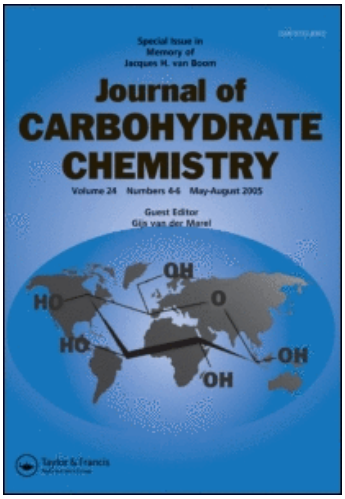

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Stereocontrolled Conversion of Allylic Alcohols Into Vicinal Cis-Diols: New Syntheses of Methyl α-L-Digitoxoslde and Methyl 2-Deoxy-α-L-Fucoside

Henry W. Pauls[a]; Bert Fraser-reid[a]

[a] Paul M. Gross Chemical Laboratories, Duke University, Durham, North Carolina

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STEREOCONTROLLED CONVERSION OF ALLYLIC ALCOHOLS INTO VICINAL CIS-DIOLS: NEW SYNTHESES OF METHYL α-L-DIGITOXOSIDE AND METHYL 2-DEOXY-α-L-FUCOSIDE

Henry W. Pauls and Bert Fraser-Reid*

Paul M. Gross Chemical Laboratories
Duke University
Durham, North Carolina 27706

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ABSTRACT

A synthetic process is outlined in which an allylic alcohol is converted into its primary urethane derivative, which is then subjected to iodonium ion induced cyclization to give a single iodo-carbonate. The carbonate is then deiodinated reductively and hydrolyzed to afford the vicinal diol. By use of this process the two title sugars have been prepared from methyl 2,3,6-trideoxy-α-L-erythro-hex-2-enopyranoside and its α-L-threo counterpart.

INTRODUCTION

As part of our program on the development of routes to cis-hydroxyamino sugars, we have recently described the syntheses of a number of aminodeoxy sugars.[1] In the course of developing our strategies for these syntheses we encountered certain reactions which, although initially unwanted, appeared to be potentially valuable for other synthetic targets. Accordingly we describe here the syntheses of the L-digitoxose and 2-deoxy-L-fucose skeleta.

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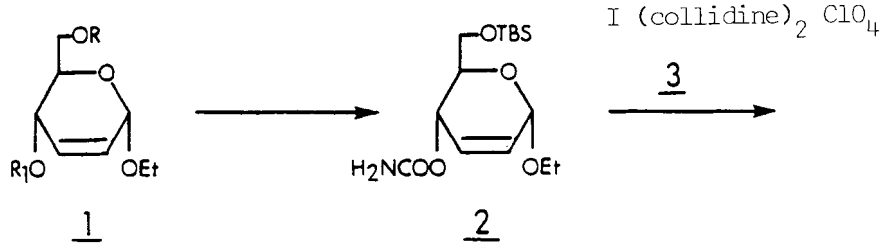
Barluenga and co-workers[2] have reported the intermolecular, Hg(II) induced addition of urethanes to isolated double bonds. We wished to examine an intramolecular version of this process, and the required urethane, 2, (ethyl 6-O-tert-butyldimethylsilyl-4-O-carbamoyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside) was obtained by ammonolysis of the mixed carbonate 1c which in turn had been prepared from alcohol 1b (ethyl 6-O-tert-butyldimethylsilyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside) by treatment with p-nitrophenyl chloroformate. It turned out that Hg(II)-induced cyclization of 2 was unsuccessful. We therefore tried iodonium dicollidine percholorate, 3,[1] with chloroform as solvent. The reaction of 2 with 3 was very slow, but with acetonitrile as solvent, the starting materials were consumed over a period of 24 hours.

The course of the reaction as followed by thin layer chromatography proved to be very instructive. The disappearance of the starting material 2 was followed by the emergence of two products of R_f, 0.55 and 0.62 (see Experimental). The product of lower R_f did not survive the work-up procedure, but the higher-running product proved to be the trans-iodo-carbonate 5a, (ethyl 6-O-tert-butyldimethylsilyl-2-deoxy-2-iodo-α-D-altro-pyranoside 3,4-carbonate). The unstable, unisolable substance was presumed to be the trans-iodo-iminocarbonate 4. Support for this assignment came from the fact that as the reaction proceeded, the proportion of 5a increased at the expense of 4. Furthermore, the relative amounts of 4 and 5a were dependent on the water content of the reaction medium [vide infra]. Comparable hydrolysis of an iminocarbonate has been reported independently by Copeland and Stick.[3] The reduction of iodo-carbonate 5a with tri-n-butyltin hydride gave the expected 2-deoxy compound 5b which was characterized as the corresponding alcohol 5c (ethyl 2-deoxy-α-D-ribo-hexopyranoside 3,4-carbonate).

