Synthetic Studies on Methyl α-Trioxacarcinoside B

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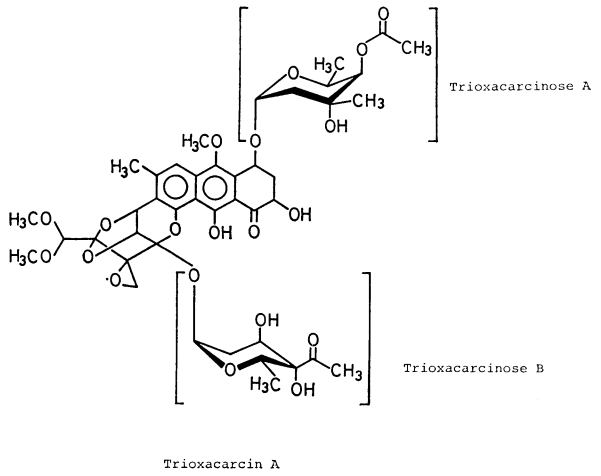
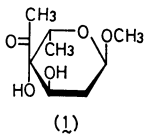
Trioxacarcinose B is a unique carbohydrate which has been discovered in antibiotic trioxacarcin A as a component. As a step of total synthesis of the antibiotic, methyl α-trioxacarcinoside B has been synthesized from methyl 2,3-anhydro-6-deoxy-α-L-*allo*-hexopyranoside by a 7 steps reaction in a yield of 4.3%. The product has been identified by comparison with the authentic sample which was prepared by methanolysis of the antibiotic.

Trioxacarcinose A and B are unique carbohydrates which are components of antitumor antibiotic trioxacarcin A produced by *Streptomyces ochraceus*.[1,2,3]

Methanolysis of the antibiotic afforded a mixture of two methyl glycosides: methyl trioxacarcinoside A and B.



Trioxacarcin A



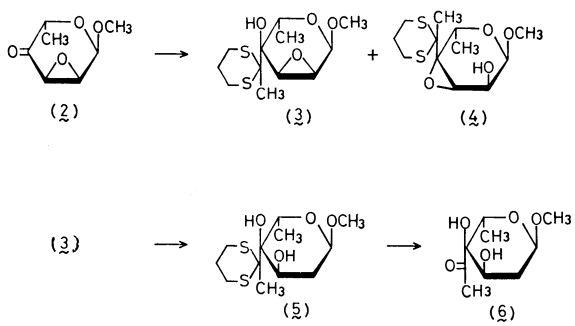
(1)

Trioxacarcinose A is a known sugar and its de-*O*-acetyl derivative is named axenose, which has been synthesized by Garegg and Norberg.[4] Trioxacarcinose B has been known as a component of naturally occurring isoquinocycline B[5] but its synthesis has never been described; a closely related compound, methyl 2,6-dideoxy-4-*C*-(L-glycero-4[1]-hydroxyethyl)-α-L-*xylo*-hexopyranoside, was synthesized by Paulsen and Sinnwell.[6]

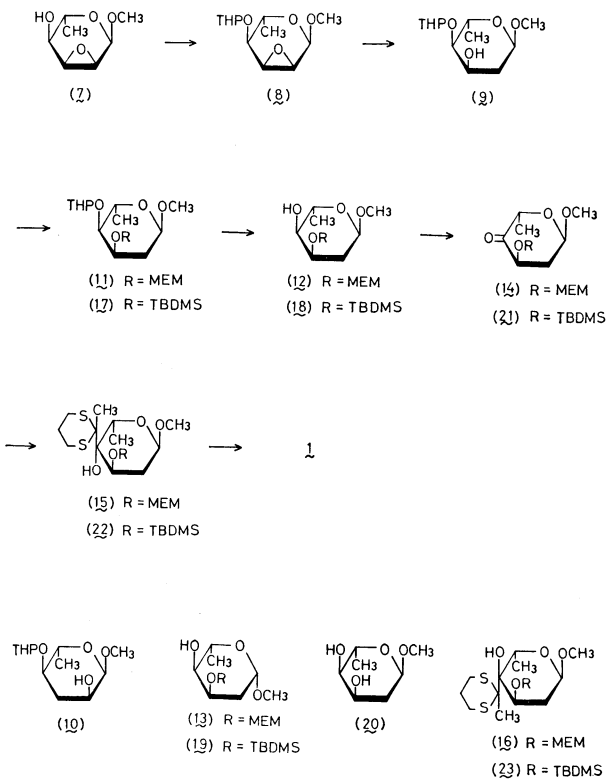
We have attempted to synthesize methyl α-trioxacarcinoside B (**1**) from the readily accessible methyl 2,3-anhydro-6-deoxy-α-L-*ribo*-hexopyranosid-4-ulose (**2**).[6]

Treatment of **2** with 2-methyl-1,3-dithiane[7] in the presence of butyllithium in tetrahydrofuran (THF) yielded two products: methyl 2,3-anhydro-6-deoxy-4-*C*-(2-methyl-1,3-dithiolan-2-yl)-α-L-*allo*-hexopyranoside (**3**) and the corresponding L-*galacto* derivative (**4**) in 26 and 7% yields, respectively.

