Chiral Pool Synthesis of 4a-Substituted Carbocyclic Cyclopentanoid Nucleoside Precursors, II

René Csuk*a, Petra Dörrb, Martin Kühnb, Claus Kriegerc, Hermann Irngartingerd,
Thomas Oeserd, Michael Yu. Antipine

a Institut für Organ. Chemie, Martin-Luther-Universität Halle-Wittenberg, Kurt-Mothes-Str. 2, D-06120 Halle (Saale), Germany
b Pharmazeutisch-Chemisches Institut, Universität Heidelberg, Im Neuenheimer Feld 364, D-69120 Heidelberg, Germany
c Max-Planck-Institut für Medizinische Forschung, Jahn-Straße 29, D-69120 Heidelberg, Germany
d Organisch-Chemisches Institut, Universität Heidelberg, Im Neuenheimer Feld 270, D-69120 Heidelberg, Germany
e Institute of Organoelement Compounds, Russian Academy of Science, Vavilow St. 28 B-334, Moscow 117813, Russia

* Reprint requests to Prof. Dr. R. Csuk. E-mail: csuk@chemie.uni-halle.de

Z. Naturforsch. 54b, 1079–1091 (1999); received May 27, 1999

Nucleosides, Carbohydrates, X-Ray Data

Suitable protected 4,4a-anhydro-cyclopentane derivatives have been used for the straightforward of cyclopentanoid nucleoside precursors. Thus, by simple transformations nucleoside precursors modified at the positions C(4), C(4a) and C(4,4a) as well as side-chain modified derivatives were accessible. The structures of the key intermediates were determined by x-ray analyses.

Introduction

Nucleoside analogues have been used quite successfully for the chemotherapy of viral infections. In order to obtain biological activity as well as molecules resisting biodegradation, suitable modifications have to be made. Thus, among others, alterations of the sugar moiety have been performed including deoxygenations, eliminations, chain extensions at C(5’) and at the anomeric centre, (hetero)substitutions as well as modifications with replacement of the ribose ring by a carbocyclic ring system. Among these derivatives, analogues possessing a cyclopentane ring [1–3] have been most promising.

Results and Discussion

Recently a straightforward chiral pool approach to the key intermediate 1 has been elaborated [4] starting from commercially available d-ribo-1,4-lactone.

Reduction of the epoxide 1 with lithium aluminiumhydride gave 90% of the 4a-carba-β-L-lyxofuranose (2), whereas reduction of 3 under the same conditions gave access to the 4a-carba-β-D-ribofuranose (4) in 69% yield. Both reductions follow formally a S_n2 ring opening reaction according to the rule of Fürst-Plattner leading to products with trans (pseudo)-diaxially oriented substituents. Both compounds are characterized by the presence of a broad signal in the IR spectrum at υ = 3465 (for 2) and υ = 3508 cm⁻¹ (for 4) indicating the presence of a hydroxy group. The newly created methylene group at C(4a) (carbohydrate numbering has been used throughout this work for convenience) is found in the 13C NMR spectrum at δ = 40.02 ppm (for 2) and at δ = 42.83 ppm (for 4), respectively.

No reductive opening of the epoxide ring could be achieved, however, using diborane [5] diborane/boron trifluoride diethyl etherate [6] or sodium cyanoborohydride/boron trifluoride diethyl etherate [7]. The hydrogenation of 1 in the presence of 5% Pd/C resulted in a reductive debenzylation without any reductive cleavage of the oxirane ring: 5 was obtained in 87% isolated yield after chromatographic purification. Due to the failure of these methods to obtain C(4a)-substiti-
tuted derivatives the rearrangement reaction of these epoxides to the corresponding 4a-oxo-derivatives was investigated.

Thus, treatment of 3 with lithium bromide/hexamethyl phosphoric triamide in refluxing benzene [8] failed as well as the reaction of 3 with lithium perchlorate in benzene [8] did not proceed at all. The reaction of 1 with lithium diethylamide [9] finally gave 60% of an oily 6 that showed in its IR spectrum the presence of a hydroxy group (ν = 3578 cm⁻¹) as well as the presence of a double bond as indicated by the signals at δ = 118.3 and δ = 146.32 ppm in the ¹³C NMR spectrum; H-C(5) was found in the ¹H NMR spectrum at δ = 6.43 ppm. From these findings the structure of 6 as an exocyclic alkene was deduced but neither these data nor further NMR experiments did allow an unambiguous assignment of the configuration of the double bond; after prolonged standing of a solution in CDCl₃ the ¹³C NMR spectrum showed besides huge deterioration the presence of a second isomer albeit in low abundance. Treatment of the isomeric epoxide 3 under the same conditions resulted in huge deterioration of the starting material.

Hydrogenolysis of the alcohol 6 in the presence of Pd/C afforded 7 as a single stereoisomer whose absolute configuration at the newly created stereogenic centre was determined by a single X-ray analysis of its 2,4-dinitro-benzoate (8). This analysis revealed 8 to possess the structure of a (4a R)-4a-carba-β-L-lyxofuranose. The results of this analysis are depicted in Fig 1.*

Hydroboration of 9 resulted in the formation of two products, 10 and 11, in a ratio of 6:1. Both compounds possess a hydroxy group as indicated in the IR spectra by the presence of signals at ν = 3465 and 3470 cm⁻¹. In the corresponding ¹H NMR spectra the signals for these hydroxy groups were found at δ = 2.50 and 2.61 ppm, respectively. Whereas for 10 an one-proton signal for H-C(4) was found no such signal could be detected for 11. This compound, however, shows a two-proton signal for HC-(4a) at δ = 1.37 ppm. Thus, the formation of 10 follows the expected pathway for hydroboration reactions, whereas 11 results from a formal addition of water. The absolute configura-

* The atomic coordinates, bond lengths and angles, torsion angles and thermal parameters are available on request from the Director of the Cambridge Crystallographic Centre, University Chemical Laboratory, Lensfield Road, Cambridge CB21EW. Any request should be accompanied by the full literature citation for this communication.

![Chemical Structures](image)
Fig. 1. X-ray analysis of 8: C_{32}H_{44}SiN_{2}O_{10}, monoclinic, space group P2_{1}1, unit cell dimensions: a = 11.159(3) Å, b = 11.825(2) Å, c = 13.685(2) Å, β = 102.04(2)°, F(000) = 688; reflections collected 3638, 2005 observed reflections, I > 3.0 σ(I), 467 parameters refined (H-atoms in disorder area included but not in refinement); R = 0.054; R_{w} = 0.062; colorless prism; Z = 2; crystal size 0.15 x 0.2 x 0.35 mm; C(1)-C(2) = 1.5526(7) Å, C(1)-C(4a) = 1.516(6) Å, C(2)-C(3) = 1.532(8) Å, C(3)-C(4) = 1.553(7) Å, C(4)-C(4a) = 1.520(8) Å, O(11)-C(4a) = 1.465(5) Å, C(2)-C(1)-C(4a) = 101.3(4)°, C(1)-C(2)-C(3) = 105.7(4)°, C(3)-C(4)-C(4a) = 103.7(4)°, C(1)-C(4a)-C(4) = 102.3(4)°, C(1)-C(4a)-O(11) = 109.2(4)°, C(4)-C(4a)-O(11) = 111.2(4)°.