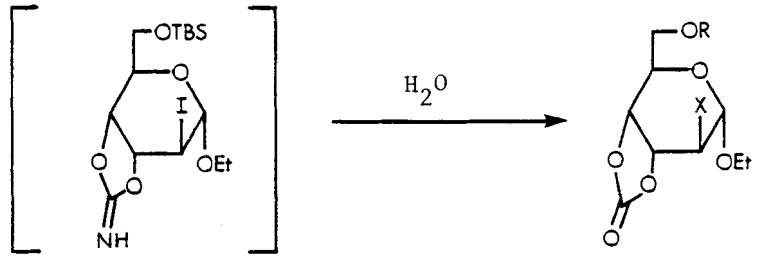
The side products from the reactions in Scheme I gave no evidence for cyclic urethanes thereby indicating that the reaction of 2 had given compound 5a as the only product of

SCHEME 1



1 2

	R	R_1
a	H	H
b	TBS	H
c	TBS	$CO_2C_6H_4pNO_2$



4 5

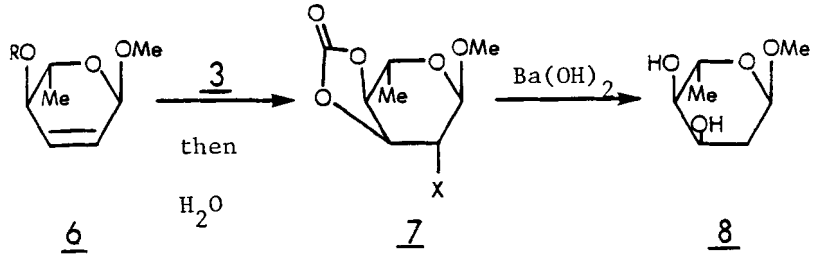
TBS = tert-butyldimethylsilyl

	X	R
a	I	TBS
b	H	TBS
c	H	H

cyclization. In order to utilize this exploratory study for specific syntheses, a number of operational changes were made.

First, a more convenient and efficient route to the primary urethanes had to be developed that was more convenient, and proceeded in better yield. It was determined that compound 6c, (methyl 4-O-carbamoyl-2,3-6,-trideoxy-α-L-threo-hex-2-enopyranoside) could be obtained in overall quantitative yield

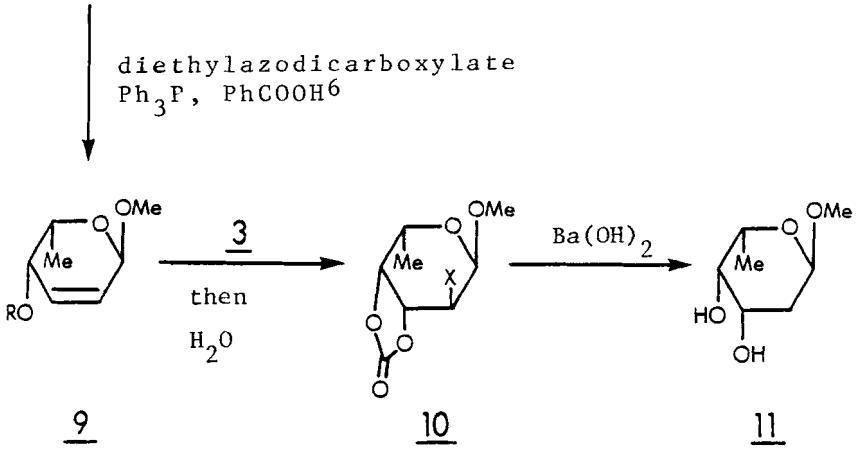
SCHEME 2



6 7 8

a R = H
b R = $CONHCOCCl_3$
c R = $CONH_2$

a X = I
b X = H



9 10 11

a R = Bz
b R = H
c R = $CONH_2$

from the allylic alcohol 6a (methyl 2,3-6-trideoxy-α-L-threo-hex-2-enopyranoside) via the N-trichloroacetyl carbamate 6b.[4] Second, guided by our preliminary observations on the conversion 4 --> 5a in Scheme 1, [vide supra]; the urethane 6c was treated with iodonium dicollidine perchlorate (3), until all the starting material had been consumed (TLC), and a few drops of water were

added to the reaction mixture to speed up the iminocarbonate --> carbonate conversion. After stirring overnight, the reaction mixture was washed with dilute hydrochloric acid followed by saturated solutions of sodium bicarbonate and sodium thiosulphate. In this way the trans-iodo-carbonate 7a (methyl 2,6-dideoxy-2-iodo- α-L-altropyranoside 3,4-carbonate) was obtained in 78% yield. Deiodination and hydrolysis then afforded methyl α-L-digitoxoside (8), whose 250 MHz ^{1}H-NMR spectrum and optical rotation were consistent with those in the literature.[5]

