PhSeCH_2CO_2H$/LDA, THF, 0°C, 1 h, rt, 16 h; CH_3CO_2H 50%, 80°C, 20 h.

with mesyl chloride in pyridine and dichloromethane at rt for 32 h gave **25** (77% yield), which in turn was treated with sodium methoxide[16] to give **26** in 61% yield and its diastereoisomer **27** in 31% yield, easily separated by column chromatography. The confirmation of the orientation of the epoxide in **26** and **27** was possible from NOESY experiments. While the NOESY spectrum from **26** gave correlations of H-2 with H-1 and H-3, and H-3 with H-4, with $J_{3,4} = 1.1$ Hz (determined only at 400 MHz), the experiment with **27** led to the correlations of H-2 with H-3 and OCH_3, thus confirming the proposed configurations for C-2 and C-3 in these diastereoisomers. The synthesis of **27** starting from **24** in 68% yield was also accomplished using *N-p*-tosylimidazole in DMF, a procedure already described in the literature.[17] Reaction of **26** with the dianion of phenylselenoacetic acid, followed by treatment with acetic acid (50%) under reflux for 12 h gave the lactone **28** and the acid **29**, isolated by column chromatography in yields of 14% and 32%, respectively. The IR spectrum of **28** contained a carbonyl band at 1774 cm^{-1} characteristic of a five-membered ring lactone. In the ^1H NMR spectrum of **28**, H-2′ resonated at δ 3.58 as a doublet, with a coupling constant of $J_{2,2'} = 12.3$ Hz, while the signal of H-2 appeared at δ 2.56, also as a doublet. The carbonyl carbons, C-2 and C-2′ were detected at δ 175.8, 48.3 and 48.9, respectively. The proposed structure for **28** was confirmed by NOESY



Scheme 6. a) MsCl, Py, CH_2Cl_2, rt, 32 h, η = 77%; b) NaOMe, 2.7 N, CH_2Cl_2, 2°C, 4 days, rt, 16 h; c) $PhSeCH_2CO_2H$/LDA, THF, 0°C, 1 h, rt, 20 h; CH_3CO_2H 50%, 80°C, 12 h.

experiments which indicated correlations between H-2′ and H-1, H-2, H-4 and Ph protons, as well as those between H-2 and H-2′, H-1, and between H-4 and H-2′, C *H*Ph. The structure of **29** was found to contain a carboxylic acid unit, with an IR carbonyl band at 1728 cm^{-1}. The ^1H NMR spectrum of **29** showed H-2 as a doublet, with $J_{2,2'} = 1.5$ Hz. A NOESY experiment showed correlations of H-2 with Ph protons and H-1. The H-1 signal was seen as a broad singlet, and that of H-4 as a double doublet with $J_{3,4} = 2.7$ Hz and $J_{4,5} = 9.6$ Hz. HMQC and DEPT experiments allowed assignment of the ^{13}C NMR spectrum, with C-2 at δ 47.0, C-2′ at δ 58.1, C-3 at δ 69.7, the carbonyl group at δ 168.0 and the resonances confirming the presence of two phenyl groups in the molecule.

In summary, a new synthetic pathway for the stereoselective synthesis of the miharamycin sugar moiety C-3 epimer was described, which consists of an easy and efficient method improving considerably the yield of the target molecule **3** (63% overall yield starting from **4**, in comparison with the yields 6% and 16% previously reported[3]). Construction of a branch at positions 2 and 3 of pyranosidic units was also investigated, leading to new five-membered ring compounds, some of which can be regarded as interesting precursors of miharamycin sugar moiety analogues.

EXPERIMENTAL

General methods. Melting points were determined with a melting point apparatus (Tottoli) and are uncorrected. Optical rotations were measured with a Perkin-Elmer 343 polarimeter, and IR spectra were recorded with a Biorad FTS 25 PC spectrophotometer. ^1H NMR spectra were run with a Varian Unity-300 MHz spectrometer and NOE and HMQC experiments with a Bruker AM-400 WB. Chemical shifts are expressed in parts per million downfield from TMS. Homonuclear $^1H\{^1H\}$ experiments were performed at 400 MHz in C_3D_6O or $CDCl_3$, using a low decoupler setting (typically 40 L, 5 mW approximately) with a total presaturation time of 6 s. The FIDs were acquired using 16 K points and a sweep width of 5000 Hz in alternate groups of eight, irradiation on/off resonance. A 90° pulse was used during acquisition. The ^{13}C NMR spectra were recorded with a Varian Unity spectrometer at 75.4 MHz. The progress of all reactions was monitored by thin-layer chromatography (TLC) using aluminum sheets precoated with silica gel $60F_{254}$ with a thickness of 0.2 mm (Merck). Preparative TLC was performed with aluminum plates coated with silica gel $60F_{254}$ with a thickness of 0.5 mm (Merck). Detection was effected by observation under UV light (254 nm) and/or by spraying the sheets with a 3% vanillin–sulfuric acid solution. Column chromatography was conducted with silica gel (0.040–0.063 mm, Merck) under low pressure.

Methyl 2,3″-Anhydro-4,6-*O*-benzylidene-3-*C*-[(*R*)-1,2-dihydroxyethyl]-α-D-glucopyranoside (3). Osmium tetroxide (130 mg, 0.51 mmol) was added to a soln of **7** (110 mg, 0.38 mmol) in pyridine (3 mL), and the mixture was stirred at rt for 3 h. Saturated $NaHSO_3$ soln (11.5 mL) and pyridine (4 mL) were added to the reaction mixture and within 5 min the complex was cleaved to give an orange soln, which was extracted with chloroform (3×25 mL). The organic phase was dried over sodium sulfate and concentrated to give crystalline **3** (100 mg, 80%): mp 125–126°C (lit. 124–

126°C).[3] Physical and spectroscopic data were in full agreement with those reported previously in the literature.[3]

