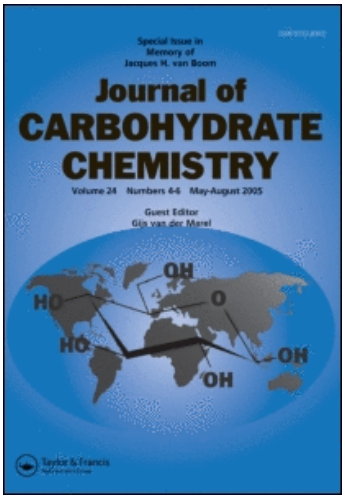


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# Sterecselective Epoxidation of a Pendant Vinyl Group at C3 of a Pyranoside

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# STEREOSELECTIVE EPOXIDATION OF A PENDANT VINYL GROUP AT C3 OF A PYRANOSIDE

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ABSTRACT

The epoxidation of a pendant vinyl group, axially oriented at C3 of the pyranoside ring, can be effected with complete diastereofacial selectivity, depending upon whether a free hydroxyl group is located at C2 or C4.

A survey of the pertinent literature shows that a high degree of stereocontrol can be achieved in reactions at "on-template" trigonal sites on pyranose or furanose rings;[1] however, stereoselectivity at "off-template" stereogenic centers is usually low.[2] One approach for overcoming these limitations involves the ingenious use of chelation phenomena, particularly in reactions where organometallic reagents are employed.[3-6] Alternatively, control can be achieved, for example, in electrophilic additions to off-template olefinic sites, by the judicious deployment of steric obstacles so that the approach from one diastereomeric face is favored over the other.[7,8] In this manuscript, we discuss an



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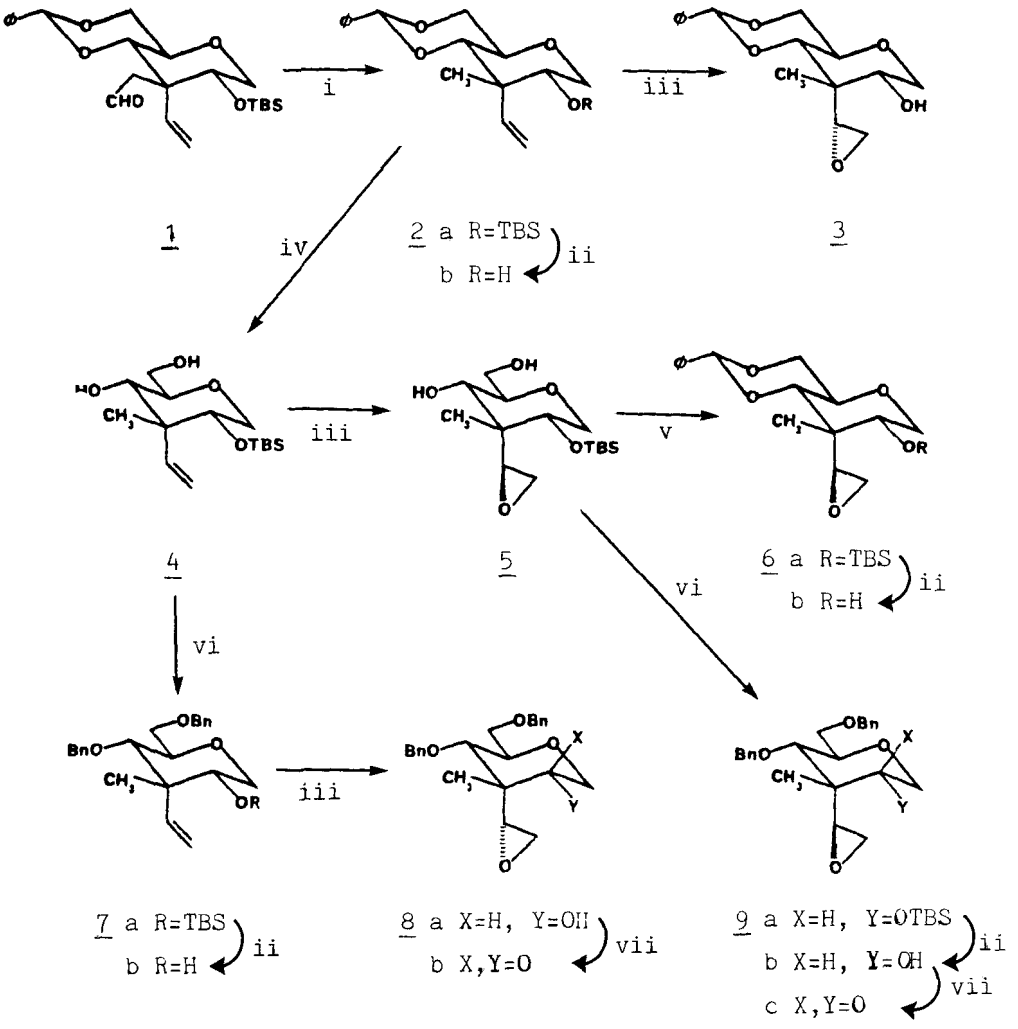