For the synthesis of 2-deoxy-L-fucose, the C4 oxygen of 6a was epimerized by the Mitsunobu reaction[6] and the derived alcohol 9b was converted by a similar sequence of reactions into 11.

The hydrolyses of the glycosides 8 and 11 to the free sugars are straightforward, the latter conversion having been described previously.[7]

While our work was in progress a related series of reactions based on homoallyl urethanes was described by Hirama and Uei[8] as a stereoselective method for making 1,3-diols.

EXPERIMENTAL

General Methods Melting points were determined in capillary tubes on a Buchi model 510 apparatus, and are uncorrected. Elemental analyses were performed by M-H-W Laboratories, P. O. Box 15149, Phoenix, AZ. High resolution mass spectra (HRMS) were performed at the Research Triangle Institute, Research Triangle Park, NC. Optical rotations ($[\alpha]^{23}$) were determined at the sodium D line on a Perkin-Elmer 241 polarimeter. Infrared spectra (ν_{max}) were determined on a Perkin-Elmer IR-297 using sodium chloride cells and chloroform as solvent for solids, or sodium chloride plates for thin film smears.

Proton magnetic resonance spectra (^{1}H NMR) were recorded on the following spectrometers: 60 MHz, Varian Em-360A; 80 MHz, Bruker NR-80; 100 MHz, Varian XL-100; 250 MHz, Bruker WM-250. Tetramethylsilane (in deuterochloroform) was used as an internal standard for the 60 MHz spectra; residual chloroform was used as a standard in all other ^{1}H-NMR spectra. The reported coupling

constants were obtained by measuring the spacings of the relevant signals in the spectra assumed to be first order.

The progress of all reactions was monitored by thin layer chromatography (TLC) using one of the following solvent systems: A, ethyl acetate-light petroleum ether, 1:9; B, 1:4; C, acetone-light petroleum ether, 1.5:8.5; D, methanol-methylene chloride, 1:24; E, 1:9. Flash column chromatography was performed using Merck Kieselgel 60 (230-400 mesh A.S.T.M.).

Ethyl 6-O-tert-Butyldimethylsilyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside 1b. Ethyl 2,3-dideoxy-α-D-erythro-hex-2-enopyranoside, 1a (2.27 g, 13.0 mmol) was dissolved in dry pyridine (50 mL) and tert-butyldimethylsilyl chloride (2.54 g, 16.9 mmol) was added. The solution was stirred with the exclusion of moisture for one day, and then was poured into cold 5% hydrochloric acid (100 mL) and the mixture was extracted with methylene chloride (2 x 75 mL). The organic layers were dried and concentrated, and residual pyridine was removed azeotropically with toluene. The resulting residue was chromatographed (solvent B) to yield 1b (3.24 g, 86%) as a syrup; R_f 0.30 (solvent B); $[\alpha]_D^{23}$ + 21.8° (c 1.2, $CHCl_3$); ν_{max}^{NaCl} 3450 (OH) cm^{-1}; ^{1}H-NMR data (60 MHz, $CDCl_3$) δ 0.11 (s, 6H, $Si(CH_3)_2$), 0.92 (s, 9H, $Si(CH_3)_3$), 1.23 (t, 3H, $OCH_2\underline{CH_3}$), 2.85 (bd, 1H, OH), 3.35-4.36 (m, 6H, H-4, H-5, H-6, H-6', $O\underline{CH_2}CH_3$), 4.97 (bs, 1H, H-1), 5.57-6.10 (m, 2H, H-2, H-3).

Anal. Calcd for $C_{14}H_{28}O_4Si$: C, 58.29; H, 9.79. Found: C, 58.07; H, 9.92.