Reduction of **3** with $LiAlH_4$ in THF afforded methyl 2,6-dideoxy-4-*C*-(2-methyl-1,3-dithiolan-2-yl)-α-L-*ribo*-hexopyranoside (**5**) in a quantitative yield.



Scheme 1.



Scheme 2.

Deprotection of **5** with mercury(II) chloride and mercury(II) oxide in aq methanol gave crystalline methyl 4-*C*-acetyl-2,6-dideoxy-α-L-*ribo*-hexopyranoside (**6**) in 38% yield, which was found to be the 4-epimer of **1** by ^1H NMR spectroscopy.

To avoid the formation of **4**, an alternative route has been attempted. Protection of the hydroxyl group on C-4 of methyl 2,3-anhydro-6-deoxy-α-L-*allo*-hexo-

pyranoside[6] (**7**) with 3,4-dihydro-2*H*-pyran and successive hydrogenation of the 2,3-oxirane ring with $LiAlH_4$ afforded two products: the 2-deoxy derivative (**9**) and the 3-deoxy derivative (**10**) in 80 and 19% yields, respectively.

Protection of another hydroxyl group on C-3 in **9** with a 2-methoxyethoxymethyl group (MEM) gave the fully protected compound (**11**) as a syrup. Selective deprotection of the tetrahydropyranyl group in **11** with pyridinium *p*-toluenesulfonate in methanol[8] gave the anomers (**12**) and (**13**) in 71 and 23% yields, respectively.

Oxidation of **12** with ruthenium tetraoxide gave methyl 2,6-dideoxy-3-*O*-(2-methoxyethoxymethyl)-α-L-*erythro*-hexopyranosid-4-ulose (**14**) in a yield of 86%. When **14** reacted with 2-methyl-1,3-dithiane[7] in the presence of butyllithium, methyl 2,6-dideoxy-3-*O*-(2-methoxyethoxymethyl)-4-*C*-(2-methyl-1,3-dithiolan-2-yl)-α-L-*xylo*-hexopyranoside (**15**) was obtained in 54% yield, together with a small amount of the corresponding 4-epimer (**16**). Deprotection of **15** in methanolic hydrogen chloride gave **1** in 23% yield.

In this reaction process (**11**→**12**→**14**→**15**→**1**), another protective group, *t*-butyldimethylsilyl group (TBDMS), was used analogously to result in the process (**17**→**18**→**21**→**22**→**1**).

Experimental

General Methods. Melting points were determined on a Büchi 510 capillary melting point apparatus and are uncorrected. Solutions were concentrated under reduced pressure below 50 °C. Optical rotation was measured on a Japan Spectroscopic Co. DIPL-SL polarimeter. ^1H NMR spectra were taken on a Varian EM-390 (90 MHz) spectrometer in deuteriochloroform with reference to tetramethylsilane as an internal standard. Chemical shifts are given in δ-values, and the *J*-values given are of first-order. TLC was performed on precoated Wakogel B-5F plates (Wako Pure Chemical Co., Ltd.), and silica gel (Wakogel C-200) was employed for column chromatography.

*Methyl 2,3-Anhydro-6-deoxy-4-C-(2-methyl-1,3-dithiolan-2-yl)-α-L-allo-hexopyranoside (**3**) and Methyl 3,4-Anhydro-6-deoxy-4-C-(2-methyl-1,3-dithiolan-2-yl)-α-L-galacto-hexopyranoside (**4**).* To a stirred solution of 2-methyl-1,3-dithiane (342 mg, 2.5 mmol) in THF (3.0 ml), a 1.8 ml portion of 1.6 M (1 M= 1 mol dm^{-3}) butyllithium hexane solution (2.9 mmol) was added with acetone–Dry Ice cooling (−30 °C) in an argon atmosphere. After 1.5 h, the mixture was cooled at −70 °C and a solution of methyl 2,3-anhydro-6-deoxy-α-L-*ribo*-hexopyranosid-4-ulose (**2**, 400 mg, 2.5 mmol) in THF (3.0 ml) was added to the mixture. After stirring for 10 min, a 0.6 ml portion of acetic acid was added to the reaction mixture. The mixture was concentrated and the residue was dissolved in chloroform. The chloroform solution was washed with H_2O, dried over anhydrous Na_2SO_4 and concentrated. The residue was recrystallized from ethyl acetate–hexane to give 189 mg (26%) of **3**: mp 140—141 °C; $[\alpha]_D^{23}$ −65.5° (*c* 0.84, $CHCl_3$). The ^1H NMR spectrum of **3** was superimposable on that of the corresponding D-diastereomer.[7]

Found: C, 49.17; H, 6.69; S, 21.75%. Calcd for $C_{12}H_{20}S_2O_4$: C, 49.29; H, 6.81; S, 21.93%.