Fig. 2. X-ray analysis of 13: C_{29}H_{39}O_{8}NSi, space group P, unit cell dimensions: a = 10.652(2) Å, b = 14.265(1) Å, c = 10.456(1) Å, α = 99.22(1)°, β = 96.98(1)°, γ = 74.56(1)°, F(000) = 596; 7204 independent reflections, 4345 observed I > 2.5 σ(I) parameters refined; R = 0.045; R_{w} = 0.054; Z = 2; yellowish needle; crystal size 0.5 x 0.35 x 0.24 mm; C(1)-C(4a) = 1.517(2) Å, C(4)-C(4a) = 1.520(3) Å, C(1)-C(2) = 1.524(2) Å, C(2)-C(3) = 1.541(3) Å, C(3)-C(4) = 1.537(2) Å, O(3)-C(4a)-C(1) = 108.8(1)°, O(3)-C(4a)-C(4) = 112.0(2)°, C(1)-C(4a)-C(4) = 1.541(3) Å, C(3)-C(4) = 1.537(2) Å, O(3)-C(4a)-C(1) = 108.8(1)°, O(3)-C(4a)-C(4) = 112.0(2)°, C(1)-C(4a)-C(4) = 104.2(1)°, C(4a)-C(1)-C(2) = 103.4(1)°, C(1)-C(2)-C(3) = 105.3(1)°, C(2)-C(3)-C(4) = 106.9(1)°.

Treatment of 9 with catalytic amounts of osmium tetroxide in the presence of N-methylmorpholine N-oxide gave a si-face attack of the oxidant from the sterically less hindered side to afford 22 whose ^{13}C NMR spectrum shows the presence of a quaternary carbon at δ = 75.85 ppm that was assigned to C(4). Oxidation of 22 with pyridinium chlorochromate did not result in the formation of a keto group at C(4a) but gave the epoxides 23 and 24 in a 1:1 ratio [13]. These epoxides are the product of an elimination reaction of the intermediary chromate ester whose epoxidation from the less hindered re-face then affords the epoxides 23 and 24, respectively. The absolute configuration of 23 was deduced from {^1}H-{^3}H NOE-experiments that showed a strong NOE at H-C(3) and at H_{A}=C(benzyl) upon irradiation of H-C(5). Hydrogenolysis of 23/24 resulted in a reductive opening of the oxirane ring as well as a deprotection and afforded 25 and 26 in a 8:1 ratio, the latter product resulting from an additional methanalysis of the silyl protecting group during the reaction;
was also obtained by the fluoride mediated desilylation of 36.

The formation of a single stereoisomer from the hydrogenolysis starting from a 1:1 mixture 23/24 gives an additional proof for the assigned absolute configuration for these epoxides. Reaction of dimethyldioxirane with 22 did not give any trace of a compound possessing a keto group at C(4), instead a smooth debenzylation reaction took place and afforded 25. Similarly, 10 gave upon treatment with dimethyldioxirane 27 [14].

Attempted fluorination of 10 by its treatment with diethylaminosulur trifluoride (DAST) did not result in the formation of a C(4a) mono-fluorinated cyclopentane, but gave the epoxide 28, the formation of which can be explained by a neighboring group participating reaction starting by a fluoride-mediated desilylation of 10 and finally an intramolecular S_N2 reaction.

The synthetic potential of these novel synthetic precursors for the synthesis of cyclopentanoid nucleoside analogues is currently under investigation in our laboratories.

Experimental

General methods

Melting points are uncorrected (Leica hot stage microscope), optical rotations were obtained using a Perkin-Elmer 341 polarimeter (1 cm micro cell). NMR spectra (internal Me_4Si) were recorded using the Varian spectrometers XL300, Gemini 200, Gemini 2000 or Unity 500 (δ given in ppm, J in Hz, internal Me_4Si for 'H and 13C NMR spectra, internal CC_1_3F was used for 19F NMR spectra, C' correspond to the atoms of the heterocycle). IR spectra (film or KBr pellet) on a Perkin-Elmer FT-IR spectrometer Spectrum 1000. MS spectra were taken on a Intectra GmbH AMD 402 (electron impact, 70 eV) or on a Finnigan MAT LCQ 7000 (electrospray, voltage 4.5 kV, under nitrogen) instrument; for elemental analysis a Foss-Heraeus Vario EL instrument was used; TLC was performed on silica gel (Merck 5554, detection by
UV absorption or by treatment with a solution of 10% sulfuric acid, ammonium molybdate and cerium(IV) sulfate followed by gentle heating).

5-O-Benzyl-4a-carba-2,3-O-isopropylidene-6-O-triisopropylsilyl-pent-4-ulo-β-1-lyxofuranose = (3a S, 4R, 6S, 6a R)-4-benzyloxymethyl-2,2-dimethyl-6-triisopropylsilyloxy-tetrahydro-cyclopenta[d]-[1,3]dioxol-4-ol (2)

To a 0 °C cold suspension of LiAlH₄ (50 mg, 1.26 mmol) in abs. diethyl ether (2 ml) a solution of 1 (90 mg, 0.198 mmol) in abs. diethyl ether (1 ml) was slowly added. After warming to room temperature, stirring was continued for an additional 6 h. The mixture was cooled to 0 °C, and ethanol (96%, 3 ml) and water (2 ml) were carefully added, the mixture was filtered and the aqueous phase extracted with diethyl ether (3 x 10 ml), the combined organic layers were washed with brine, dried (MgSO₄), the solvent was removed and the residue subjected to chromatography (silica gel, hexane/ethyl acetate 20:1) to afford 2 (80 mg, 90%); [a][b]° = -3.0° (c, 1.0 CHCl₃); Rf = 0.28 (hexane/ethyl acetate 10:1); ¹H NMR (300 MHz, CDCl₃): δ = 7.27–7.38 (m, 5 H, H-(ar)), 4.65 (d, 1 H, J = 12.1 Hz, HA-CH₂(ar)), 4.57 (d, 1 H, J = 12.1 Hz, HB-CH₂(ar)), 4.57 (d, 1 H, J = 5.2 Hz, H-C(2)), 4.47 (m 1 H, H-C(1)), 4.24 (d, 1 H, J = 5.4 Hz, H-C(3)), 3.70 (d, 1 H, J = 9.2 Hz, HA-C(5)),
3.47 (d, 1 H, J = 9.2 Hz, H_a-C(5)), 2.65 (s, 1 H, OH), 1.79-1.84 (m, 2 H, H_3(1)), 1.33, 1.45 (s, 3 H, 2 × CH_3(isopropyl)), 1.10 (s, 18 H, CH_3(TIPS)), 1.09 (s, 3 H, CH(TIPS)); \(^{13}\)C NMR (75 MHz, CDCl_3): \(\delta = 137.93\) (s, C_g(ar)), 128.31 (d, C_g(ar)), 127.61 (d, C_g(ar)), 119.09 (C_g(isopropyl)), 84.47, 79.86 (d, C(2), C(3)), 77.67 (s, C(4)), 73.49 (t, CH_2(C(4)), 72.44 (t, C(5)), 71.40 (d, C(1)), 40.02 (t, C(4a)), 26.29, 24.64 (q, 2 × CH_3(isopropyl)), 18.06 (q, CH(TIPS)), 12.32 (d, CH(TIPS)); MS (ei, 80 eV, 134 °C): 450 (M, 0.2%), 435 (M -CH_3, 1.3%), 258 (2.7%), 257 (12.9%), 129 (5.4%), 187 (3.3%), 185 (13.4%), 173 (5.5%), 157 (3.6%), 105 (8.1%), 91 (100%); HRMS calcd. for C_{25}H_{34}O_{8}Si: 450.28015; found: 450.2802.