Methyl 2-*O*-Benzoyl-4,6-*O*-benzylidene-3-*C*-[(*Z*)-(ethoxycarbonyl)methylene]-α-D-*ribo*-hexopyranoside (5a). A soln of [(ethoxycarbonyl)methylene]triphenylphosphorane (1.7 g, 4.9 mmol) in dry chloroform (8 mL) was added at rt to a soln of **4**[3] (465 mg, 1.21 mmol) in dry chloroform (2 mL). The mixture was stirred under reflux for 5.5 h. Evaporation of the solvent and purification by column chromatography eluted with ethyl acetate–petroleum ether (2:7 v/v) afforded a mixture of the (*Z*/*E*)-isomers in a 7:3 ratio as a syrup (559 mg, 100%). Its spectroscopic data were in accordance with those reported in the literature.[3] The soln of the (*Z*/*E*)-mixture (285 mg, 0.63 mmol) in dichloromethane (45 mL) was added to a soln of iodine (38 mg, 0.15 mmol) in dichloromethane (3 mL), and the mixture was stirred at rt in the dark for 24 h. A saturated soln of $Na_2S_2O_3$ was added until the reaction mixture changed from violet to colorless. The organic phase was extracted with dichloromethane (3×20 mL) and dried over sodium sulfate. Evaporation of the solvent gave a residue which was purified by column chromatography eluted with ethyl acetate–hexane (1:3 v/v) to give **5a** (285 mg, 100%) as a syrup. Its physical and spectroscopic data were in agreement with those reported in the literature.[3]

Methyl 4,6-*O*-Benzylidene-3-*C*-[(*Z*)-(hydroxymethyl)methylene]-α-D-*ribo*-hexopyranoside (6). A soln of **5a**[3] (132 mg, 0.29 mmol) in dry THF (6 mL) was added to a suspension of $LiAlH_4$ (135 mg, 3.4 mmol) in dry THF (5 mL) at 0°C, and the mixture was stirred for 30 min at 0°C and then for 2.5 h at rt. A mixture of dry THF/chloroform (20 mL, 1:1 v/v) was added, followed by a saturated soln of ammonium chloride (7 mL). After stirring for 2 h, the mixture was extracted with THF/chloroform (3:1 v/v). The organic phase was dried over sodium sulfate and concentrated to dryness. The residue was purified by column chromatography eluted with ethyl acetate–toluene (2:1 v/v) to give crystalline **6** (89.6 mg, 90%); mp 158–160°C; $[\alpha]_D^{20}$ +12.7 (*c* 0.5, EtOH); R_f 0.37 (ethyl acetate–toluene 2:1); ^{1}H NMR ($CDCl_3$) δ 7.51 – 7.46 (m, 5H, Ph), 6.03 (t, 1H, H-3′, $J_{3',3''a} = J_{3',3''b} = 6$ Hz), 5.60 (s, 1H, C*H*Ph), 4.75 (d, 1H, H-1, $J_{1,2} = 3$ Hz), 4.40 (d, 1H, H-2), 4.37 – 4.27 (m, 2H, H-4, H-6e), 3.94 – 3.66 (m, 4H, H-6a, H-5, H-3″a, H-3″b), 3.47 (s, 1H, OCH_3); ^{13}C NMR ($CDCl_3$) δ 137.1 (C_q, Ph), 135.7 (C-3), 129.0, 128.7, 128.3, 128.1, 126.1 (Ph), 115.3 (C-3′), 101.4 (*C*HPh), 97.2 (C-1), 87.4 (C-4), 73.3 (C-2), 69.1 (C-6), 58.7 (C-5), 51.2 (OCH_3), 30.2 (C-3″).

Anal. Calcd for $C_{16}H_{20}O_6$ (308.33): C, 62.33; H, 6.54. Found: C, 62.61; H, 6.48.

Methyl 2,3″-Anhydro-4,6-*O*-benzylidene-3-*C*-[(*Z*)-(hydroxymethyl) methylene]-α-D-*ribo*-hexopyranoside (7). Triphenylphosphine (292 mg, 1.11 mmol) and 4 Å powdered molecular sieves (42 mg) were added to a soln of **6** (139 mg, 0.45 mmol) in dry chloroform (11.5 mL) at rt under argon. After cooling to 5°C, diethyl azodicarboxylate (0.2 mL, 1.33 mmol) was added and the reaction was stirred at 5°C for 6.5 h. Filtration and solvent evaporation gave a residue which was purified by column chromatography eluted with ethyl acetate–hexane (2:3 v/v) giving **7** (115 mg, 88%) as

a syrup; $[\alpha]_D^{20} + 34$ (*c* 0.9, chloroform); R_f 0.57 (ethyl acetate–hexane 2:3); IR (cm^{-1}, KBr) 3500 (OH); ^1H NMR ($CDCl_3$) δ 7.41 – 7.36 (m, 5H, Ph), 5.77 (s, 1H, H-3′), 5.65 (s, 1H, C*H*Ph), 4.89 – 4.79 (m, 4H, H-1, H-2, H-3″a, H-3″b), 4.29 (dd, 1H, H-6e, $J_{6e,6a} = 10$ Hz, $J_{5,6e} = 4.2$ Hz), 4.23 (dd, 1H, H-4, $J_{4,5} = 9$ Hz, $^4J_{3',4} = 2.4$ Hz), 3.85 (t, 1H, H-6a, $J_{5,6a} = 10$ Hz), 3.76 (ddd, H-5), 3.45 (s, 1H, OCH_3); ^{13}C NMR ($CDCl_3$) δ137.5 (C_q, Ph), 133.2 (C-3), 129.2, 128.3, 128.2, 126.3 (Ph), 116.6 (C-3′), 100.4 (*C*HPh), 97.2 (C-1), 84.0 (C-4), 69.5 (C-6), 64.8 (C-2), 55.3 (C-5), 51.2 (OCH_3), 29.7 (C-3″).

Anal. Calcd for $C_{16}H_{18}O_5$ (290.31): C, 66.19; H, 6.25. Found: C, 65.85; H, 6.33.