The mother liquor was concentrated and the residue was purified on a silica-gel column with 1:8 (v/v) ethyl acetate–toluene as an eluant. Fractions homogeneous on TLC (R_f 0.59) in 1:1 (v/v) ethyl acetate–toluene were combined and concentrated. The residue was recrystallized from ether to give 54 mg (7%) of **4**: mp 127—128 °C; $[\alpha]_D^{23}$ −115.9° (*c* 2.67, CH_3OH). The ^1H NMR spectrum of **4** was superimposable on that of the corresponding D-diastereomer.[7]

Found: C, 49.46; H, 6.81; S, 21.72%. Calcd for $C_{12}H_{20}S_2O_4$: C, 49.29; H, 6.81; S, 21.93%.

*Methyl 2,6-Dideoxy-4-C-(2-methyl-1,3-dithiolan-2-yl)-α-L-ribo-hexopyranoside (**5**).* To a suspension of $LiAlH_4$ (83 mg, 2.2 mmol) in THF (8.0 ml), a solution of **3** (245 mg, 0.8 mmol) in THF (8.0 ml) was added. After refluxing for 1 h, the reaction mixture was quenched in ice-cooled water (10 ml). The precipitates were filtered off and the filtrate was concentrated. The residue was purified on a silica-gel column with 1:9 (v/v) ethyl acetate–toluene. Fractions homogeneous on TLC (R_f 0.48) in 1:3 (v/v) ethyl acetate–toluene were combined and concentrated to give 239 mg (97%) of **5** as a syrup: $[\alpha]_D^{23}$ −67.1° (*c* 2.16, CH_3OH). The ^1H NMR spectrum of **5** was identical with that of the corresponding D-diastereomer.[7]

Found: C, 48.73; H, 7.43; S, 21.52%. Calcd for $C_{12}H_{22}S_2O_4$: C, 48.95; H, 7.53; S, 21.78%.

*Methyl 4-C-Acetyl-2,6-dideoxy-α-L-ribo-hexopyranoside (**6**).* To a stirred solution of **5** (207 mg, 0.7 mmol) in 80% aq methanol (16.0 ml), mercury(II) chloride (344 mg, 1.3 mmol), and mercury(II) oxide (365 mg, 1.7 mmol) were added. After 1 h, the mixture was filtered and the filtrate was concentrated. The residue was dissolved in chloroform and the solution was washed with 1 M KI solution and cold water, dried over anhydrous Na_2SO_4 and concentrated. The residue was purified on a silica-gel column with 5:1 (v/v) cyclohexane–ethyl acetate. Fractions homogeneous on TLC (R_f 0.50) in 30:1 (v/v) chloroform–methanol were combined and concentrated to give 55 mg (38%) of **6**: mp 35—39 °C; $[\alpha]_D^{23}$ −183.2° (*c* 0.61, $CHCl_3$); ^1H NMR δ= 1.18 (3H, d, $J_{5,6}$=7.0 Hz, H-6), 2.01 (1H, ddd, $J_{1,2ax.}$= 3.0 Hz, $J_{2ax.,2eq.}$=15.0 Hz, $J_{2ax.,3}$=4.5 Hz, H-2ax.), 2.30 (3H, s, CH_3), 2.44 (1H, ddd, $J_{1,2eq.}$=4.0 Hz, $J_{2eq.,2ax.}$= 15.0 Hz, $J_{2eq.,3}$=3.5 Hz, H-2eq.), 3.38 (3H, s, OCH_3), 3.85 (1H, q, $J_{5,6}$=7.0 Hz, H-5) and 4.84 (1H, dd, $J_{1,2ax.}$=3.0 Hz, $J_{1,2eq.}$=3.5 Hz, H-1).

Found: C, 52.12; H, 7.54%. Calcd for $C_9H_{16}O_5$: C, 52.93; H, 7.90%.