5-O-Benzyl-4a-carba-4-hydroxy-2,3-O-isopropylidene-6-O-triisopropylsilyl-4-pent-4-en-3-ol (5)

The preparation was performed according to the synthesis of 2, starting from 3 (250 mg, 0.56 mmol) to afford 4 (172 mg, 69%) after column chromatography (silica gel, hexane/ethyl acetate 20:1): \([\alpha]_D^2 = -6.5^\circ\) (c, 1.4 CHCl_3); \(R_F = 0.55\) (hexane/ethyl acetate 5:1); \(^1\)H NMR (300 MHz, CDCl_3): \(\delta = 7.27-7.34\) (m, 5 H, H-C(ar)), 4.53 (d, 1 H, J = 5.6 Hz, H-C(2)), 4.22 (d, 1 H, J = 5.6 Hz, H-C(4)), 4.10 (d, 1 H, J = 12.8 Hz, H_a-C(5)), 3.89 (d, 1 H, H_b-C(5)), 3.54 (s, 1 H, H_C(4a)), 1.94 (bs, 1 H, OH), 1.48, 1.36 (s, 3 H, 2 × CH_3(isopropyl)), 1.10 (s, 18 H, CH_3(TIPS)), 1.05 (s, 3 H, CH(TIPS)); \(^{13}\)C NMR (75 MHz, CDCl_3): \(\delta = 137.39\) (s, C_g(ar)), 128.19, 127.51 (d, C_g(ar)), 119.09 (C_g(isopropyl)), 84.47, 79.86 (d, C(2), C(3)), 77.67 (s, C(4)), 73.49 (t, CH_2(C(4)), 72.44 (t, C(5)), 71.40 (d, C(1)), 40.02 (t, C(4a)), 26.29, 24.64 (q, 2 × CH_3(isopropyl)), 18.06 (q, CH(TIPS)), 12.32 (d, CH(TIPS)); MS (ei, 80 eV, 113 °C): 358 (M, 0.1%), 343 (M – CH_3, 9.2%), 315 (M – isopropyl, 21.3%), 257 (100%); HRMS calcd. for C_{18}H_{34}O_{8}Si: 358.2176; found: 358.2175.

(4a R, 5 Z,E) 5-O-Benzyl-4a-carba-4-hydroxy-2,3-O-isopropylidene-1-O-triisopropylsilyl-\(\beta\)-d-erythro-pent-4-en-3-ol (6)

To a solution of freshly distilled diethylamine (256 mg, 3.50 mmol) in abs. diethyl ether (11 ml) at \(-10^\circ\) C-butyl lithium (1.7 ml, 1.6 M in hexane) was slowly added; stirring at this temperature was continued for 10 min, then a solution of I (500 mg, 1.11 mmol) in abs. diethyl ether (7 ml) was slowly added and the mixture warmed to room temperature within 6 h. The mixture was diluted with diethyl ether (20 ml), washed with a saturated aqueous solution of NH_4Cl (3 × 30 ml), brine (30 ml), dried (MgSO_4) and the solvent removed under reduced pressure. After chromatographic purification of the residue (silica gel, hexane/ethyl acetate 20:1 \(\rightarrow\) 10:1 containing 1% of triethylamine) 6 (250 mg, 0.60%) was obtained as a colorless oil; \([\alpha]_D^2 = +64.7^\circ\) (c, 1.2 CHCl_3); \(R_F = 0.45\) (hexane/ethyl acetate 5:1); \(^1\)H NMR (300 MHz, CDCl_3): \(\delta = 7.29-7.38\) (m, 5 H, H-C(ar)), 6.43 (dd, 1 H, J = 0.9, 2.3 Hz, H-C(5)), 4.86 (dd, vrt, 1 H, J = 2.0 Hz, H-C(4a)), 4.82 (d, 2 H, J = 1.4 Hz, CH_3(C(4)), 4.75 (d, 1 H, J = 5.6 Hz, H-C(3)), 4.43 (dd, vrt, 1 H, J = 5.3 Hz, H-C(2)), 3.92 (dd, 1 H, 4.9, 7.6 Hz, H-C(1)), 3.17 (d, 1 H, J = 1.8 Hz, OH), 1.42, 1.28 (q, 3 H, 2 × CH_3(isopropyl)), 1.11
A solution of 6 (600 mg, 1.34 mmol) in abs. THF (40 ml) was hydrogenated at atmospheric pressure in the presence of Pd/C (5%) for 4 h. After filtration, evaporation of the solvent and chromatographic purification (silica gel, hexane/ethyl acetate 20:1 → 10:1) gave 7 (120 mg, 99%); m.p. 100–101 °C; [α]_D^20 = −63° (c, 1.0 CHCl_3). 

Analysis for C_{59}H_{50}O_{11}N_5Si: Calcd C 59.43 H 6.78 N 4.34% , Found C 59.43 H 6.88 N 4.34%. 