Ethyl 6-O-tert-Butyldimethylsilyl-4-O-carbamoyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside 2. The alcohol obtained above (1b) (0.245 g, 0.849 mmol) was dissolved in dry methylene chloride (25 mL) to which was added 4-dimethylaminopyridine (0.016 g, 0.13 mmol) and triethylamine (0.18 mL, 1.29 mmol). The solution was cooled in an ice bath, then treated with 4-nitrophenyl chloroformate (0.203 g, 1.01 mmol) and stirred at room temperature with the exclusion of moisture. After 4 h more 4-nitrophenyl chloroformate (0.101 g,

0.50 mmol) was added and the reaction was monitored by TLC. Upon completion (24 h) the solution was poured into 5% hydrochloric acid (25 mL), the layers were separated, and the aqueous phase was extracted with methylene chloride (2 x 25 mL). The organic layers were combined, washed with saturated aqueous bicarbonate (25 mL), dried, and concentrated to ca. 15 mL containing 1c. The solution was diluted with methanol (35 mL), saturated with ammonia gas, and upon stirring at room temperature for 1 h, an intense yellow color developed. The solvent was removed and the residue was dissolved in methylene chloride (50 mL) and washed with N sodium carbonate (5 x 10 mL). The organic layer was dried and concentrated and the resulting residue was purifeid by flash chromatography (solvent B) to yield amorphous 2 (0.207 g, 73.5%); R_f 0.18 (solvent B); $[\alpha]_D^{23}$ +93.7° (c 1.3, $CHCl_3$); $\nu_{max}^{CHCl_3}$ 3435, 3355, 3280, 3205(NH_2), 1727 (C=O) cm^{-1}; ^1H NMR. (60 MHz, $CDCl_3$); δ 0.09 (s, 6H, $Si(CH_3)_2$, 0.95 (s, 9H, $SiC(CH_3)_3$), 1.23 (t, 3H, $OCH_2\underline{CH})_3$), 3.32-4.16 (m, 5H, H-5, H-6, H-6', $O\underline{CH}_2CH_3$), 5.00-5.34 (m, 4H, H-1, H-4, NH_2), 5.67-6.12 (m, 2H, H-2, H-3).

Anal. Calcd for $C_{15}H_{29}NO_5Si$: C, 54.35; H, 8.82; N, 4.23. Found: C, 54.40; H,8.98, N, 4.23.

Ethyl 6-O-tert-Butyldimethylsilyl-2-deoxy-2-iodo-α-D-altropyranoside 3,4-Carbonate 5a. The urethane prepared above, 2, (0.273 g, 0.825 mmol) was dissolved in acetonitrile and iodonium dicollidine perchlorate 3 (0.387 g, 0.826 mmol) was added. The reaction mixture was stirred at room temperature in the dark, and a fresh equivalent of complex 3 was added after six-hour periods. The course of the reaction was monitored by TLC until all of the starting material was consumed, typically 24 h. The acetonitrile was removed and the residue was redissolved in methylene chloride (15 mL). Ethyl ether (60 mL) was added and the precipitate was removed by filtration. The filtrate was washed with 10% sodium thiosulfate, 5% hydrochloric acid, and aqueous saturated bicarbonate, then dried, and concentrated. Chromatography (solvent B) yielded starting material 2 (0.020 g, 7%) and iodo-carbonate 5a (0.241 g, 64%). The iodo-carbonate 5a

showed R_f 0.62 (solvent B); $[\alpha]_D^{23}$ +16.0° (c 0.95, $CHCl_3$); ν_{max}^{NaCl} 1815 (C=O) cm^{-1}); ^1H NMR (80 MHz, $CDCl_3$), δ 0.10 (s, 6H, $Si(CH_3)_2$), 0.92 (s, 9H, $Si(CH_3)_3$), 1.22 (t, 3H, $OCH_2\underline{C}H_3$), 3.20-4.50 (m, 6H, H-2, H-5, H-6, H-6', $OC\underline{H}_2CH_3$), 4.65-5.35 (m, 3H, H-1, H-3, H-4).

Anal. Calcd for $C_{15}H_{27}IO_5Si$: C, 40.73; H, 6.15; I. 28.69. Found: C, 40.52; H, 6.02; I, 28.47.