*Methyl 2,6-Anhydro-6-deoxy-4-O-tetrahydropyranyl-α-L-allo-hexopyranoside (**8**).* To a stirred mixture of 3,4-dihydro-2*H*-pyran (896 mg, 10.6 mmol) and pyridinium *p*-toluenesulfonate (234 mg, 0.9 mmol) in CH_2Cl_2 (60.0 ml), methyl 2,3-anhydro-6-deoxy-α-L-*allo*-hexopyranoside[6] (**7**, 1.50 g, 9.4 mmol) was added. After 22 h, the reaction mixture was diluted with CH_2Cl_2, washed with cold water, dried over anhydrous Na_2SO_4 and concentrated. The residue was purified on a silica-gel column with 1:12 (v/v) ethyl acetate–toluene. Fractions homogeneous on TLC (R_f 0.29) in 1:3 (v/v) ethyl acetate–toluene were combined and concentrated to give 2.19 g (96%) of **8** as a syrup: ^1H NMR δ=1.17 (d, $J_{5,6}$=6.5 Hz) and 1.25 (d, $J_{5,6}$=6.5 Hz) (3H, H-6), 3.41 (3H, s, OCH_3), 4.77 (3/2 H, d, *J*=3.0 Hz, H-1 and THP's H-1) and 5.00 (1/2 H, bs, THP's H-1).

Found: C, 59.29; H, 8.14%. Calcd for $C_{12}H_{20}O_5$: C, 59.00: H, 8.25%.

*Methyl 2,6-Dideoxy-4-O-tetrahydropyranyl-α-L-ribo-hexopyranoside (**9**) and Methyl 3,6-Dideoxy-4-O-tetrahydropyranyl-α-L-ribo-hexopyranoside (**10**).* To a mixture of $LiAlH_4$ (0.4 g, 10.5 mmol) and THF (50 ml), a solution of **8** (2.36 g, 9.7 mmol) in THF (10 ml) was added. After the mixture was heated under reflux for 1 h, water (60 ml) was added to the mixture. The mixture was filtered and the filtrate

was concentrated. The residue was purified on a silica-gel column with 1:12 (v/v) acetone–hexane. Fractions homogeneous (R_f 0.40) on TLC in 1:3 (v/v) acetone–hexane were combined and concentrated to give 1.91 g (80%) of **9** as a syrup.

Found: C, 58.75; H, 8.80%. Calcd for $C_{12}H_{22}O_5$: C, 58.52; H, 9.00%.

Fractions homogeneous (R_f 0.30) on TLC in the same solvent system were combined and concentrated to give 0.45 g (19%) of **10** as a syrup.

Found: C, 58.59; H, 8.76%. Calcd for $C_{12}H_{22}O_5$: C, 58.52; H, 9.00%.

*Methyl 2,6-Dideoxy-3-*O*-(2-methoxyethoxymethyl)-4-*O*-tetrahydropyranyl-α-*L*-ribo-hexopyranoside (**11**).* To a stirred solution of **9** (0.68 g, 2.8 mmol) in CH_2Cl_2 (4.0 ml), 2-methoxyethoxymethyl chloride (0.68 g, 2.8 mmol) and *N,N*-diisopropylethylamine (0.72 g, 5.5 mmol) were added. After 1 h, the mixture was diluted with CH_2Cl_2, washed with water, dried over anhydrous Na_2SO_4 and concentrated. The residue was purified on a silica-gel column with 1:8 (v/v) ethyl acetate–toluene. Fractions homogeneous (R_f 0.22) on TLC in 1:1 (v/v) ethyl acetate–toluene were combined and concentrated to give 0.68 g (74%) of **11** as a syrup: ^{1}H NMR δ=1.19 (d, $J_{5,6}$=6.5 Hz) and 1.28 (d, $J_{5,6}$=6.5 Hz) (3H, H-6), 3.30 (3H, s, OCH_3), 3.36 (3H, s, OCH_3) and 4.57—4.95 (4H, m, H-1, THP's H-1 and $-OCH_2O-$ of MEM).

Found: C, 57.57; H, 8.83%. Calcd for $C_{16}H_{30}O_7$: C, 57.47; H, 9.04%.

*Methyl 2,6-Dideoxy-3-*O*-(2-methoxyethoxymethyl)-α-*L*-ribo-hexopyranoside (**12**) and Methyl 2,6-Dideoxy-3-*O*-(2-methoxyethoxymethyl)-β-*L*-ribo-hexopyranoside (**13**).* A mixture of **11** (0.68 g, 2.0 mmol) and pyridinium *p*-toluenesulfonate (51 mg, 0.2 mmol) in methanol (30 ml) was heated at 50 °C for 1 h. The mixture was concentrated and the residue was purified on a silica-gel column with 1:1 (v/v) ethyl acetate–toluene. Fractions homogeneous (R_f 0.10) on TLC in the same solvent were combined and concentrated to give 0.36 g (71%) of **12** as a syrup: $[\alpha]_D^{23}$ −184.4° (*c* 1.28, $CHCl_3$); ^{1}H NMR δ=1.25 (3H, d, $J_{5,6}$=6.5 Hz, H-6), 1.84 (1H, ddd, $J_{1,2ax.}$=4.5 Hz, $J_{2ax.,2eq.}$=15.0 Hz, $J_{2ax.,3}$=3.5 Hz, H-2eq.), 3.32 (3H, s, OCH_3), 4.64 (1H, dd, $J_{1,2ax.}$=4.5 Hz, $J_{1,2eq.}$=1.5 Hz, H-1) and 4.80 (2H, s, $-OCH_2O-$ of MEM).