Methyl 2-*O*-Benzoyl-4,6-*O*-benzylidene-3-*C*-(ethoxycarbonyl)methylene-α-D-allopyranoside (8). Ethyl bromoacetate (1.67 mL, 15.6 mM), diluted with THF (4.5 mL), was added dropwise to the suspension of activated zinc (1.09 g, 16.7 mM) in a soln of **4**[3] (2 g, 5.2 mM) in anhydrous THF (8 mL), under argon. After stirring at 60°C for 3 days, the mixture was cooled to rt. Addition of conc. ammonium hydroxide (4 mL) in water (16 mL) under stirring was followed by extraction with dichloromethane (3 × 25 mL). The organic phase was dried over sodium sulfate and concentrated under reduced pressure. The residue was purified by column chromatography with ethyl acetate/toluene (1:5 v/v) to give **8** (1.75 g, 71%); mp 125–126°C; $[\alpha]_D^{20} + 71°$ (*c* 1.0, dichloromethane); R_f 0.5 (ethyl acetate–toluene 1:5); IR (KBr) 3372 cm^{-1} (OH), 1736 cm^{-1} (C═O); ^1H NMR (C_6D_6) δ 8.27 – 8.24 (m, 4H, Ph), 7.69 – 7.68 (m, 6H, Ph), 5.60 (d, 1H, H-2), 5.51 (s, 1H, C*H*Ph), 5.10 (d, 1H, $J_{1,2} = 3.9$ Hz, H-1), 4.35 – 4.19 (m, 2H, H-5, H-6e), 4.01 – 3.69 (m, 3H, H-4, CH_2, Et), δ 3.59 (t, 1H, $J_{6e,6a} = J_{5,6a} = 10.3$ Hz, H-6a), 3.16, 3.11, 2.97, 2.92 (H-3′a, H-3′b, AB system, $J_{A,B} = 15.3$ Hz), 2.80 (s, 3H, OCH_3), 0.80 (t, 3H, $J_{CH2,CH3} = 6.8$ Hz, CH_3, Et); ^{13}C NMR (C_6D_6) δ 170.6 (C═O, CO_2Et), 165.8 (C═O, Bz), 138.4 (Cq, Ph), 136.5 (Cq, Ph), 133.5 (C-3), 130.3, 129.9, 129.1, 128.8, 127.7, 126.9 (Ph), 102.3 (*C*HPh), 98.8 (C-1), 79.6 (C-4), 71.5 (C-2), 69.2 (C-6), 60.5 (CH_2, Et), 59.7 (C-5), 55.5 (OCH_3), 37.5 (CH_2-3′), 13.9 (CH_3, Et).

Anal. Calcd for $C_{25}H_{28}O_9$ (472.46): C, 63.55; H, 5.97. Found: C, 63.26; H, 5.95.

Methyl 4,6-*O*-Benzylidene-3-*C*-(methoxycarbonyl)methylene-α-D-allopyranoside (9). Dry potassium carbonate (29 mg, 0.21 mmol) was added to a soln of **8** (100 mg, 0.21 mmol) in anhyd methanol (5 mL). The suspension was stirred for 60 h at rt under argon. Neutralisation with Amberlite IR 120 (H^+), filtration, solvent evaporation and purification by column chromatography eluted with ethyl acetate–hexane (1:1) gave **9** (63 mg, 93%); mp 185.5–186.5°C; $[\alpha]_D^{20} + 19°$ (*c* 1.0, dichloromethane); R_f 0.22 (ethyl acetate–hexane 1:1); IR (KBr) 3556 cm^{-1} (OH), 1710 cm^{-1} (C═O); ^1H NMR ($CDCl_3$): δ 7.45 – 7.34 (m, 5H, Ph), 5.53 (s, 1H, C*H*Ph), 4.76 (d, 1H, H-1, $J_{1,2} = 4.2$ Hz), 4.35 (dd, 1H, H-6e, $J_{6e,5} = 5.4$ Hz, $J_{6e,6a} = 10.5$ Hz), 4.14 (ddd, 1H, H-5), 3.73 (t, 1H, H-6a, $J_{5,6a} = 10.2$ Hz), 3.62 (d, 1H, H-2), 3.58 (d, 1H, H-4, $J_{4,5} = 9.3$ Hz), 3.50 (s, 3H, OCH_3), 3.48 (s, 3H, OCH_3), 2.95, 2.90, 2.62, 2.57 (H-3′a, H-3′b, AB system, $J_{3'a,3'b} = 15.3$ Hz); ^{13}C NMR ($CDCl_3$): δ 172.6 (C═O), 137.0 (Cq, Ph), 129.0, 128.1, 126.2 (Ph), 101.7 (*C*HPh), 100.2 (C-1), 80.5 (C-4), 73.0 (C-3), 70.3 (C-2), 69.0 (C-6), 58.5 (C-5), 56.4 (OCH_3), 51.8 (COO *C*H_3), 37.7 (C-3′).

Anal. Calcd for $C_{17}H_{22}O_8$ (354.3): C, 57.62; H, 6.25. Found: C, 57.13; H, 6.14.

Methyl 4-*O*-Acetyl-2,6-di-*O*-pivaloyl-α-D-*ribo*-hexopyranosid-3-ulose (12). Acetic anhydride (0.147 mL, 1.55 mmol) was added to a soln of **11**[1] (80 mg, 0.77 mmol) in dry pyridine (1 mL). The mixture was stirred for 16 h at rt. After solvent evaporation, the residue was purified by column chromatography eluted with ethyl acetate–toluene (1:5, v/v) to give **12** (290 mg, 93%) as a syrup. $[\alpha]_D^{20} + 100°$ (*c* 1.0, chloroform); R_f 0.65 (ethyl acetate–toluene 1:5); IR (neat): 1746 cm^{-1} (C═O); ^1H NMR ($CDCl_3$) δ 5.36 (d, 1H, H-2, $J_{1,2} = 3$ Hz), 5.30 (d, 1H, H-4, $J_{4,5} = 9$ Hz), 5.18 (d, 1H, H-1), 4.37 – 4.20 (m, 3H, H-5, H-6a, H-6b), 3.45 (s, 3H, OCH_3), 2.16 (s, 3H, CH_3, Ac), 1.26 (s, 9H, CH_3, Piv), 1.23 (s, 1H, 9H, CH_3, Piv); ^{13}C NMR ($CDCl_3$) δ 193.0 (C-3, C═O), 177.8 (C═O, Piv), 176.8 (C═O, Piv), 168.6 (C═O, Ac), 99.8 (C-1), 74.2, 72.0, (C-2, C-4), 69.5 (C-5), 62.1 (C-6), 55.6 (OCH_3), 38.9 (Cq, Piv), 27.0 (CH_3, Piv), 26.9 (CH_3, Piv), 20.1 (CH_3, OAc).

Anal. Calcd for $C_{19}H_{30}O_9$ (402.4): C, 56.71; H, 7.50. Found: C, 57.11; H, 8.00.