Ethyl 2-Deoxy-α-D-ribo-hexopyranoside 3,4-carbonate, 5c. The above described iodo-carbonate, 5a, (0.155 g, 0.338 mmol) was dissolved in 25 mL of dry toluene and to the solution was added tri-n-butyltin hydride (0.18 mL, 0.60 mmol) and isobutyronitrile (0.010 g, 0.007 mmol). The mixture was boiled under reflux for 3 h. The toluene was removed by distillation under vacuum and the resultant residue was partitioned between acetonitrile (20 mL) and hexane (40 mL). The layers were separated and the hexane phase was washed twice more with acetonitrile (2 x 20 mL). The acetonitrile layers were combined and concentrated to yield a syrupy residue which was chromatographed (solvent B) to give the carbonate 5a (0.088 g, 78%); R_f 0.37 (solvent B); $[\alpha]_D^{23}$ +93.8° (c 1.1, $CHCl_3$); ν_{max}^{NaCl} 1810 (C=O), 1460, 1360, 1250 cm^{-1}; ^1H NMR. (80 MHz; $CDCl_3$): δ 0.09 (s, 6H, $Si(CH_3)_2$), 0.90 (s, 9H, $SiC(CH_3)_3$), 1.20 (t, 3H, $OCH_2\underline{C}H_3$), 2.0-2.27 (m, 2H, H-2, H-2'), 3.26-4.05 (m, 5H, H-5, H-6, H-6', $OC\underline{H}_2CH_3$), 4.50-5.00 (m, 3H, H-1, H-3, H-4). Carbonate 5a (0.084 g, 0.253 mmmol) was treated with tetra-n-butylammonium fluoride (0.14 mL of 1.0 M, 0.14 mmol) in dry THF (10 mL), for 2 h at room temperature and the solvents were removed. The resultant residue was chromatographed (solvent E) to yield alcohol 5c (0.029 g, 53%); R_f 0.28 (solvent E); $[\alpha]_D^{23}$ +129.5 (c 0.5, $CHCl_3$); ν_{max}^{NaCl} 3300 (OH), 1795 (C=O), 1630, 1350 cm^{-1}; ^1H NMR (100 MHz, $CDCl_3$): δ 1.24 (t, 3H, $OCH_2\underline{C}H_3$), 1.85 (bs, 1H, OH), 2.24 (m, 2H, H-2, H-2'), 3.32-4.06 (m, 5H, H-5, H-6, H-6', $OC\underline{H}_2CH_3$), 4.64-5.05 (m, 3H, H-1, H-3, H-4).

Anal. Calcd for $C_9H_{14}O_6$: C, 49.54; H, 6.47. Found: C, 49.46; H, 6.42.

Methyl 4-O-Carbamoyl-2,3,6-trideoxy-α-L-threo-hex-2-enopyranoside 6c. (a) Methyl 2,3,6-trideoxy-α-L-threo-hex-2-enopyranoside, 6a, (2.24 g, 15.6 mmol) was treated with 4-nitrophenyl chloroformate (4.82 g, 24.2 mmol) followed by ammonia in a manner identical to that used for the preparation of urethane 2. The residue obtained after workup was chromatographed (solvent D) to give solid 6c (1.54 g, 53%). the product was recrystallized from ethyl acetate: mp 143-143.5°C; R_f 0.20 (solvent D); $[\alpha]_D^{23}$ -173.3° (c 0.5, $CHCl_3$); $\nu_{max}^{CHCl_3}$ 3545, 3510, 3435, 3345 (NH_2), 1725 (C=O) cm^{-1}; ^1H NMR (60 MHz, $CDCl_3$): δ 1.24 (d, 3H, CH_3, $J_{5,6}$ = 6 Hz), 3.47 (s, 3H, OCH_4), 3.90 (dq, 1H, H-5, $J_{4,5}$ = 9.5 Hz), 4.86 (s, 1H, H-1), 4.96 (d, 1H, H-4), 5.16 (bs, 2H, NH_2), 5.6-6.10 (m, 2H, H-2, H-3).

Anal. Calcd for $C_8H_{13}NO_4$: C, 51.33; H, 7.00; N, 7.48. Found: C, 51.10; H, 7.27; N, 7.71.

(b) Alcohol 6a (1.802 g, 12.5 mmol) was dissolved in dry methylene chloride (125 mL) and the solution cooled to 0°C. Trichloroacetyl isocyanate (2.60 g, 13.8 mmol) was then added and the reaction mixture was stirred with the exclusion of moisture for 30 min whereupon a less polar product (R_f 0.55, solvent D), presumably 6b was produced. A saturated solution of potassium carbonate in 50% aqueous methanol was added and the mixture was stirred for 2 h at room temperature. The layers were separated; the organic layer was washed with brine, dried, and concentrated. The white solid obtained (2.34 g, 100%) was identical to 6c above.