Analysis for C_{25}H_{44}N_3O_9Si: (644.79)


(4a R) 5-O-Benzyl-4a-carba-2,3-O-isopropylidene-1-O-triisopropylsilyl-4a-(3,5-dinitrobenzoyl)-β-L-lyxofuranose = (3a R, 4 R, 5 R, 6 S, 6a R) 4-benzoxylmethyl-6-triisopropylsilylxylo-2,2-dimethylperhydro-cyclopent[a][1,3]dioxol-5-yl-3,5-dinitrobenzoate (8)
of BH₃·THF (4.2 ml, 1.1 equiv.) was slowly added. After stirring at this temperature for an additional 3 h, methanol (5 ml) was added, the mixture allowed to warm to 25 °C and 3 m NaOH solution (10 ml) and 30% H₂O₂ (30%, 10 ml) were added in succession. Stirring at 55 °C was continued for 1 h, then the mixture was diluted with diethyl ether (50 ml) and water (30 ml), the phases were separated, the aqueous layer was extracted with diethyl ether (3 × 50 ml), the combined organic layers were washed with brine (20 ml), dried (MgSO₄), the solvents removed under reduced pressure and the residue was subjected to chromatography (silica gel, hexane/ethyl acetate 20:1 → 1:1).

Data for 10. – [α]D²⁰ -23.6° (c, 0.6 CHCl₃); R₂ = 0.22 (hexane/ethyl acetate 1:1); ¹H NMR (250 MHz, CDC₁₃); δ = 7.35 - 7.28 (m, 5 H, H-C(ar)); 4.54 (s, 2 H, CH₂(ar)); 4.50 (1 H, J = 5.6 Hz, H-C(2)); 4.36 (1 H, J = 5.6 Hz, H-C(3)); 3.91 (dd, 1 H, J = 8.6, 10.1 Hz, H-C(4a)); 3.83 (dd, 1 H, J = 6.9, 9.0 Hz, Hₐ-C(Si)); 3.72 (1 H, J = 8.0 Hz, Hₐ-C(Si)); 3.67 (dd, 1 H, J = 5.4, 8.4 Hz, H-C(1)); 2.50 (bs, 1 H, OH); 1.96 - 1.86 (m, 1 H, H-C(4)); 1.40 (s, 3 H, CH₃(isopropyl)); 1.26 (s, 3 H, CH₃(isopropyl)); 0.92 (s, 9 H, CH₃ tert-butyl), 0.12 (s, 6 H, CH₂-Si); ¹³C NMR (62 MHz, CDC₁₃); δ = 138.20 (s, Cq(ar)); 128.39 (d, Cq(ar)), 127.64 (d, Cq(ar)), 110.28 (s, Cq(isopropyl)); 78.67, 77.72, 77.47, 76.34 (d, C(2), C(3), C(1), C(4a)); 73.48 (t, CH₂(ar)); 69.48 (t, C(5)); 44.17 (s, C(4)); 25.92 (q, CH₂(isopropyl)); 25.90 (q, CH₃ tert-butyl); 24.23 (q, CH₃(isopropyl)); 18.41 (s, Cq tert-butyl), -4.57 (q, CH₃-Si); -4.55 (q, CH₃-Si); MS (ei, 80 eV, 130 °C): 408 (0.3%), 351 (14.7%), 245 (3.7%), 185 (9.7%), 171 (3.8%), 159 (4.6%), 157 (4.8%), 143 (4.0%), 131 (5.4%), 129 (16.2%), 117 (10.5%), 116 (4.9%), 105 (3.3%), 101 (4.0%), 92 (20.5%), 91 (100%).

Analysis for C₉H₉O₃N₃Si (408.61)
Calcd C 64.67 H 8.88%.
Found C 64.44 H 8.99%.

Data for 11. – [α]D²⁰ -4.7° (c, 0.8 CHCl₃); R₂ = 0.44 (hexane/ethyl acetate 1:1); ¹H NMR (250 MHz, CDC₁₃); δ = 7.35 - 7.28 (m, 5 H, H-C(ar)); 4.63 (d, 1 H, J = 12.2 Hz, Hₐ-C₂H₂(ar)); 4.55 (d, 1 H, J = 11.9 Hz, Hₐ-C₂H₂(ar)); 4.53 (t, 1 H, J = 5.2 Hz, H-C(2)); 4.41 - 4.32 (m, 1 H, H-C(1)); 4.22 (d, 1 H, J = 4.9 Hz, H-C(3)); 3.68 (d, 1 H, J = 9.0 Hz, Hₐ-C₃(Si)); 3.43 (d, 1 H, J = 8.2 Hz, Hₐ-C₃(Si)); 2.61 (s, 1 H, OH); 1.47 - 1.26 (m, 2 H, H₂C(4a)); 1.43 (s, 3 H, CH₃(isopropyl)); 1.31 (s, 3 H, CH₃(isopropyl)); 0.90 (s, 9 H, CH₃ tert-butyl); 0.09 (s, 6 H, CH₃-Si); ¹³C NMR (62 MHz, CDC₁₃); δ = 138.08 (s, Cq(ar)), 128.45, 127.77, 127.72 (d, Cq(ar)), 111.17 (s, Cq(isopropyl)), 84.56, 79.89 (d, C(2), C(3)), 77.76 (s, C(4)), 75.34 (t, CH₂(ar)); 72.45 (t, C(5)), 71.58 (d, C(1)), 39.79 (t, C(4a)); 26.23 (q, CH₃(isopropyl)), 26.01 (q, CH₃ tert-butyl); 24.55 (q, CH₃(isopropyl)), 18.41 (s, Cq tert-butyl), -4.48 (q, CH₃-Si), -4.68 (q, CH₃-Si); MS (ei, 80 eV, 72 °C): 557 (1.4%), 550 (11.4%), 275 (2.1%), 225 (2.4%), 224 (11.2%), 150 (8.3%), 120 (3.9%), 92 (9.1%), 91 (100%).

Analysis for C₉H₉O₃N₃Si (557.71)
Calcd C 62.45 H 7.05 N 2.51%.
Found C 62.80 H 6.76 N 2.36%.
Compound 10 (100 mg, 0.25 mmol) was acylated in dry dichloromethane (5 ml) in the presence of pyridine (0.2 ml) and 3,5-dinitrobenzoyl chloride (63 mg, 0.27 mmol) for 12 h to afford after usual work up and chromatography (silica gel, hexane/ethyl acetate 20:1) 12 (138 mg, 90%). m.p. 150–153°C; R_f = 0.41 (hexane/ethyl acetate 5:1); 1H NMR (300 MHz, CDCl_3): δ = 9.00 (t, 1 H, J = 2.2 Hz, H-C(4')), 8.88 (d, 2 H, J = 2.2 Hz, H-C(2')), H-C (6')), 7.09–6.97 (m, 5 H, H-C(5')), 5.57 (dd, 1 H, J = 8.7, 10.4 Hz, H-C(3)), 4.65 (t, 1 H, J = 5.6 Hz, H-C(4)), 4.48 (t, 1 H, J = 5.6 Hz, H-C(2)), 4.38 (d, 1 H, J = 11.0 Hz, H_ACH_2(ar)), 4.28 (d, 1 H, J = 11.0 Hz, H_BCH_2(ar)), 4.11 (dd, 1 H, J = 5.7, 8.6 Hz, H-C(1')), 3.90 (dd, 1 H, J = 5.2, 9.3 Hz, H_ACH_3(isopropyl)), 3.60 (t, 2 H, J = 2.2 Hz, H-C_2(isopropyl)), 1.54 (s, 3 H, CH_3(isopropyl)), 1.33 (s, 3 H, CH_3(isopropyl)), 0.84 (s, 9 H, CH_3(tert-buty1)), 0.10, 0.02 (s, 6 H, CH_3-Si); 13C NMR (75 MHz, CDCl_3): δ = 137.71 (s, C_(benzyl)), 133.87 (s, C_(isopropyl)), 130.70, 128.97, 128.95, 127.64, 127.43, 127.41, 127.04 (d, C_(ar)), 110.76 (s, C_(isopropyl)), 86.34 (d, C(4a)), 76.40, 76.38, 76.37 (d, C(1)), 73.34 (t, C_(ar)), 67.61 (t, C(5)), 43.86 (d, C(4)), 26.08 (q, CH_3(isopropyl)), 25.68 (q, CH_3(tert-buty1)), 19.12 (q, C_(isopropyl)), 18.20 (q, C_(tert-buty1)), -4.73, -4.96 (q, CH_3-Si); MS (ei, 80 eV, 104°C): 498 (0.1%), 483 (0.8%), 441 (12.2%), 165 (20.0%), 155 (14.5%), 105 (13.0%), 91 (100%); HRMS calcd. for C_{36}H_{33}N_2O_2Si: 498.1930; found 498.1929.