Methyl 4-*O*-Acetyl-2,6-di-*O*-pivaloyl-3-*C*-(ethoxycarbonyl)methylene-α-D-glucopyranoside (13) and Methyl 2,6-Di-*O*-pivaloyl-3-*C*-(ethoxycarbonyl)methylene-α- D-glucopyranoside (14). A soln of ethyl bromoacetate (0.234 mL, 2.12 mmol) in anhyd THF (0.6 mL) was added dropwise to a suspension of activated zinc (10.15 mg, 2.28 mmol) in the soln of **12** (315 mg, 0.783 mmol) in THF (0.6 mL) under argon. The mixture was stirred at 50°C for two days and cooled to rt. Ammonium hydroxide (0.3 mL) was then added and the mixture was extracted with diethyl ether (3 × 5 mL) and with dichloromethane (3 × 5 mL). The organic phase was dried with sodium sulfate, concentrated in vacuo and the residue purified by column chromatography eluted with ethyl acetate–toluene (1:5 v/v) to give **13** (95 mg, 29%) and **14** (73 mg, 23%), on the basis of the reacted starting material, recovered in 16% yield.

Physical and spectroscopic data of **13**: $[\alpha]_D^{20} + 54°$ (*c* 1, dichloromethane); R_f 0.50 (ethyl acetate–toluene 1:5); IR (neat) 3492 cm^{-1} (OH),1744 cm^{-1} (C═O); ^1H NMR ($CDCl_3$) δ 5.18 – 5.13 (m, 2H, H-2, H-4), 5.04 (d, 1H, H-1, $J_{1,2} = 3.9$ Hz), 4.23 – 4.18 (m, 3H, H-5, H-6a, H-6b), 4.22 (q, 2H, CH_2, Et), $J_{CH2,CH3} = 7.2$ Hz), 3.44 (s, 3H, OCH_3), 2.67, 2.62, 2.53, 2.48 ($H_{3'a}$, $H_{3'b}$, AB system, $J_{3'a,3'b} = 16.2$ Hz), 2.14 (s, 3H, CH_3, Ac), 1.26 – 1.21 (m, 21H, CH_3, Piv, CH_3, Et); ^{13}C NMR ($CDCl_3$) δ 177.2 (C═O, Piv), 169.4 (C═O, CO_2Et), 167.9 (C═O, Ac), 97.4 (C-1), 73.6 (C-3), 69.2 (C-2), 68.8 (C-4), 65.5 (C-5), 62.5 (C-6), 60.8 (O*C*H_2, Et), 56.0 (OCH_3), 37.3 (*C*H_2CO_2Et), 27.1 (CH_3, Piv), 26.9 (CH_3, Piv), 20.6 (CH_3, Ac), 13.9 (CH_3, Et).

Anal. Calcd for $C_{23}H_{38}O_{11}$ (490.5): C, 56.32; H, 7.80. Found: C, 56.54; H, 7.79.

Physical and spectroscopic data of **14**: $[\alpha]_D^{20} + 11°$ (*c* 1.0, dichloromethane); R_f 0.12 (ethyl acetate–toluene 1:5); IR(neat) 3488 cm^{-1} (OH), 1738 cm^{-1} (C═O); ^1H NMR ($CDCl_3$) δ 4.98 (d, 1H, H-2, $J_{1,2} = 3.6$ Hz), 4.93 (d, 1H, H-1), 4.48 (dd, 1H, H-6a, $J_{6a,5} = 2.1$ Hz), 4.31 (dd, 1H, H-6b, $J_{5,6b} = 5.7$ Hz, $J_{6a,6b} = 11.7$ Hz), 4.08 (q, 2H, CH_2, Et), 3.85 (ddd, 1H, H-5), 3.75 (t, 1H, H-4, $J_{4,5} = 9.9$ Hz), 3.40 (s, 3H, OCH_3), 2.73 (d, 1H, OH, $J_{4,OH} = 10,2$ Hz), 2.84, 2.79, 2.61, 2.55 (H-3′a, H-3′b, AB system, $J_{3'a,3'b} = 15$ Hz), 1.24 (s, 9H, CH_3, Piv), 1.22 (s, 9H, CH_3, Piv), 1.19 (t; 3H, CH_3, Et); ^{13}C NMR($CDCl_3$) δ 177.3 (C═O, Piv), 176.4 (C═O, Piv), 170.1 (C═O, CO_2Et), 97.5 (C-1), 73.9 (C-3), 69.3 (C-2), 68.0 (C-4), 67.8 (C-5), 63.6 (C-6), 60.7 (O*C*H_2, Et), 55.9 (OCH_3), 37.3 (*C*H_2-3′), 27.2 (CH_3, Piv), 27.0 (CH_3, Piv), 14.0 (CH_3, Et).

Anal. Calcd for $C_{21}H_{36}O_{10}$ (448.47): C, 56.24; H, 8.08. Found: C, 56.05; H, 8.00.

Methyl 2,6-Di-*O*-pivaloyl-3-*C*-(carboxymethyl)-α-D-allopyranoside-3′,3-lactone (15). A soln of **14** (77 mg, 0.17 mmol) in anhyd THF (2.6 mL) was added to a soln of 2 M dimethylzinc in toluene (0.75 mL, 1.5 mmol) under argon and stirred at rt for 29 h. A saturated soln of ammonium chloride (5 mL) was added, and the mixture was stirred at rt for 24 h. The organic phase was extracted with diethyl ether (3 × 5 mL), dried with sodium sulfate and concentrated in vacuo. The residue was purified by column chromatography eluted with ethyl acetate–toluene (1:2 v/v) to give **15** (57 mg, 83%) as a syrup. $[\alpha]_D^{20} + 38°$ (*c* 1.0, dichloromethane); R_f 0.20 (ethyl acetate–toluene1:2); IR (neat) 1780 cm^{-1} (C═O), 1736 cm^{-1} (C═O, Piv); ^1H NMR ($CDCl_3$) δ 4.97 (d, 1H, H-1, $J_{1,2} = 3.6$ Hz), 4.88 (d, 1H, H-2), 4.68 (d, 1H, H-4, $J_{4,5} = 9.9$ Hz), 4.48 (dd, 1H, H-6a, $J_{6a,6b} = 12$ Hz, $J_{6a,5} = 2.1$ Hz), 4.34 (dd, 1H, H-6b, $J_{6b,5} = 5.4$ Hz), 3.91 – 3.86 (m, 1H, H-5), 3.43 (s, 3H, OCH_3), 2.75 (s, 2H, H-3′a, H-3′b), 1.25 (s, 9H, CH_3, Piv), 1.23 (s, 9H, CH_3, Piv); ^{13}C NMR ($CDCl_3$) δ 177.5 (C═O, Piv), 179.0 (C═O, Piv), 173.4 (C-3″), 97.4 (C-1), 74.2 (C-3) 69.9, 68.4, 67.7 (C-2, C-4, C-5), 63.6 (C-6), 56.0 (OCH_3), 39.1 (Cq, Piv), 37.3 (*C*-3′), 27.2 (CH_3, Piv), 26.9 (CH_3, Piv).