Found: C, 53.02; H, 8.60%. Calcd for $C_{11}H_{22}O_6$: C, 52.79; H, 8.86%.

Fractions homogeneous (R_f 0.16) on TLC were concentrated to give 0.12 g (23%) of **13** as a syrup: $[\alpha]_D^{24}$ −36.5° (*c* 1.24, $CHCl_3$); ^{1}H NMR δ=1.28 (3H, d, $J_{5,6}$=6.5 Hz, H-6), 1.61 (1H, ddd, $J_{1,2ax.}$=9.5 Hz, $J_{2ax.,2eq.}$=14.0 Hz, $J_{2ax.,3}$=3.0 Hz, H-2ax.), 2.11 (1H, ddd, $J_{1,2eq.}$=2.5 Hz, $J_{2ax.,2eq.}$=14.0 Hz, $J_{2,3}$=4.0 Hz, H-2eq.), 3.35 (3H, s, OCH_3), 3.44 (3H, s, OCH_3), 4.60 (1H, dd, $J_{1,2ax.}$=9.5 Hz, $J_{1,2eq.}$=2.5 Hz, H-1) and 4.77 (2H, s, $-OCH_2O-$ of MEM).

Found: C, 53.04; H, 8.68%. Calcd for $C_{11}H_{22}O_6$: H, 52.79; H, 8.86%.

*Methyl 2,6-Dideoxy-3-*O*-(2-methoxyethoxymethyl)-α-*L*-erythro-hexopyranosid-4-ulose (**14**).* To a stirred mixture of **12** (0.34 g, 1.3 mmol), K_2CO_3 (56 mg, 0.5 mmol), RuO_2 (8.9 mg), and chloroform (4 ml), a solution of $NaIO_4$ (0.48 g, 2.3 mmol) in water (5 ml) was added. After 5 h, 2-propanol was added to the reaction mixture. The mixture was filtered, and the filtrate was diluted with chloroform, washed with water, dried over anhydrous Na_2SO_4 and concentrated. The residue was purified on a silica-gel column with 1:2 (v/v) ethyl acetate–toluene. Fractions homogeneous (R_f 0.36) on TLC in 1:1 (v/v) ethyl acetate–toluene were combined and concentrated to give 0.29 g (86%) of **14** as a syrup: $[\alpha]_D^{22}$ −127.7° (*c* 5.68, $CHCl_3$); ^{1}H NMR δ=1.29 (3H, d, $J_{5,6}$=6.5 Hz, H-6), 1.86 (1H, ddd, $J_{1,2}$=6.0 Hz, $J_{2,2'}$=13.5 Hz, $J_{2,3}$=13.0 Hz, H-2), 2.63 (1H, dt, $J_{1,2'}$=7.0 Hz, $J_{2,2'}$=13.5 Hz, $J_{2',3}$=7.0 Hz, H-2'), 3.36 (3H, s, OCH_3), 3.37 (3H, s, OCH_3), 4.31 (1H, q, $J_{5,6}$=6.5 Hz, H-5), 4.51 (1H, dd, $J_{2,3}$=13.0 Hz, $J_{2',3}$=7.0 Hz, H-3), 4.80 (2H, s, $-CH_2O-$ of MEM) and 4.97 (1H, dd, $J_{1,2}$=6.0 Hz, $J_{1,2'}$=7.0 Hz, H-1).

Found: C, 53.40; H, 8.05%. Calcd for $C_{11}H_{20}O_6$: C, 53.22; H, 8.12%.