5-O-Benzyl-1-O-(3-[(4a,4a,4a)-4a-carba-4,4a-O-[(S-methyl)-dithiocarboxyl]-2,3-O-isopropylidene-1-β-lyxofuranose-3′,5′-dinitrobenzyl]-2,3-O-isopropylidene-1-β-lyxofuranose-4-[(benzoxyl-methyl)-6-(tert-butyldimethylsilyloxy)-2,2-dimethyl-tetrahydro-cyclopenta[1,3]dioxol-5-yl)methansulfanyl methanithioate (14)

A solution of 14 (80 mg, 0.16 mmol) and phenylsilane (40 μl, 0.32 mmol) was heated under reflux and a solution of dibenzylpiperoxide (155 mg, dissolved in 2 ml toluene) was added in several portions within 20 min. The solvents were removed under reduced pressure and the residue subjected to column chromatography (silica gel, hexane/ethyl acetate 20:1) to afford 15 (135 mg, 44%). Besides unchanged starting material 10 (80 mg, 32%); m.p. 94–95°C; [α]_D^20 = −8.5° (c, 1.0 CHCl_3); R_f = 0.68 (hexane/ethyl acetate 5:1); 1H NMR (300 MHz, CDCl_3): δ = 7.33–7.25 (m, 5 H, H-C(ar)), 6.12 (dd, 1 H, J = 8.3, 10.6, H_B-C(4a)), 4.65 (t, 1 H, J = 5.5 Hz, H-C(5)), 4.48 (s, 2 H, CH_2(ar)), 4.41 (t, 1 H, J = 5.7 Hz, H-C(2)), 4.03 (dd, 1 H, J = 5.8, 8.3 Hz, H-C(1)), 3.84 (t, 1 H, J = 8.9 Hz, H_A-C(5)), 3.60 (dd, 1 H, J = 5.6, 9.3 Hz, H_B-C(5)), 2.52 (s, 3 H, S-CH_3), 2.23–2.17 (m, 1 H, H-C(4)), 1.49 (s, 3 H, CH_3(isopropyl)), 1.32 (s, 3 H, CH_3(isopropyl)), 0.87 (s, 9 H, CH_3(tert-buty1)), 0.09, 0.06 (s, 3 H, 2 x Si-CH_3); 13C NMR (62 MHz, CDCl_3): δ = 196.38 (s, C=O), 138.54 (s, C_(ar)), 128.37, 127.59, 127.41 (d, C_(ar)), 110.76 (s, C_(isopropyl)), 86.34 (d, C(4a)), 76.40, 76.38, 76.37 (d, C(1)), 73.34 (t, C_(ar)), 67.61 (t, C(5)), 43.86 (d, C(4)), 26.08 (q, CH_3(isopropyl)), 25.68 (q, CH_3(tert-buty1)), 24.63 (q, CH_3(isopropyl)), 19.12 (q, C-Si-CH_3), 18.20 (q, C_(tert-buty1)), -4.73, -4.96 (q, CH_3-Si); MS (ei, 80 eV, 104°C): 498 (0.1%), 483 (0.8%), 441 (12.2%), 165 (20.0%), 155 (14.5%), 105 (13.0%), 91 (100%); HRMS calcd. for C_{42}H_{41}N_2O_4Si: 498.1930; found 498.1929.
(1a R, 3a R, 6 S)-6-(Hydroxymethyl)-2,2-dimethyl-tetrahydrocyclopenta[1,3]dioxol-4-on (17)

Hydrogenation of (−)-16 (100 mg, 0.36 mmol) in methanol in the presence of hydrogen (atmospheric pressure) with Pd/C (10%, catalytical) for 24 h gave after usual work up and chromatography (silica gel, hexane/ethyl acetate 3:1 → 1:1) 17 (36 mg, 53%) and 18 (2.4 mg, 2.4%). Data for 17: m.p. 87–89 °C; [α]D20 –173.3° (c, 1.0 CHCl3); 1H NMR (250 MHz, acetone-d6): δ = 4.88 (dd, 1 H, J = 4.3, 4.5 Hz, H-C(3)), 4.28 (d, 1 H, J = 4.5 Hz, H-C(2)), 3.85 (dd, 1 H, J = 8.6, 10.8 Hz, H-A-C(5)), 3.74 (dd, 1 H, J = 6.8, 11.1 Hz, H-B-C(5)), 3.62 (bs, 1 H, OH), 2.55 (m, 1 H, H-C(4)), 2.25 (d, 2 H, J = 11.7 Hz, H-C(3A)), 1.34, 1.31 (s, 3 H, CH3(isopropyl)); 13C NMR (62.8 MHz, acetone-d6): δ = 213.69 (s, C(1)), 112.35 (s, C(4a(isopropyl))), 81.12, 78.82 (d, C(2)), 73.42 (d, C(3)), 62.33 (t, C(5)), 38.56 (d, C(4)), 37.30 (t, C(4a)), 27.06, 25.24 (q, CH3(isopropyl)); MS (FAB, matrix glycerol): 186 (31.2%, M), 185 (34.7%), 127 (32.8%), 111 (62.2%), 83 (41.8%), 69 (50.7%), 59 (100%); HRMS calcd. for C9H16O4: 186.0893; found: 186.0894.