Anal. Calcd for $C_{19}H_{30}O_9$ (402.40): C, 56.71; H, 7.50. Found: C, 56.51; H, 7.25.

Methyl 4-Deoxy-3,6-di-*O*-pivaloyl-α-D-*glycero*-hex-3-enopyranosid-2-ulose (16). A soln of **12** (240 mg, 0.6 mmol) in anhyd THF (3.8 mL) was added dropwise to a 2 M soln of lithium bis(trimethylsilyl)amide (1.4 mL, 2.8 mmol) in THF (2.5 mL), previously cooled to −78°C, under argon. The mixture was stirred at −78°C for 1.5 h and then poured into an HCl 2N soln (2 mL). The mixture was stirred until rt was reached. The organic layer was separated, and the aqueous phase was extracted with ethyl acetate (3 × 5 mL). The organic phases were stirred over sodium chloride and concentrated. The residue was extracted with dichloromethane, dried with sodium sulfate, concentrated and purified by column chromatography eluted with ethyl acetate–toluene (1:8 v/v) to give methyl 2,6-di-*O*-pivaloyl-α-D-*ribo*-hexopyranosid-2-ulose **11**[1] (74 mg, 67%) and **16** (36 mg, 33%) as a syrup, on the basis of the reacted starting material, recovered in 43% yield. Physical and spectroscopic data of **16**: $[\alpha]_D^{20} + 38°$ (*c* 1, dichloromethane); R_f 0.60 (ethyl acetate–toluene 1:8); IR (neat): 1766 cm^{-1} (C═O), 1726 cm^{-1} (C═O), 1663 cm^{-1} (C═C); ^1H NMR ($CDCl_3$) δ 6.55 (d, 1H, H-4, $J_{4,5} = 1.5$ Hz), 4.94 (td, 1H, H-5), 4.89 (s, 1H, H-1), 4.41 (dd, 1H, H-6a, $J_{5,6a} = 5.7$ Hz, $J_{6a,6b} = 11.7$ Hz), 4.23 (dd, 1H, H-6b, $J_{5,6b} = 5.1$ Hz), 3.55 (s, 3H, OCH_3), 1.25 (s, 9H, CH_3, Piv), 1.24 (s, 9H, CH_3, Piv) ^{13}C NMR ($CDCl_3$) δ 182.4 (C-2), 178.1 (C═O, Piv), 175.7 (C═O, Piv), 142.2 (C-3), 132.1 (C-4), 99.1 (C-1), 67.6 (C-5), 64.3 (C-6), 56.9 (OCH_3), 39.0 (Cq, Piv), 27.1 (CH_3, Piv).

Anal. Calcd for $C_{17}H_{26}O_7$ (342.40): C, 59.63; H, 7.65. Found: C, 59.55; H, 7.87.

Methyl 2,6-Di-*O*-pivaloyl-3,4-anhydro-α-D-allopyranoside (19). *Method 1.* Triphenylphosphine (946 mg, 3.61 mmol) was added to a soln of **18** (500 mg, 1.38 mmol) in anhyd benzene (24 mL). The soln was stirred for 15 min at rt, then activated molecular sieves powder 3 Å (1.1 g) was added and DEAD (0.58 mL, 3.61 mmol) was added dropwise. The reaction mixture was stirred for 48 h at 80°C. Filtration and evaporation of the solvent gave a residue which was purified by column chromatography eluted with ethyl acetate–toluene (1:5 v/v) to give **19** (122.2 mg, 26% yield).

Method 2. *m*-CPBA (264 mg, 1.53 mmol) and sodium acetate (126 mg, 1.53 mmol) were added to a soln of **20** (130 mg, 0.33 mmol) in dichloromethane (7 mL), and the reaction mixture was stirred at rt for 40 h. A saturated sodium hydrogen carbonate soln was added, and the organic phase was extracted with dichloromethane, washed with a saturated sodium thiosulfate soln, with a saturated soln of sodium chloride, with water, dried over sodium sulfate and concentrated. The residue was purified by column chromatography as described for *Method 1* to give **19** (20 mg, 29%) on the basis of the reacted starting material, recovered in 46% yield. Physical and spectroscopic data of **19**: $[\alpha]_D^{20}+47°$ (*c* 1, dichloromethane); R_f 0.57 (ethyl acetate–hexane 1:3); mp 51–52.5°C; IR (KBr): 1738 cm^{-1} (C═O), 1852 cm^{-1} (C═O); ^1H NMR ($CDCl_3$) δ 4.86 (d, 1H, H-1, $J_{1,2}=6$ Hz), 4.71 (d, 1H, H-2), 4.30 – 4.15 (m, 3H, H-5, H-6a, H-6b), 3.37 (s, 3H, OCH_3), 3.26 – 3.24 (m, 2H, H-3, H-4), 1.22 (s, 9H, CH_3, Piv), 1.21 (s, 9H,CH_3, Piv), ^{13}C NMR ($CDCl_3$): δ 178.0 (C═O, Piv), 94.1 (C-1), 65.4 (C-2), 63.5 (C-5), 63.3 (C-6), 55.8 (OCH_3), 51.0 (C-3), 49.7 (C-4), 27.1 (CH_3, Piv), 27.0 (CH_3, Piv).

Anal. Calcd for $C_{17}H_{28}O_7$ (344.36): C, 59.30; H, 8.20. Found: C, 58.63; H, 7.96.