*Methyl 2,6-Dideoxy-3-*O*-(2-methoxyethoxymethyl)-4-*C*-(2-methyl-1,3-dithiolan-2-yl)-α-*L*-xylo-hexopyranoside (**15**) and Methyl 2,6-Dideoxy-3-*O*-(2-methoxyethoxymethyl)-4-*C*-(2-methyl-1,3-dithiolan-2-yl)-α-*L*-ribo-hexopyranoside (**16**).* A mixture of 2-methyl-1,3-dithiane (0.16 g, 1.2 mmol), 1.6 M hexane solution of butyllithium (0.82 ml, 1.3 mmol), and THF (2.0 ml) was stirred for 1.5 h at −30 °C in an argon atmosphere. To the mixture, a solution of **14** (0.29 g, 1.2 mmol) in THF (2.0 ml) was added at −70 °C. After 20 min, the reaction mixture was mixed with acetic acid (0.3 ml) and concentrated. The residue was dissolved in chloroform and the solution was washed with water, dried over anhydrous Na_2SO_4 and concentrated. The residue was purified on the column with 1:5 (v/v) ethyl acetate–toluene. Fractions homogeneous (R_f 0.49) on TLC in the same solvent were combined and concentrated to give 0.24 g (54%) of **15** as a syrup: $[\alpha]_D^{24}$ −82.8° (*c* 1.69, $CHCl_3$); ^{1}H NMR δ=1.35 (3H, d, $J_{5,6}$=6.5 Hz, H-6), 1.75 (3H, s, CH_3), 2.92 (1H, s, OH), 3.31 (3H, s, OCH_3), 3.36 (3H, s, OCH_3), 4.30 (1H, t, J=3.0 Hz, H-3), 4.36 (1H, q, $J_{5,6}$=6.5 Hz, H-5), 4.64 (1H, t, J=2.5 Hz, H-1), 4.84 (1H, d, J=13.5 Hz, $-OCH(H')O-$ of MEM) and 4.92 (1H, d, J=13.5 Hz, $-OCH(H')O-$ of MEM).

Found: C, 50.49; H, 7.71; S, 16.52%. Calcd for $C_{16}H_{30}S_2O_6$: C, 50.24; H, 7.90; S, 16.76%.

Fractions homogeneous (R_f 0.36) gave 94 mg (22%) of **16** as a syrup. The structure of **16** was established by converting **5** into **16** as follows.

To a stirred solution of **5** (56 mg, 0.2 mmol) in CH_2Cl_2 (2 ml), 2-methoxyethoxymethyl chloride (47 mg, 0.4 mmol), and *N,N*-diisopropylethylamine (49 mg, 0.4 mmol) were added. The mixture was worked up as described in the preparation of **16** to give 20 mg (28%) of **16**.

*Methyl 3-*O*-(t-Butyldimethylsilyl)-2,6-dideoxy-4-*O*-tetrahydropyranyl-α-*L*-ribo-hexopyranoside (**17**).* To a stirred solution of **9** (1.86 g, 7.6 mmol) in DMF (5.0 ml), imidazole (1.28 g, 18.8 mmol) and *t*-butyldimethylsilyl chloride (1.59 g, 10.6 mmol) were added. After 20 h, the mixture was concentrated and the residue was purified on a column with 1:20 (v/v) ethyl acetate–hexane were concentrated to give 2.67 g (97%) of **17** as a syrup: ^{1}H NMR δ=0.87 and 0.89 (9H, s×2, $-SiC(CH_3)_3$), 1.17 (d, $J_{5,6}$=6.5 Hz) and 1.26 (d, $J_{5,6}$=6.5 Hz) (3H, H-6), 3.25 and 3.27 (3H, s×2, OCH_3), 4.56—4.68 (3/2 H, m, H-1 and THP's H-1) and 4.80 (1/2 H, bs, THP's H-1).

Found: C, 59.68; H, 9.75%. Calcd for $C_{18}H_{36}O_5Si$: C, 59.96; H, 10.06%.

*Methyl 3-*O*-(t-Butyldimethylsilyl)-2,6-dideoxy-α-*L*-ribo-hexopyranoside (**18**), Methyl 3-*O*-(t-Butyldimethylsilyl)-2,6-dideoxy-β-*L*-ribo-hexopyranoside (**19**), and Methyl 2,6-Dideoxy-α-*L*-ribo-hexopyranoside (**20**).* To a stirred solution of **17** (0.53 g, 1.5 mmol) in methanol (20 ml), pyridinium *p*-toluenesulfonate (37 mg) was added at 40 °C. After 1.5 h, the mixture was concentrated and the residue was purified on a column with 1:20 (v/v) ethyl acetate–hexane. Fractions homogeneous (R_f 0.58) on TLC in the same solvent were concen-