Methyl 2,6-Dideoxy-2-iodo-α-L-altropyranoside 3,4-carbonate 7a. Urethane 6c (0.133 g, 0.711 mmol) was treated with complex 3 as described for the preparation of 5a with the following modification; after all of the starting material had been consumed, a few drops of water were added and the reaction was stirred for another 12 h. The order of aqueous washes was also changed to 5% hydrochloric acid, followed by saturated sodium bicarbonate, then finally 10% sodium thiosulfate. The organic layer was processed in the usual way, then chromatographed

(solvent D) to yield iodo-carbonate 7a (0.174 g, 78%). The product was recrystallized from ether; mp 122°C (decomposition), R_f 0.62 (solvent D); $[\alpha]_D^{23}$ -5.4°; $\nu_{max}^{CHCl_3}$ 1810 (C=O) cm^{-1}; ^1H NMR (60 MHz, $CDCl_3$): δ 1.40 (d, 3H, CH_3, $J_{5,6}$ = 6.0 Hz), 3.44 (s, 3H, OCH_3), 3.72-4.62 (m, 3H, H-2, H-4, H-5), 4.80-5.20 (m, 2H, H-1, H-3).

Anal. Calcd for $C_8H_{11}IO_5$: C, 30.59; H, 3.53; I, 40.41. Found: C, 30.77; H, 3.75; I, 40.28.

Methyl 2-Deoxy-α-L-ribo-hexopyranoside 3,4-Carbonate 7b. The iodo-carbonate prepared above, 7a, (0.394 g, 1.25 mmol) was deiodinated as previously described for 5a to yield carbonate 7b (0.201 g, 85%) after chromatography (solvent E). The syrupy product did not give satisfactory elemental analysis but showed R_f 0.55 (solvent D); $[\alpha]_D^{23}$ -110.7° (c 0.97, $CHCl_3$); ν_{max}^{NaCl} 1807 (C=O), 1450, 1355, 1176, 1153, 1068, 1040 cm^{-1}; ^1H NMR (60 MHz, $CDCl_3$) δ 1.37 (d, 3H, CH_3, $J_{5,6}$ = 6.0 Hz), 2.10-2.36 (m, 2H, H-2, H-2'), 3.40 (s, 3H, OCH_3), 3.66-4.45 (m, 2H, H-4, H-5, $J_{3,4}$ = 6.5, $J_{4,5}$ = 8.5 Hz), 4.65-5.0 (m, 2H, H-1, H-3). HRMS: m/s 188.0687 (calcd for M^+ 188.0685).

Methyl α-L-Digitoxoside 8. A portion of carbonate 7b obtained above (0.073 g, 0.388 mmol) was dissolved in 50% aqueous methanol (20 mL) and to the solution was added barium hydroxide octahydrate (0.15 g, 0.475 mmol). The mixture was boiled under reflux for 30 min, then cooled. A few lumps of dry ice were added with stirring and the resultant precipitate was filtered through Celite. The filtrate was concentrated to give a solid residue which was chromatographed (solvent E) to yield syrupy 8 (0.040 g, 64%); R_f 0.38 (solvent E); $[\alpha]_D^{23}$ -158.4° (c 0.07, $CHCl_3$); ν_{max}^{NaCl} 3420 (OH) cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$, D_2O exchanged): δ 1.31 (d, 3H, CH_3, $J_{5,6}$ = 6.5 Hz), 1.88 (dt, 1H, H-2a, $J_{2a,2e}$ = 15 Hz, $J_{2a,1}$ = $J_{2a,3}$ = 3.5 Hz), 2.15 (ddd, H-2e, 1H, $J_{2e,1}$ = f1.5 Hz, $J_{2e,3}$ = 3.5 Hz), 3.11 (d, 1H, H-4, $J_{3,4}$ = 3.0 Hz, $J_{4,5}$ = 9.5 Hz), 3.36 (s, 3H, OCH_3), 3.68 (dq, 1H, H-5), 3.91 (bd, 1H, H-3), 4.72 (d, 1H, H-1).

Anal. Calcd for $C_7H_{14}O_4$: C, 51.84; H, 8.70. Found: C, 52.06; H, 9.00.

Literature[5] reports for 8: $[\alpha]_D^{23}$ -170.7° (c 1.0, $CHCl_3$); ^1H NMR (100 MHz, $CDCl_3$, D_2O exchanged): δ 1.32 (CH_3, $J_{5,6}$ = 6.2 Hz), 1.89 (H-2a, $J_{2a,2e}$ = -14.5 Hz, $J_{2a,1}$ = 3.4 Hz, $J_{2a,3}$ = 3.5 Hz), 2.15 (H-2e, $J_{2e,1}$ = 1.2 H, $J_{2e,3}$ = 3.0 Hz), 3.10 (H-4, $J_{3,4}$ = 3.5 Hz, $J_{4,5}$ = 10.2 Hz), 3.37 (OCH_3), 3.71 (H-5), 3.92 (H-3), 4.76 (H-1).