Methyl 3,4-Dideoxy-2,6-di-*O*-pivaloyl-α-D-*erythro*-hex-3-enopyranoside (20). Triphenylphosphine (472 mg, 2.63 mmol), **18** (280 mg, 0.657 mmol), triiodoimidazole (472 mg, 1.045 mmol) recently prepared[12] and imidazole (90 mg, 1.3 mmol) were added to toluene (15 mL), and the reaction mixture was stirred at 90°C for 7 h. The mixture was cooled to rt, toluene (15 mL) was added and then a saturated hydrogen carbonate soln (90 mL). After stirring for 10 min at rt, the organic phase was washed with aqueous sodium thiosulfate, then with a saturated sodium hydrogen carbonate soln and finally with water. The organic phase was dried over sodium sulfate and concentrated. The residue was purified by column chromatography eluted with ethyl acetate–hexane (1:4 v/v) to give **20** as a syrup (130 mg, 62%); $[\alpha]_D^{20}+16°$ (*c* 1, dichloromethane); R_f 0.36 (ethyl acetate–hexane 1:4); IR (neat) 1740 cm^{-1} (C═O); ^1H NMR ($CDCl_3$): δ 5.85 (dt, 1H, H-3, $J_{3,4}=19.5$ Hz, $J_{2,3}=J_{3,5}=1.5$ Hz), 5.73 (dt, 1H, H-4, $J_{4,5}=J_{2,4}=2.7$ Hz), 5.24 (ddd, 1H, H-2, $J_{1,2}=4.2$ Hz), 5.11 (d, 1H, H-1), 4.39 (m, 1H, H-5), 4.27 (dd, 1H, H-6a, $J_{5,6a}=5.4$ Hz, $J_{6a,6b}=11.4$ Hz), 4.16 (dd, 1H, H-6b, $J_{5,6b}=4.2$ Hz), 3.47 (s, 3H, OCH_3), 1.23 (s, 9H, CH_3, Piv), 1.21 (s, 9H, CH_3, Piv); ^{13}C NMR ($CDCl_3$): δ 178.0 (C═O, Piv), 128.0 (C-3), 124 (C-4), 95.8 (C-1), 66.7 (C-5), 66.1 (C-2), 64.8 (C-6), 56.0 (OCH_3), 27.1 (CH_3, Piv), 27.0 (CH_3, Piv).

Anal. Calcd for $C_{17}H_{28}O_6$ (328.38): C, 62.17; H, 8.58. Found: C, 62.47, H, 8.45.

Methyl 6-*O*-Pivaloyl-3,4-anhydro-α-D-allopyranoside (21). – 50% aqueous sodium hydroxide (2.8 mL) was added to the mixture of **18** (2 g, 5.5 mmol) and benzyltriethylammonium bromide (55 mg) in dichloromethane (10 mL). The mixture was stirred at rt for 15 min and then cooled to 0°C. A soln of tosyl chloride (1.048 g, 5.5 mmol) in dichloromethane (5.5 mL) was added dropwise under cooling, and the reaction mixture was then stirred at 25°C for 20 min. Water was added (10 mL), and the organic phase was separated, dried with sodium sulfate and concentrated. The residue was purified by column chromatography eluted with ethyl acetate-hexane 1:2 to give **21** (1.26 g, 88%); mp 75–76°C; $[\alpha]_D^{20}+17°$ (*c* 1, chloroform); IR (KBr) 1736 cm^{-1} (C═O), 3544 cm^{-1} (OH), 1299 cm^{-1} (C—O, epoxide); ^1H NMR ($CDCl_3$) δ

4.61 (d, 1H, H-1, $J_{1,2}$ = 4.2 Hz), 4.44 (d, 1H, H-2, $J_{2,3}$ = 4.2 Hz, 4.26 – 4.23 (m, 3H, H-5, H-6a, H-6b), 3.35 (s, 3H, OCH_3), 3.22 – 3.21 (m, 2H, H-3, H-4), 1.21 (s, 9H, CH_3, Piv); ^{13}C NMR ($CDCl_3$) δ 178.0 (C═O, Piv), 94.4 (C-1), 71.0 (C-2), 64.1 (C-5), 63.0 (C-6), 55.9 (OCH_3), 50.9 (C-3), 49.8 (C-4), 38.8 (Cq, Piv), 27.1 (CH_3, Piv).

Anal. Calcd for $C_{12}H_{20}O_6$ (260.3): C, 55.38; H, 7.74. Found: C, 55.70; H, 7.66.

Methyl 3″,4-Anhydro-3-deoxy-6-*O*-pivaloyl-3(*S*)-*C*-(3″,3″-dihydroxy-3′-phenylselenylethenyl)-α-D-*ribo*-hexopyranoside (22) and Methyl 3,4-Anhydro-α-D-allopyranoside (23). 1.6 M *n*-BuLi in hexane (3.83 mL, 6.13 mmol) was added dropwise to a soln of diispropylamine (0.9 mL, 6.13 mmol) in THF (12 mL), previously cooled to 0°C, under argon. After stirring for 25 min at 0°C, a soln of phenylselenoacetic acid (622 mg, 2.88 mmol) in anhyd THF (3 mL) was added dropwise for 1 h at 0°C under stirring, and a white precipitate was formed after a few minutes indicating the formation of the dianion. A soln of **21** (497 mg, 1.44 mmol) in anhyd THF (1.5 mL) was then added dropwise for 1 h at 0°C. The reaction mixture was stirred for 23 h at rt, and the precipitate dissolved, giving a clear soln. A 50% soln of acetic acid (2.5 mL) was added and the reaction mixture was heated at 80°C for 20 h. After cooling, neutralisation was effected with a saturated $NaHCO_3$ soln, and the organic phase was extracted with diethyl ether (3 × 10 mL), dried with sodium sulfate and concentrated. The syrup was purified by column chromatography eluted with ethyl acetate–toluene 1:8 to give **22** (68 mg, 8%) and **23** (107 mg, 33%). Physical and spectroscopic data of **22**: $[\alpha]_D^{20}$ + 18° (*c* 1, dichloromethane); R_f 0.45 (ethyl acetate–hexane 1:3); IR (neat): 3450 cm^{-1} (OH), 1732 cm^{-1} (C═O); ^{1}H NMR ($CDCl_3$): δ 7.91 (d, 1H, H-6″, $J_{5'',6''}$ = 9 Hz), 7.79 (d, 1H, H-2″, $J_{2'',3''}$ = 9 Hz), 7.53 (d, 1H, H-4″, $J_{3'',4''}$ = 9 Hz), 7.34 – 7.26 (m, 2H, Ph, H-3″, H-5″), 5.10 (t, 1H, H-3, $J_{3,4}$ = 9.6 Hz), 4.78 – 4.73 (m, 2H, H-1, H-4), 4.36 (dd, 1H, H-6a, $J_{5,6a}$ = 1.8 Hz), 4.24 (dd, 1H, H-2, $J_{1,2}$ = 3.3 Hz, $J_{2,3}$ = 9.6 Hz), 4.10 (dd, 1H, H-6b, $J_{6a,6b}$ = 12 Hz, $J_{5,6b}$ = 5.1 Hz), 3.95 (ddd, 1H, H-5), 3.24 (s, 3H, OCH_3), 1.23 (s, 9H, CH_3, Piv); ^{13}C NMR ($CDCl_3$): 177.8 (C═O, Piv), 145.4, 144.9 (C-3′,C-4′), 132.6 (Cq, Ph), 129.8, 129.6, 128.4, 128.0 (CH, Ph), 96.4 (C-1), 75.6 (C-3), 75.5 (C-2), 73.1 (C-4), 67.6 (C-5), 61.7 (C-6), 55.6 (OCH_3), 38.8 (Cq, Piv), 27.1 (CH_3, Piv).