trated to give 0.16 g (40%) of **18** as a syrup: $[\alpha]_D^{22}$ −134.5° (*c* 1.12, $CHCl_3$); ^1H NMR δ=0.09 (3H, s, $-SiC(CH_3)_3$), 0.11 (3H, s, $-SiCH_3$), 0.91 (9H, s, $-SiC(CH_3)_3$), 1.25 (3H, d, $J_{5,6}$=6.5 Hz, H-6), 1.77 (1H, dt, $J_{1,2ax.}$=4.0 Hz, $J_{2ax.,2eq.}$=15.0 Hz, $J_{2ax.,3}$=4.0 Hz, H-2ax.), 2.00 (1H, ddd, $J_{1,2eq}$=2.0 Hz, $J_{2ax.,2eq.}$=15.0 Hz, $J_{2eq.,3}$=4.0 Hz, H-2eq.), 2.18 (1H, d, $J_{4,4-OH}$=10.0 Hz, 4-OH), 3.25 (3H, s, OCH_3), 3.83 (1H, dq, $J_{4,5}$=9.0 Hz, $J_{5,6}$=6.5 Hz, H-5), 4.03 (1H, q, $J_{2ax.,3}$=4.0 Hz, $J_{2eq.,3}$=4.0 Hz, $J_{3,4}$=4.0 Hz, H-3) and 4.63 (1H, dd, $J_{1,2ax.}$=4.0 Hz, $J_{1,2eq.}$=2.0 Hz, H-1).

Found: C, 56.84; H, 9.79%. Calcd for $C_{13}H_{28}O_4Si$: C, 56.48; H, 10.21%.

Fractions homogeneous (R_f 0.44) on TLC gave 0.10 g (25%) of **19** as a syrup: $[\alpha]_D^{22}$ −11.6° (*c* 1.22, $CHCl_3$); ^1H NMR δ=0.12 (6H, s, $-Si(CH_3)_2$), 0.94 (9H, s, $-SiC(CH_3)_3$), 1.28 (3H, d, $J_{5,6}$=6.0 Hz, H-6), 1.57 (1H, ddd, $J_{1,2ax.}$=9.0 Hz, $J_{2ax.,2eq.}$=13.5 Hz, $J_{2ax.,3}$=3.0 Hz, H-2ax.), 1.84 (1H, d, $J_{4,4-OH}$=10.0 Hz, 4-OH), 1.97 (1H, ddd, $J_{1,2eq.}$=2.5 Hz, $J_{2ax.,eq.}$=13.5 Hz, $J_{2eq.,3}$=3.5 Hz, H-2eq.), 3.13 (1H, ddd, $J_{3,4}$=3.5 Hz, $J_{4,4-OH}$=10.0 Hz, $J_{4,5}$=9.0 Hz, H-4), 3.55 (3H, s, OCH_3), 3.71 (1H, dq, $J_{4,5}$=9.0 Hz, $J_{5,6}$=6.0 Hz, H-5), 4.11 (1H, dt, $J_{3,4}$=3.5 Hz, $J_{2ax.,3}$=3.0 Hz, $J_{2eq.,3}$=3.5 Hz, H-3) and 4.62 (1H, dd, $J_{1,2ax.}$=9.0 Hz, $J_{1,2eq.}$=2.5 Hz, H-1).

Found: C, 56.66; H, 9.93%. Calcd for $C_{13}H_{28}O_4Si$: C, 56.48; H, 10.21%.

Fractions homogeneous (R_f 0.05) on TLC gave 44 mg (12%) of **20** as a syrup: $[\alpha]_D^{23}$ −165.4° (*c* 1.08, $CHCl_3$); ^1H NMR δ=1.31 (3H, d, $J_{5,6}$=6.0 Hz, H-6), 1.87 (1H, dt, $J_{1,2ax.}$=3.5 Hz, $J_{ax.,2eq.}$=15.0 Hz, $J_{2eq.,3}$=3.0 Hz, H-2eq.), 3.10 (1H, dd, $J_{3,4}$=3.0 Hz, $J_{4,5}$=10.0 Hz, H-4), 3.36 (3H, s, OCH_3), 3.70 (1H, dq, $J_{4,5}$=10.0 Hz, $J_{5,6}$=6.0 Hz, H-5) and 4.76 (1H, dd, $J_{1,2ax.}$=3.5 Hz, $J_{1,2eq.}$=1.5 Hz, H-1).

Found: C, 51.79; H, 8.55%. Calcd for $C_7H_{14}O_4$: C, 51.84; H, 8.70%.

*Methyl 3-O-(t-Butyldimethylsilyl)-2,6-dideoxy-α-L-erythro-hexopyranosid-4-ulose (**21**).* Compound **18** (0.16 g, 0.6 mmol) was oxidized with ruthenium tetraoxide in a chloroform solution and the reaction mixture was worked up analogously as described in the preparation of **14** to give 82 mg (52%) of **21** as a homogeneous syrup: R_f 0.76 on TLC in 1:4 (v/v) ethyl acetate–hexane; $[\alpha]_D^{22}$ −173.9° (*c* 3.86, $CHCl_3$); ^1H NMR δ=0.05 (3H, s, $SiCH_3$), 0.13 (3H, s, $SiCH_3$), 0.90 (9H, s, $SiC(CH_3)_3$), 1.30 (3H, d, $J_{5,6}$=6.5 Hz, H-6), 1.89 (1H, ddd, $J_{1,2}$=7.0 Hz, $J_{2,2'}$=14.0 Hz, $J_{2,3}$=13.0 Hz, H-2), 2.55 (1H, dt, $J_{1,2'}$=7.0 Hz, $J_{2,2'}$=14.0 Hz, $J_{2',3}$=7.0 Hz, H-2'), 3.39 (3H, s, OCH_3), 4.29 (1H, q, $J_{5,6}$=7.0 Hz, H-5), 4.46 (1H, dd, $J_{2,3}$=13.0 Hz, $J_{2',3}$=7.0 Hz, H-3), 4.91 (1H, t, $J_{1,2}$=7.0 Hz, $J_{1,2'}$=7.0 Hz, H-1).