Methyl 2,3,6-Trideoxy-α-L-threo-hex-2-enopyranoside 9b. A solution of triphenylphosphine (1.89 g, 7.21 mmol) in dry THF (20 mL) was blanketed with argon and cooled in a dry ice/acetone bath. A solution of diethyl azodicarboxylate (1.14 mL, 7.21 mmol) in dry THF (5 mL) was added slowly, with stirring. After approximately 30 min at -10°C a solid had formed and a solution of alcohol 6a (0.519 g, 3.60 mmol) and benzoic acid (0.792 g, 7.20 mmol) in dry THF (20 mL) was added dropwise over 10 min. The reaction mixture was allowed to warm to room temperature, and stirred for an additional 3 h to give a yellow solution. The THF was removed, and the white solid obtained was dissolved in ether (40 mL). The resulting solution was cooled and triphenylphosphine oxide, which precipitated, was removed. The filtrate was concentrated, and the residue was chromatographed (solvent C) to give methyl 4-O-benzoyl-2,3-6-trideoxy-α-L-threo-hex-2-enopyranoside, 9a; (0.821 g, 91%); R_f 0.36 (solvent C); ^1H NMR data (60 MHz, $CDCl_3$): δ 1.33 (d, 3H, CH_3, $J_{5,6}$ = 6.5 Hz), 3.43 (s, 3H, OCH_3), 4.33 (qd, 1H, H-5, $J_{4,5}$ = 2.5 Hz), 4.95 (d, 1H, H-1, $J_{1,2}$ = 2.5 Hz), 5.14 (dd, 1H, H-4, $J_{3,4}$ = 4.0 Hz), 5.80-6.43 (m, 2H, H-3, H-4), 7.20-7.90 (m, 3H, m, p-phenyl), 8.0-8.30 (m, 2H, o-phenyl). Compound 9a was dissolved in absolute methanol (100 mL), sodium methoxide (0.20, 3.74 mmol) was added to the solution and the mixture was stirred overnight with the exclusion of moisture. Evaporation of the solvent afforded a residue to which methylene chloride was added. Insoluble material was removed by filtration, and the filtrate was concentrated to yield 9b as a white solid (0.462 g, 89%). A

sublimed sample of 9b had mp 66-67°C; R_f 0.26 (solvent D); $[\alpha]_D^{23}$ +148.2° (c 0.96, $CHCl_3$); $\nu_{max}^{CHCl_3}$ 3425 (OH), 1660, 1448, 1400, 1340, 1190, 1108 cm^{-1}; ^1H NMR (60 MHz, $CDCl_3$): δ 1.32 (d, 3H, CH_3, $J_{5,6}$ = 6.5), 2.6 (bd, 1H, OH), 3.42 (s, 3H, OCH_3), 3.4-3.8 (m, 1H, H-4), 4.12 (qd, 1H, H-5, $J_{4,5}$ = 2.0 Hz), 4.84 (d, 1H, H-1, $J_{1,2}$ = 2.8 Hz), 5.73-6.38 (m, 2H, H-2, H-3, $J_{2,3}$ = 10.0 Hz, $J_{3,4}$ = 5.5 Hz).

HRMS: m/s 113.0605 (calc. for $M^+ - OCH_3$, 113.0602).

Methyl 3-O-Carbamoyl-2,3,6-trideoxy-α-L-threo-hex-2-enopyranoside 9c. Urethane 9c was prepared from 9a in quantitative yield by use of the same procedure as was used above for preparation of 6c (method b). A sample of 9c recrystallized from ethanol, had a mp 189-191°C; R_f 0.20 (solvent D); $[\alpha]_D^{23}$ +223.8° (c 0.97, $CHCl_3$); $\nu_{max}^{CHCl_3}$ 3420, 3280 (NH_2), 1710 (C=O), 1575 cm^{-1}; ^1H NMR data (80 MHz, $CDCl_3$): δ 1.24 (d, 3H, CH_3, $J_{5,6}$ = 6.5 Hz), 3.41 (s, 3H, OCH_3), 4.18 (qd, 1H, H-5, $J_{4,5}$ = 2.5 Hz), 4.85-5.05 (m, 4H, H-1, H-4, NH_2), 5.85-6.17 (m, 2H, H-2, H-3).

Anal. Calcd for $C_8H_{13}NO_4$: C, 51.33; H, 7.00; N, 7.48. Found: C, 51.11, H, 7.09, N, 7.31.