Anal. Calcd for $C_{20}H_{26}O_8Se$ (437.35): C, 54.92; H, 5.98; Se, 17.26. Found: C, 54.25; H, 6.12.

Physical and spectroscopic data of **23**: mp 128–129°C; $[\alpha]_D^{20}$ + 38° (*c* 1, dichloromethane); R_f 0.20 (ethyl acetate–hexane 1:3); IR (neat): 3500 cm^{-1} (OH); ^{1}H NMR ($CDCl_3$): δ 4.59 (d, 1H, H-1, $J_{1,2}$ = 6 Hz), 4.40 (d, 1H, H-2), 4.02 (brt, 1H,H-5), 3.82 – 3.70 (m, 2H, H-6a, H-6b), 3.33 (s, 3H, OCH_3), 3.21 – 3.16 (m, 2H, H-3, H-4); ^{13}C NMR ($CDCl_3$): δ 94.4 (C-1), 71.1 (C-2), 66.0 (C-5), 62.5 (C-6), 55.9 (OCH_3), 50.4, 50.0 (C-3, C-4).

Anal. Calcd for $C_7H_{12}O_5$ (176.14): C, 47.73; H, 6.86. Found: C, 48.08; H, 6.74.

Methyl 4,6-*O*-Benzylidene-2,3-di-*O*-mesyl-α-D-glucopyranoside (25). Mesyl chloride (2.5 mL, 32.4 mmol) was added dropwise to a stirred soln of **24**[15] (3 g, 10.63 mmol) in anhyd dichloromethane (48 mL) and anhyd pyridine (18 mL), previously cooled to − 20°C. The reaction mixture was stirred for 32 h at rt and then cooled to 0°C. Addition of solid sodium hydrogen carbonate was followed by extraction of the organic

phase with dichloromethane, which was dried over magnesium sulfate. The soln was concentrated, dissolved in toluene (15 mL), and concentrated again. This procedure was repeated 3 times. The residue was purified by column chromatography eluted with ethyl acetate–toluene 1:4 to give **25** (3.6 g, 77%); mp 241–242°C; $[\alpha]_D^{20}$ +9° (*c* 1, dichloromethane); R_f 0.27 (ethyl acetate–toluene 1:4); IR (KBr) 1372 cm^{-1} (S═O); ^1H NMR ($CDCl_3$): δ 7.47 – 7.37 (m, 5H, Ph), 5.56 (s, 1H, C*H*Ph), 5.10 (t, 1H, H-3, $J_{2,3} = J_{3,4} = 9.6$ Hz), 5.03 (d, 1H, H-1, $J_{1,2} = 3.6$ Hz), 4.64 (dd, 1H, H-2), 4.35 (dd, 1H, H-6e, $J_{5,6e} = 4.8$ Hz, $J_{6e,6a} = 10.5$ Hz), 3.95 (ddd, 1H, H-5, $J_{4,5} = 9.6$ Hz), 3.83 – 3.71 (m, 2H, H-4, H-6a), 3.50 (s, 3H, OMe), 3.18, 2.98 (each s, 3H, Me, Ms); ^{13}C NMR ($CDCl_3$): δ 136.2 (Cq, Ph), 129.5, 128.5, 126.0 (Ph), 102.0 (*C*HPh), 98.8 (C-1), 79.0 (C-4), 77.1 (C-3), 75.8 (C-2), 68.7 (C-6), 62.2 (C-5), 56.1 (OMe), 38.9, 38.8 (Me, Ms).

Anal. Calcd for $C_{16}H_{22}O_{10}S_2$ (438.45): C, 43.83; H, 5.05; S, 14.62. Found: C, 44.29; H, 55.23; S, 14.33.

Methyl 2,3-Anhydro-4,6-*O*-benzylidene-α-D-allopyranoside (26)[18] and Methyl 2,3-Anhydro-4,6-*O*-benzylidene-α-D-mannopyranoside (27)[17]. Sodium methoxide 2.7 N (14 mL) was added to a soln of **25**[15] (3.36 g, 7.62 mmol) in anhyd dichloromethane (78.5 mL), previously cooled to 0°C, and the reaction mixture was kept at 2°C for 4 days and then at rt for 16 h. After addition of dichloromethane (70 mL) and water (25 mL) under stirring, the aqueous phase was extracted with dichloromethane (3 × 20 mL), and the organic phase was washed with water until pH 7, dried over sodium sulfate and concentrated. The residue was purified by column chromatography eluted with ethyl acetate–hexane 1:2 to give **26** (1226 mg, 61%) and **27** (623 mg, 31%). Physical and spectroscopic data of **26**: mp 198–200°C; R_f 0.32 (ethyl acetate–hexane 1:3); $[\alpha]_D^{20}$ +90° (*c* 1, chloroform); IR (KBr) 1257 cm^{-1} (C—O, epoxide); ^1H NMR ($CDCl_3$) δ 7.45 – 7.42 (m, 2H, Ph), 7.31 – 7.29 (m, 3H, Ph), 5.51 (s, 1H, C*H*Ph), 4.83 (dd, 1H, H-6a, $J_{5,6a} = 5.1$ Hz, $J_{6a,6b} = 10.2$ Hz), 4.00 (ddd, 1H, H-5, $J_{5,6b} = 10.2$ Hz, $J_{4,5} = 9.0$ Hz), 3.90 (d, 1H, H-4), 3.62 (t, 1H, H-6b), 3.47 – 3.44 (m, 5H, OCH_3, H-2, H-3); ^{13}C NMR ($CDCl_3$) δ 137.2 (Cq, Ph), 129.2, 128.3, 126.3 (Ph), 102.8 (*C*HPh), 95.4 (C-1), 78.0 (C-4), 68.9 (C-6), 60.1 (C-5), 55.8 (OCH_3), 53.1, 50.7 (C-2, C-3). Physical and spectroscopic data of **27**: mp 144–145.5°C (lit.[17] 145.5–146°C); $[\alpha]_D^{20}$ +100° (*c* 1,chloroform); R_f 0.50 (ethyl acetate–hexane 1:3); IR (KBr) 1257 cm^{-1} (C—O, epoxide); ^1H NMR ($CDCl_3$) δ 7.45 – 7.42 (m, 2H, Ph), 7.35 – 7.31 (m, 3H, Ph), 5.53 (s, 1H, C*H*Ph), 4.84 (s, 1H, H-1), 4.20 (dd, 1H, H-6a, $J_{5,6a} = 7.8$ Hz, $J_{6a,6b} = 14.1$ Hz), 3.71 – 3.59 (m, 3H, H-4, H-5, H-6b), 3.45 – 3.37 (m, 4H, OMe, H-3), 3.10 (d, 1H, H-2, $J_{2,3} = 3.6$ Hz); ^{13}C NMR ($CDCl_3$): δ 137.1 (Cq, Ph), 129.3, 128.4, 126.2 (Ph), 102.4 (*C*HPh), 96.9 (C-1), 74.9 (C-4), 69.4 (C-6), 61.7 (C-5), 55.8 (OMe), 53.8 (C-3), 50.5 (C-2).