5-O-Benzyl-4a-carba-2,3-O-isopropylidene-β-L-lyxofuranose = (3a R, 4 S, 6 S, 6a R) 6-(benzoxymethyl)-2,2-dimethyl-tetrahydro-cyclopenta[1,3]dioxol-4-ol (19)

Reduction of 18 (55 mg, 0.26 mmol) with sodium borohydride (10 mg, 0.26 mmol) and CeCl3·7H2O (60 mg, 0.16 mmol) in methanol (2 ml) as described (vide supra) gave 19 (35 mg, 66%). Data for 19. – [α]D20 87.0° (c, 1.0 CHCl3); Rf = 0.51 (hexane/ethyl acetate 1:1); 1H NMR (300 MHz, MeOH-d4): δ = 7.33–7.25 (m, 5 H, H-C(ar)), 4.57 (t, 1 H, J = 5.5 Hz, H-C(2)), 4.50 (s, 2 H, CH2(ar)), 4.43 (t, 1 H, J = 5.1 Hz, H-C(3)), 3.85 (dt, 1 H, J = 5.6, 11.2 Hz, H-C(1)), 3.67 (dd, 1 H, J = 7.9, 9.2 Hz, H-A-C(5)), 3.47 (dd, 1 H, J = 6.5, 9.3 Hz, H-B-C(5)), 1.99–1.94 (m, 1 H, H-C(4)), 1.80–1.77 (m, 1 H, H-C(4a)), 1.48–1.27 (m, 1 H, H-B-C(4a)), 1.43 (s, 3 H, CH3(isopropyl)), 1.31 (s, 3 H, CH3(isopropyl)); 13C NMR (75 MHz, MeOH-d4): δ = 139.67 (s, C(4a)), 129.14, 128.66, 128.42 (d, C(ar)), 111.18 (s, C(q(isopropyl))), 80.61, 80.41 (d, C(2,3)), 74.06 (t, C(4a(ar))), 73.35 (d, C(1)), 70.32 (t, C(5)), 40.27 (d, C(4)), 33.59 (t, C(4a)), 25.92, 24.26 (q, 2 × CH3(isopropyl)); MS (FAB, matrix glycerol + LiCl): 278 (100%), 277 (99%), 263 (45.5%), 92 (12.1%), 91 (100%); HRMS calcd. for C10H22O7: 278.1518; found: 278.1518.

4a-Carba-2,3-O-isopropylidene-β-L-lyxofuranose = (3a S, 4 S, 6 S, 6a R) 6-(hydroxymethyl)-2,2-dimethyl-tetrahydro-cyclopenta[1,3]dioxol-4-ol (20)

Reduction of 17 (50 mg, 0.33 mmol) with sodium borohydride (12 mg, 0.32 mmol) and CeCl3·7H2O (85 mg, 0.23 mmol) in methanol (3 ml) as described (vide supra) gave 20 (45 mg, 89%). Hydrogenation of 21 (0.5 g, 1.81 mmol) with Raney-nickel (catalytical) in water (10 ml) at 25 °C for 24 h gave 20 (0.18 g 52%) and 19 (0.18 g, 36%); reduction at 3 °C for 24 h gave 20 (traces) and 19 (94%). Data for 20. – [α]D20 87.0° (c, 1.0 CHCl3); Rf = 0.06 (hexane/ethyl acetate 1:1); 1H NMR (300 MHz, MeOH-d4); δ = 4.5 (t, 1 H, J = 5.4 Hz, H-C(2)), 4.44 (t, 1 H, J = 5.3 Hz, H-C(3)), 3.85 (dt, 1 H, J = 5.5, 11.1 Hz, H-C(1)), 3.74 (dd, 1 H, J = 7.5, 10.6 Hz, H-A-C(5)), 3.56 (dd, 1 H, J = 6.2, 10.6 Hz, H-B-C(5)), 1.90–1.74 (m, 2 H, H-A-C(4a)), 1.51–1.39 (m, 1 H, H-B-C(4a)), 1.44 (s, 3 H, CH3(isopropyl)), 1.30 (s, 3 H, CH3(isopropyl)); 13C NMR (75 MHz, MeOH-d4): δ = 111.18 (s, C(q(isopropyl))), 80.68, 80.40 (d, C(2,3)), 73.42 (d, C(1)), 61.93 (t, C(5)), 42.51 (d, C(4)), 33.30 (t, C(4a)), 25.91, 24.21 (q, 2 × CH3(isopropyl)); MS (FAB, matrix glycerol + LiCl): 189 (46.0%); MS (FAB, matrix glycerol + LiCl): 195 (100%); HRMS calcd. for C9H16O4: 188.1050; found: 188.1050.
(4a S) 5-O-Benzyl-1-O-(tert-butyldimethylsilyl)-4a-carba-4a-dihydroxy-2,3-O-isopropylidene-β-l-lyxofuranose (23) and (4a S, 5 S) 4,5-anhydro-5-O-benzyl-1-O-(tert-butyldimethylsilyl)-4a-carba-4a-hydroxy-2,3-O-isopropylidene-β-l-lyxofuranose (24)

To a solution of 22 (0.50 g, 1.18 mmol) in abs. dichloromethane (45 ml) pyridinium chlorochromate (0.375 g, 1.74 mmol), anhydrous sodium acetate (0.375 g, 4.57 mmol) and powdered molecular sieves 3 Å (0.70 g) were added and the stirring was continued for 18 h. Approx. 2/3 of the solvents were removed under reduced pressure and the resulting suspension poured onto the top of a chromatographic column containing diethylether. Chromatography with diethyl ether and re-chromatography of the combined product-containing fractions (silica gel, hexane/ethyl acetate 20:1) gave 23 (0.12 g, 25%) and 24 (0.13 g, 26%). Data for 23. – [α]D = −34.7 (c, 1.4 CHCl3); Rf = 0.68 (hexane/ethyl acetate 3:1); 1H NMR (250 MHz, CDCl3): δ = 7.60−7.32 (m, 5 H, H-C(ar)), 5.84 (s, 1 H, H-C(5)), 4.50 (dd, 1 H, J = 5.6, 5.7 Hz, H-C(2)), 4.41 (d, 1 H, J = 7.0 Hz, H-C(3)), 4.36 (d, 1 H, J = 8.9 Hz, H3-CH2(ar)), 4.12 (d, 1 H, J = 8.9 Hz, H3-CH2(ar)), 3.97 (dd, 1 H, J = 9.3, 9.5 Hz, H-C(4a)), 3.84 (dd, 1 H, J = 5.0, 8.9 Hz, H-C(1)), 1.95 (bs, 1 H, OH), 1.44, 1.32 (s, 3 H, CH3(isopropyl)), 0.92 (s, 9 H, CH3(tert-butyl)), 0.10, 0.11 (s, 3 H, Si-CH3); 13C NMR (62 MHz, CDCl3): δ = 137.10 (s, C6 (ar)), 130.09, 128.95, 127.05 (d, C(ar)), 111.82 (s, C3(isopropyl)), 104.15 (d, C(5)), 84.35 (s, C4), 80.52, 77.19, 77.00, 76.74 (d, C1), 76.48 (t, CH3(ar)), 76.21 (q, CH3(tert-butyl)), 24.61 (q, CH3(isopropyl)), 24.67 (s, C4(isopropyl), -4.19, -4.25 (q, Si-CH3); MS (FAB, glycerol): 424 (1.8%, M+1), 423 (7.4%, M), 422 (0.8%), 129 (9.5%), 107 (10.0%), 105 (16.4%), 93 (11.7%), 75 (48.6%), 73 (100%).