Methyl 2,6-Dideoxy-2-iodo-α-L-galactopyranoside 3,4-carbonate 10a. Urethane 9c (0.632 g, 3.38 mmol) was dissolved in acetonitrile (125 mL), iodonium dicollidine perchlorate 3 (1.59 g, 3.38 mmol) was added and the solution was stirred in the dark for three days, a fresh equivalent of 3 being added for each 24 h of reaction time. The reaction was worked up as previously described for 7a to yield 10a as a solid (0.697 g, 65%). The product was recrystallized from ether; mp 149°C (decomposition); R_f 0.65 (solvent D); $[\alpha]_D^{23}$ -130.2° (c 1.1, $CHCl_3$); $\nu_{max}^{CHCl_3}$ 1805 (C=O) cm^{-1}; ^1H NMR (80 MHz, $CDCl_3$): δ 1.39 (d, 3H, CH_3, $J_{5,6}$ = 6.4 Hz), 3.45 (s, 3H, OCH_3), 4.20 (dd, 1H, H-2, $J_{1,2}$ = 3.3 Hz, $J_{2,3}$ = 8.8 Hz), 4.26 (qd, 1H, H-5, $J_{4,5}$ = 2.5 Hz), 4.47 (dd, 1H, H-4, $J_{3,4}$ = 6.0 Hz).

Anal. Calcd for $C_8H_{11}IO_5$: C, 30.59; H, 3.53; I, 40.41. Found: C, 30.78; H, 3.74; I, 40.17.

Methyl 2,6-Dideoxy-α-L-lyxo-hexopyranoside 3,4-carbonate 10b. Compound 10a (0.0507 g, 0.16 mmol) was deiodinated (described previously for 5a) to yield, after chromatography (solvent D), carbonate 10b (0.0265 g, 88%) as a syrup; R_f 0.50 (solvent D); $[\alpha]_D^{23}$ -64.1° (c 0.76, $CHCl_3$); ν_{max}^{NaCl} 1790 (C=O), 1365, 1170 cm^{-1}; ^1H NMR (80 MHz, $CDCl_3$): δ 1.34 (d, 3H, CH_3, $J_{5,6}$ = 6.9 Hz), 1.79 (ddd, 1H, H-2a, $J_{1,2a}$ = 3.3 Hz, $J_{2a,2e}$ = 15.5 Hz, $J_{2a,3}$ = 6.8 Hz), 2.44 (ddd, 1H, H-2e, $J_{1,2e}$ = 3.6 Hz, $J_{2e,3}$ = 5.8 Hz), 3.38 (s, 3H, OCH_3), 4.0 (qd, 1H, H-5, $J_{4,5}$ = 2.0 Hz), 4.52 (dd, 1H, H-4, $J_{3,4}$ = 8.1 Hz), 4.75-5.07 (m, 2H, H-1, H-3). HRMS: m/s 188.0687 (calc. for M^+ 188.0685).

Methyl 2-Deoxy-α-L-fucoside 11. Carbonate 10b (0.0210 g, 0.112 mmol) was hydrolyzed by the same method used for 7b to give diol 11 (0.0138 g, 76%) as a syrup; R_f 0.31 (solvent E); $[\alpha]_D^{23}$ -119.3° (c 0.55, $CHCl_3$); $\nu_{max}^{CHCl_3}$ 3390 (OH), 1355, 1205, 1450 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$): δ 1.26 (d, 3H, CH_3, $J_{5,6}$ = 6.3 Hz), 1.74 (ddd, 1H, H-2a, $J_{1,2a}$ = 3.6, Hz, $J_{2a,2e}$ = 13.0 Hz, $J_{2a,3}$ = 11.7 Hz), 1.89 (m, 1H, H-2e, $J_{1,2e}$ < 1 Hz, $JJ_{2e,3}$ = 5.2 Hz), 3.30 (s, 3H, OCH_3), 3.61 (bs, 1H, H-4, $J_{4,5}$ < 1 Hz), 3.88 (q, 1H, H-5), 3.97 (m, 1H, H-3, $J_{3,4}$ = 2.5 Hz), 4.75 (d, 1H, H-1).

Anal. Calcd for $C_7H_{14}O_4$: C, 51.84; H, 8.70. Found: C, 51.89; H, 8.53.

Literature[7] reports for 11: ^1H NMR (270 MHz, $CDCl_3$): δ 1.28 (CH_3, $J_{5,6}$ = 6.6 Hz), 1.77 (H-2a, $J_{1,2a}$ = 4.0 Hz, $J_{2a,2e}$ = 13.2 Hz, $J_{2a,3}$ = 11.5 Hz), 1.92 (H-2e, $J_{2e,3}$ = 5.5 Hz), 3.32 (OCH_3), 3.63 (H-4, $J_{4,5}$ < d1.0 Hz), 3.90 (H-5), 4.00 (H-3, $J_{3,4}$ = 2.9 Hz), 4.78 (H-1).

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