Found: C, 57.16; H, 9.28%. Calcd for $C_{13}H_{26}O_4Si$: C, 56.90; H, 9.55%.

*Methyl 3-O-(t-Butyldimethylsilyl)-2,6-dideoxy-4-C-(2-methyl-1,3-dithiolan-2-yl)-α-L-xylo-hexopyranoside (**22**) and Methyl 3-O-(t-Butyldimethylsilyl)-2,6-dideoxy-4-C-(2-methyl-1,3-dithiolan-2-yl)-α-L-ribo-hexopyranoside (**23**).* Compound **21** (0.13 g, 0.5 mmol) was treated with 2-methyl-1,3-dithiane in THF as described in the preparation of **15** to give 87 mg (44%) of **22** as a syrup: R_f 0.63 on TLC in 1:4 (v/v) ethyl acetate–hexane; $[\alpha]_D^{22}$ −121.6° (*c* 1.96, $CHCl_3$); ^1H NMR δ=0.11 (3H, s, $SiCH_3$), 0.13 (3H, s, $SiCH_3$), 0.91 (9H, s, $SiC(CH_3)_3$), 1.37 (3H, d, $J_{5,6}$=6.5 Hz, H-6), 1.79 (3H, s, CH_3), 3.29 (3H, s, OCH_3), 4.42 (1H, q, $J_{5,6}$=6.5 Hz, H-5) and 4.65 (1H, d, J=4.5 Hz, H-1).

Found: C, 52.00; H, 8.40; S, 15.15%. Calcd for $C_{18}H_{36}S_2O_4Si$: C, 52.90; H, 8.88; S, 15.69%.

Fractions (R_f 0.72 on TLC in the same solvent) gave 6.1 mg (3%) of **23** as a syrup: ^1H NMR δ=0.17 (6H, s, $Si(CH_3)_2$), 0.91 (9H, s, $SiC(CH_3)_3$), 1.55 (3H, d, $J_{5,6}$=7.0 Hz, H-6), 1.96 (3H, s, CH_3), 2.26 (1H, dt, $J_{1,2eq.}$=5.0 Hz, $J_{2ax.,2eq.}$=14.5 Hz, $J_{2eq.,3}$=5.0 Hz, H-2eq.), 3.30 (3H, s, OCH_3), 3.57 (1H, s, 4-OH), 4.11 (1H, q, $J_{5,6}$=7.0 Hz, H-5), 4.55 (1H, dd, $J_{2ax.,3}$=8.0 Hz, $J_{2eq.,3}$=5.0 Hz, H-3) and 4.65 (1H, t, $J_{1,2ax}$=5.0 Hz, $J_{1,2eq.}$=5.0 Hz, H-1).

The structure of **23** was elucidated by converting **5** to **23** as follows. To a stirred solution of **5** (33 mg, 0.1 mmol) in DMF (0.5 ml), imidazole (19 mg, 0.3 mmol) and *t*-butyldimethylsilyl chloride (20 mg, 0.1 mmol) were added. The mixture was worked up as described in the preparation of **17** to give 26 mg (57%) of **23**.

*Methyl α-Trioxacarcinoside B (**1**).* *(a)*: To a stirred solution of **15** (0.12 g, 0.6 mmol) in methanol (2.0 ml), methanol (2.0 ml) containing 20% HCl was added. After 20 h, the mixture was concentrated and the residue was purified on a silica-gel column with 1:7 (v/v) ethyl acetate–toluene. Fractions homogeneous (R_f 0.70) on TLC in 30:1 (v/v) chloroform–methanol were combined and concentrated. The residue was recrystallized from isopropyl ether to give 15 mg (23%) of **1**: mp 111—112 °C; $[\alpha]_D^{24}$ −154.2° (*c* 0.34, $CHCl_3$). The product was identical with an authentic sample[3,5] in all respects.

(b): An 87 mg portion of **22** was treated with methanolic HCl analogously as described in *(a)* above to give 3.5 mg (8%) of **1**.

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