Analysis for C22H36O6Si (424.61)
Calcd C 62.53 H 8.11%
Found C 62.63 H 8.23%

Data for 24. – [α]D = −31.2° (c, 2.0 CHCl3); Rf = 0.62 (hexane/ethyl acetate 3:1); 1H NMR (250 MHz, CDCl3): δ = 7.65−7.30 (m, 5 H, H-C(ar)), 5.93 (s, 1 H, H-C(5)), 4.64 (d, 1 H, J = 9.0 Hz, H3-CH2(ar)), 4.47 (dd, 1 H, J = 4.7, 5.8 Hz, H-C(2)), 4.36 (d, 1 H, J = 6.0 Hz, H-C(3)), 4.03 (d, 1 H, J = 9.0 Hz, H3-CH2(ar)), 3.85−3.89 (m, 2 H, H-C(1), H-C(4a)), 2.05 (bs, 1 H, OH), 1.45, 1.32 (s, 3 H, CH3(isopropyl)), 0.95 (s, 9 H, CH3(tert-butyl)), 0.14 (s, 6 H, 2 × Si-CH3); 13C NMR (62.89 MHz, CDCl3): δ = 137.03 (s, C6 (ar)), 129.63, 128.43, 126.77 (d, C(ar)), 111.33 (s, C3(isopropyl)), 106.07 (d, C(5)), 84.16 (s, C4), 81.20, 76.52, 76.38 (d, C(1), C(2), C(3), C(4a)), 67.99 (t, CH3(ar)), 26.07, 24.32 (q, CH3(isopropyl)), 25.83 (q, CH3(tert-butyl)), 18.28 (s, C4(isopropyl), -4.58 (q, 2x CH3-Si); MS (ei, 80 eV, 141°C): 408 (0.5%, M+1), 407 (2.2%, M), 365 (22.6%), 307 (21.5%), 259 (11.0%), 201 (28.5%), 183 (15.95%), 155 (28.9%), 129 (65.4%), 107 (31.3%), 105 (29.4%), 75 (100.0%).
Analysis for C_{22}H_{34}O_{6}Si (422.59)
Calcd C 62.53 H 8.11%
Found C 62.65 H 8.19%

(4a S) 1-O-(tert-Butyldimethylsilyl)-4a-carba-4a-dihydroxy-2,3-O-isopropylidene-ß-L-lyxofuranose = (3a S, 4 S, 5 S, 6 S, 6a R)-6-tert-butylidemethylsilyloxy-4-hydroxymethyl-2,2-dimethyl-tetrahydro-cyclopenta[1,3]di-oxol-4,5-diol (25) and (4a S) 4a-carba-4a-dihydroxy-2,3-O-isopropylidene-ß-L-lyxofuranose (26)

A 1:1 mixture of the epoxides 23 and 24 (0.26 g, 0.60 mmol) was dissolved in methanol (25 ml) and hydrogenolyzed at atmospheric pressure in the presence of Pd/C (10%) for 24 h. After filtration and evaporation of the solvents, the residue was subjected to chromatography (hexane/ethyl acetate 5:1 → 3:1) to afford 25 (0.17 g, 84%) and 26 (13 mg, 10%).

A solution of 22 (0.43 g, 1.0 mmol) in dichloromethane (25 ml) and acetone (10 ml) was debenzylated with dimethyldioxirane (ca.

10% ). After filtration and evaporation of the solvents, the residue was subjected to chromantography (hexane/ethyl acetate 5:1 → 3:1) to afford 25 (0.17 g, 84%) and 26 (13 mg, 10%).

A solution of 22 (0.43 g, 1.0 mmol) in THF/methanol/water (9:1:1, 5 ml) with tetra-AI-butyl-ammonium fluoride trihydrate (20 mg) for 48 h afforded 26 (0.19 g, 87%). Data for 26. - white solid; m.p. 78-81 °C; [α]_D^20 = -29.0° (c, 1.0 CHCl₃); \( R_f = 0.37 \) (hexane/ethyl acetate 1:1); \(^1^H\) NMR (250 MHz, CDCl₃): \( δ = 4.47 \) (dd, \( J = 4.9, 5.9 \) Hz, 1 H, H-C(2)), 4.31 (d, \( J = 6.1 \) Hz, 1 H, H-C(3)), 4.03 (dd, \( J = 4.8, 8.8 \) Hz, 1 H, H-C(4a)), 3.74 (s, 2 H, H₂C(5)), 3.25 (bs, OH), 2.90 (bs, 2 H, OH), 1.45 (s, 3 H, CH₃(isopropyl)), 1.29 (s, 3 H, CH₃(isopropyl)), 0.93 (s, 9 H, 3 × CH₃(tert-butyl)), 0.13 (s, 6 H, 2 × CH₃-Si); \(^{13}C\) NMR (62 MHz, CDCl₃): \( δ = 111.07 \) (s, C₉(tert-butyl)), 81.65 (d, C(1)), 76.55, 76.54, 76.00 (d, C(2), C(3), C(4a)), 76.10 (s, C(4)), 64.55 (t, C(5)), 25.85 (q, CH₃(tert-butyl)), 25.75 (q, CH₃(isopropyl)), 23.96 (q, CH₃(isopropyl)), 18.21 (s, C₉(tert-butyl)), -4.69 (q, CH₃-Si), -4.76 (q, CH₃-Si); MS (FAB, glycerol): 337 (M⁺, 20.0%), 336 (M⁺+1, 6.0%), 335 (M, 29.1%), 73 (100%); MS (FAB, glycerol + LiCl): 341 (M⁺+Li, 68.0%), 99 (100%); HRMS calcd. for C₁₅H₃₀O₆Si: 334.1811 found: 334.1812.