TBS = $Si(Me)_2\ CMe_3$

(i) Pd/C (ii) $(n\text{-}Bu)_4NF$ (iii) MCPBA (iv) camphorsulfonic acid, MeOH (v) $PhCH(OMe)_2$, camphorsulfonic acid (iv) NaH, $PhCH_2Br$ (vii) Swern's Ox.

instance where complete stereocontrol at an off-template stereogenic site has been achieved without the need for any specially designed maneuvers.

We have recently reported that the spiro-Claisen rearrangement can be utilized for the stereocontrolled creation of functionalized gem-dialkylated centers on pyranoside rings.[9] Thus, compound 1 was readily obtained from the corresponding 3-uloside. We wished to explore the synthetic utility of these compounds and stereoselectivity in the epoxidation of the double bond was an obvious reaction to examine. In order to remove a potentially troublesome factor, the aldehyde was decarbonylated by palladium-catalyzed thermolysis,[10] compound 2a being obtained in 89% yield.



The olefin 2a was completely inert toward epoxidation with m-chloroperoxybenzoic acid (MCPBA) even under forcing conditions. However, if the C2 silyl ether was cleaved, the resulting homoallyic alcohol 2b underwent epoxidation with MCPBA smoothly to give a single epoxide which was subjected to single-crystal X-ray analysis. It was thereby established unequivocally that the stereochemistry at C15 (i.e., C7) was as shown for 3 (Figure 1). The crystal structure was solved by direct methods.[11] Least-squares refinement of atomic parameters[12] converged to $R = 0.042$[13] over 908 reflections. Final non-hydrogen atom coordinates are listed in Table 1. A view of the solid-state conformation is provided in Figure 1. Bond lengths and angles are close to accepted values. In the crystal, molecules of 3 related by unit-translation along the c-axis are linked by O-H...O hydrogen bonds [O(2)...O(15) 2.900(5) Å].

The exclusive formation of this product can be rationalized by assuming that the transition state would be as shown in I, with the pendant vinyl group oriented away from the ring, and with the free hydroxyl group hydrogen bonded to the attacking peracid. If this rationalization were valid, it should be possible to epoxidize the other face of the pendant vinyl group by the chelation shown in II, in which the free hydroxyl group is at C4.

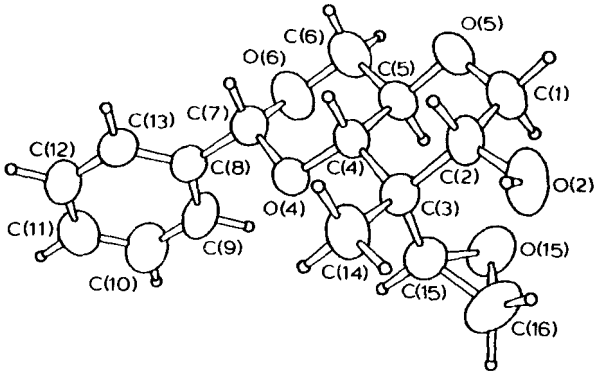



Figure 1. Crystallographic atom numbering scheme and solid-state conformation; small circles denote hydrogen atoms.



Accordingly, the benzylidene group of 2a was cleaved to give diol 4, which upon treatment with MCPBA afforded a single epoxide in 83% yield, presumed to be 5. To confirm this assignment, the product was processed to give 6b so as to undertake comparison with 3. Indeed, the $^1$H NMR spectra of both compounds were completely different, notably in the chemical shifts of the oxirane protons (see Experimental).

To demonstrate further the effectiveness of the free hydroxyl group for controlling the epoxidation, compound 4 was processed to give the C2 alcohol 7b, which was epoxidized. The product 8a was again found to be different from 9b, as were the derived ketones 8b and 9c. The results indicate the effectiveness of the hydroxyl group in controlling the diastereofacial selectivity of the epoxidation. Furthermore, the formation of a single isomer indicates the overwhelming stability of the exo-oriented vinyl group. Further exploration of this phenomenon is underway and will be reported in due course.