Anal. Calcd for $C_{14}H_{16}O_5$ (264.3): C, 63.63; H, 6.10. Found: C, 63.59; H, 6.05.

Methyl 4,6-*O*-Benzylidene-2(*S*)-deoxy-2-*C*-[2′(*S*)-(carboxy)phenylselenylmethyl]-α-D-*ribo*-hexopyranoside-3,2′-lactone (28) and Methyl 4,6-*O*-Benzylidene-3(*S*)-deoxy-3-*C*-[(carboxy)phenylselenylmethyl]-α-D-*ribo*-hexopyranoside (29). 1.6 M *n*-BuLi in hexane (1.33 mL, 2.04 mmol) was added dropwise to a soln of diispropylamine (0.3 mL, 2.04 mmol) in THF (4 mL), previously cooled to 0°C, under argon.

After stirring for 25 min at 0°C, a soln of phenylselenoacetic acid (216 mg, 1 mmol) in anhyd THF (1 mL) was added dropwise for 1 h at 0°C under stirring, and a white precipitate was formed after a few minutes indicating the formation of the dianion. A soln of **26** (130 mg, 0.5 mmol) in anhyd THF (0.5 mL) was then added dropwise for 1 h at 0°C. The reaction mixture was stirred for 20 h at rt and the precipitate was dissolved, giving a clear soln. A 50% soln of acetic acid (2.5 mL) was added, and the reaction mixture was heated at 80°C for 12 h. After cooling and neutralisation with a saturated hydrogen carbonate soln, the organic phase was extracted with diethyl ether (3×10 mL), dried with sodium sulfate and concentrated. The syrup was purified by column chromatography eluted with ethyl acetate–toluene 1:5 to give **28** (30 mg, 14%) and **29** (70 mg, 32%). Physical and spectroscopic data of **28**: mp 181–182°C; $[\alpha]_D^{20} - 34°$ (*c* 1, dichloromethane); R_f 0.35 (ethyl acetate–toluene 1:5); IR (KBr) 1774 cm^{-1} (C═O); ^1H NMR ($CDCl_3$): δ 7.62 – 7.44 (m, 4H, Ph), 7.34 – 7.23 (m, 6H, Ph), 5.60 (s, 1H, C*H*Ph), 5.24 (s,1 H, H-1), 4.31 – 4.20 (m, 3H, H-3, H-5, H-6a), 3.91 (d, 1H, H-4, $J_{4,5} = 9.9$ Hz), 3.78 (t, 1H, H-6b, $J_{6a,6b} = J_{5,6b} = 10.2$ Hz), 3.58 (d, 1H, H-2′, $J_{2,2'} = 12.3$ Hz), 3.41 (s, 3H, OMe), 2.56 (d, 1H, H-2); ^{13}C NMR ($CDCl_3$): δ 175.8 (C═O), 137.4 (Cq, Ph), 133.2, 129.0, 128.2, 127.2, 126.2 (Ph), 102.1 (*C*HPh), 101.5 (C-1), 77.4 (C-4), 69.3 (C-6), 68.0 (C-3), 58.7 (C-5), 55.6 (OMe), 48.9 (C-2′), 48.3 (C-2).

Anal. Calcd for $C_{22}H_{22}O_6Se$ (461.35): C, 57.27; H, 4.80. Found: C, 57.82; H, 4.74.

Physical and spectroscopic data of **29**: $[\alpha]_D^{20} + 49°$ (*c* 1, dichloromethane); R_f 0.58 (ethyl acetate–toluene 1:5); IR (neat) 3802 cm^{-1} (OH), 1728 cm^{-1} (C═O); ^1H NMR ($CDCl_3$): δ 7.52 – 7.43 (m, 4H, Ph), 7.29 – 7.18 (m, 6H, Ph), 5.59 (s, 1H, C*H*Ph), 4.94 (brs, 1H, H-1), 4.29 – 4.15 (m, 4H, H-2′, H-3, H-5, H-6a), 4.05 (dd, 1H, H-4, $J_{4,5} = 9.6$ Hz, $J_{3,4} = 2.7$ Hz), 3.78 (t, 1H, H-6b, $J_{5,6b} = J_{6a,6b} = 9.9$ Hz), 3.55 (d, 1H, H-2, $J_{2,2'} = 1.5$ Hz), 3.34 (s, 3H, OMe); ^{13}C NMR ($CDCl_3$): δ 168.0 (C═O), 137.4 (Cq, Ph), 134.2, 129.7, 129.3, 128.4, 126.3 (Ph), 102.4 (*C*HPh), 102.2 (C-1), 77.8 (C-4), 69.7 (C-3), 69.3 (C-6), 58.8 (C-5), 58.1 (C-2′), 55.8 (OMe), 47.0 (C-2).

Anal. Calcd for $C_{22}H_{24}O_7Se$ (479.39): C, 55.12; H, 5.05. Found: C, 55.52; H, 4.95.

ACKNOWLEDGMENTS

The authors are grateful to the Junta Nacional de Investigação Científica e Tecnológica for a research grant and Eng. Fernando Matos for running some NMR spectra.

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Received June 22, 2001
Accepted April 30, 2002