Analysis for C₁₅H₃₀O₆Si (334.49)
Calcd C 53.86 H 9.04%
Found C 53.92 H 9.04%

Data for 26. - white solid; m.p. 78-81 °C; [α]_D^20 = -25.7° (c, 1.0 CHCl₃); \( R_f = 0.07 \) (hexane/ethyl acetate 1:1); \(^1^H\) NMR (250 MHz, CDCl₃): \( δ = 4.59 \) (m, 1 H), 4.38 (m, 2 H), 4.05 (m, 2 H), 3.84 (m, 1 H), 3.77 (m, 1 H), 1.47 (s, 3 H, CH₃(isopropyl)), 1.33 (s, 3 H, CH₃(isopropyl)); \(^{13}C\) NMR (62 MHz, CDCl₃): \( δ = 111.15 \) (s, C₉(isopropyl)), 81.72, 77.19, 75.63, 74.72 (d, C(1)), (C(2), C(3), C(4a)), 76.85 (s, C(4)), 60.89 (t, C(5)), 25.82, 23.75 (q, CH₃(isopropyl)); MS (EI, 80 eV, 118 °C): 220 (0.05%), 205 (25.5%), 171 (1.4%), 144 (7.4%), 127 (5.0%), 109 (11.7%), 103 (31.1%), 100 (39.0%), 85 (49.6%), 73 (56.5%), 72 (55.0%), 71 (34.4%), 59 (100%); HRMS calcd. for C₁₉H₁₆O₂Si: 220.0947; found: 220.0947.

Analysis for C₁₉H₁₆O₂Si (318.49)
Calcd C 56.57 H 9.49%
Found C 56.88 H 9.22%

(4a S) 1-O-(tert-Butyldimethylsilyl)-4a-carba-4a-hydroxy-2,3-O-isopropylidene-ß-L-lyxofuranose = (3a R, 4 R, 5 R, 6 S, 6a R)-6-(tert-butylidemethylsilyloxy)-4-hydroxymethyl-2,3-dimethyl-tetrahydro-cyclopenta[1,3]dioxol-5-ol (27)

Following the debenzylolation procedure given for 22, from 10 (0.41 g, 1.0 mmol) 27 (0.28 g, 88%) was obtained after chromatographic work up (silica gel, hexane/ethyl acetate 20:1 → 10:1); m.p. 92-94 °C; [α]_D^20 = -15.9° (c, 1.1 CHCl₃); \( R_f = 0.60 \) (hexane/ethyl acetate 3:1); \(^1^H\) NMR (250 MHz, CDCl₃): \( δ = 4.56 \) (t, 1 H, J = 5.8 Hz), 4.34 (t, 1 H, J = 5.7 Hz), 4.10-3.70 (m, 1 H), 3.63 (dd, 1 H, J = 5.4, 8.5 Hz), 2.60 (bs, 2 H, exchangeable with D₂O), HO-C(4a), HO-C(5)), 1.65 (m, 1 H, H-C(4)), 1.42 (s, 3 H, CH₃(isopropyl)), 1.25 (s, 3 H, CH₃(isopropyl)), 0.93 (s, 9 H, 3 × CH₃(tert-butyl)), 0.10 (s, 6 H, 2 × CH₃-Si); \(^{13}C\) NMR (62 MHz, CDCl₃): \( δ = 110.31 \) (s, C₉(isopropyl)), 78.58, 77.53, 77.14, 75.00 (d, C(1), C(2), C(3), C(4a), 60.65 (t, C(5)), 44.92 (d, C(4)), 25.86 (q, 3 × CH₃(tert-butyl)), 25.76 (q, CH₃(isopropyl)), 23.82 (q, CH₃(isopropyl)), 18.33 (s, C₉(tert-butyl)), -4.56 (q, CH₃-Si); MS (EI, 80 eV, 62 °C): 318 (0.1%), 303 (3.8%), 262 (2.5%), 261 (14.4%), 203 (43.5%), 185 (33.6%), 161 (19.9%), 157 (20.4%), 155 (10.2%), 129 (35.8%), 117 (18.7%), 111 (11.6%).

Analysis for C₁₅H₃₀O₆Si (318.49)
Calcd C 56.57 H 9.49%
Found C 56.88 H 9.22%

(4a S) 1,4a-Anhydro-5-O-benzyl-1-O-(tert-butylidemethylsilyl)-4a-carba-2,3-O-isopropylidene-ß-L-lyxofuranose = (1 S, 4a R, 5 R, 6 S)-5-(benzoxoxy-methyl)-3,3-dimethyl-tetrahydro-1,2,4-trioxycycloprop[a] pentalene (28)

To a solution of 10 (35 mg, 0.1 mmol) in abs. dichloromethane (2 ml) DAST (70 μl) was slowly added at -78 °C. The mixture was allowed to...
warm to room temperature and stirred for an additional 2 h, then cooled to 0 °C, and ice water (2 ml) was added. After extraction with dichloromethane (3 × 10 ml), the mixture was dried (MgSO₄), the solvent removed and the residue purified by chromatography (silica gel, hexane/ethyl acetate 5:1) to afford 28 (15 mg, 63%); [α]_D = -16.7° (c, 0.6 CHCl₃); R_F = 0.28 (hexane/ethyl acetate 5:1); ¹H NMR (300 MHz, CDC₁₃): 4.70 (dd, 1 H, J = 1.6, 6.7 Hz), 4.62 (d, 1 H, J = 11.5 Hz, H₅-CH₂(ar)), 4.61 (t, 1 H, J = 6.9 Hz), 4.55 (d, 1 H, J = 11.9 Hz, H₄-CH₂(ar)), 3.84 (dd, 1 H, J = 6.2, 9.2 Hz), 3.79 (t, 1 H, J = 8.8 Hz), 3.65 (d, 1 H, J = 1.3 Hz, H₅-C(5)), 3.51 (d, 1 H, J = 1.3 Hz, H₃-C(5)), 2.50 (ddt, 1 H, J = 1.4, 6.7, 7.5 Hz, H-C(4)), 1.52, 1.27 (s, 3 H, CH₃(isopropyl)); ¹³C NMR (62 MHz, CDCl₃): δ = 138.46 (s, C₅(ar)), 128.37, 127.69, 127.60 (d, C₅(ar)), 112.21 (s, C₅(isopropyl)), 80.58, 78.71 (d, C(2), C(3)), 73.46 (t, CH₃(ar)), 66.59 (t, C(5)), 60.61, 57.36 (d, C(1), C(4a)), 43.26 (d, C(4)), 26.44, 25.45 (q, CH₅(isopropyl)); MS (ei, 80 eV, 90 °C): 276 (0.5%), 275 (0.6%), 262 (3.2%), 261 (18.8%), 145 (7.2%), 98 (11.1%), 91 (100%); HRMS calcd. for C₁₆H₂₀O₄: 276.1361; found: 276.1360.

Acknowledgements

Financial support by the European Communities (SC1*-CT92-0780) and the Fonds der Chemischen Industrie is gratefully acknowledged; we are indebted to Dr. P. Rosyk for his help preparing the manuscript and to Professor Dr. R. Neidlein, Pharmazeutisch-Chemisches Institut, Universität Heidelberg, for his encouragement. We are grateful to Mrs. U. Wiesinger, Organisch-Chemisches Institut, Universität Heidelberg, for the preparation of suitable crystals of 13.