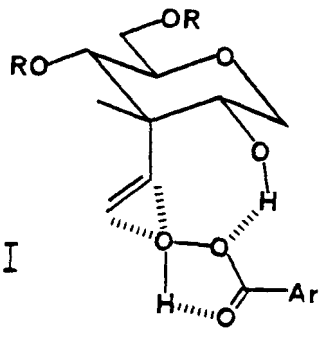
## EXPERIMENTAL

General Procedures. Melting points were determined in capillary tubes and are uncorrected. Elemental analyses were

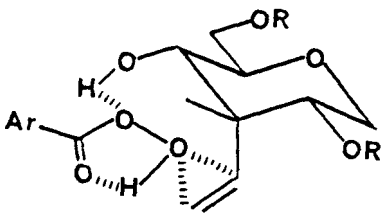
Table 1

Non-hydrogen Atom Fractional Coordinates ($x10^4$), with Estimated Standard Deviations in Parentheses

| Atom | x | y | z |
|---|---|---|---|
| C(1) | -3408(4) | 3638(2) | -1235(10) |
| C(2) | -2533(4) | 3316(2) | -2815(8) |
| C(3) | -1266(4) | 3173(2) | -1733(8) |
| C(4) | -807(3) | 3764(2) | -897(8) |
| C(5) | -1714(4) | 4044(2) | 719(9) |
| C(6) | -1186(4) | 4614(2) | 1552(12) |
| C(7) | 808(4) | 4277(2) | 789(10) |
| C(8) | 2080(4) | 4224(2) | 1712(9) |
| C(9) | 2337(4) | 3916(2) | 3705(9) |
| C(10) | 3521(5) | 3861(2) | 4450(10) |
| C(11) | 4481(4) | 4111(2) | 3274(10) |
| C(12) | 4244(4) | 4421(2) | 1336(9) |
| C(13) | 3063(4) | 4473(2) | 597(9) |
| C(14) | -373(4) | 2932(2) | -3526(8) |
| C(15) | -1261(4) | 2743(2) | 191(8) |
| C(16) | -2021(6) | 2215(2) | 251(10) |
| O(2) | -3186(3) | 2822(2) | -3652(6) |
| O(5) | -2850(2) | 4161(1) | -409(7) |
| O(6) | 20(3) | 4522(1) | 2433(8) |
| O(15) | -2289(3) | 2696(1) | 1739(6) |

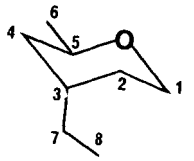



I




II

performed by M-H-W Laboratories, PO Box 15149, Phoenix, Arizona. Proton magnetic resonance ($^1$H NMR) spectra were recorded on a Bruker WM-250 (250 MHz) instrument using deuterochloroform as solvent, the residual chloroform being the internal standard ($\delta$ 7.24). Coupling constants were measured directly from the spectra or calculated from peak listings. The numbering pattern used for assignment of protons is illustrated below.




The progress of all reactions was monitored by thin-layer chromatography (TLC) which was performed on aluminum sheets precoated with Silica Gel 60 (F-254, E. Merck) to a thickness of 0.2 mm. The following solvent systems were used as eluents: (A) ethyl acetate-petroleum ether (35-60 °C), 50:50; (B) 20:80; (C) 10:90; (D) 5:95. The chromatograms were observed under 254-nm ultraviolet light, sprayed with sulfuric acid, and charred on a hot plate. Flash column chromatography was carried out using Silica Gel 60 (230-400 mesh, E. Merck). All optical rotations were measured at 20 °C.



Crystal Data. $C_{16}H_{20}O_5$, $M$ = 292.33, Orthorhombic, $a$ = 10.801(1) Å, $b$ = 23.065(6) Å, $c$ = 5.897(1) Å, $V$ = 1469.1 Å$^3$, $Z$ = 4, $D_{calc.}$ = 1.322 g cm$^{-3}$, $\mu$(Cu-K$\alpha$ radiation, $\lambda$ = 1.5418 Å) = 5.5 cm$^{-1}$. Space group $P2_12_12_1$($D_4^2$) uniquely from the systematic absences: $h00$ when $h \neq 2n$, $0k0$ when $k \neq 2n$, $00\ell$ when $\ell \neq 2n$. Sample dimensions: 0.14 x 0.20 x 0.50 mm.

Crystallographic Measurements. Intensity data for one octant of reciprocal space were recorded on an Enraf-Nonius CAD-4 diffractometer (Cu-K$\alpha$ radiation, incident-beam graphite monochromator; $\omega$-2$\theta$ scans, $\theta_{max.}$ = 67°). From a total of 1538 independent measurements, those 908 reflections with $I > 3.0\sigma(I)$ were retained for the structure analysis and corrected for the

usual Lorentz and polarization effects. Refined unit-cell parameters were derived from the diffractometer setting angles for 25 reflections ($31^{\circ} < \vartheta < 47^{\circ}$) widely separated in reciprocal space.

Structure Analysis. The crystal structure was solved by direct methods.[11] Approximate positions for the carbon and oxygen atoms were obtained from an E-map. Hydrogen atoms were located in a difference Fourier synthesis evaluated following several rounds of full-matrix least-squares adjustment of non-hydrogen atom positional and anisotropic thermal parameters, and were included at their calculated positions in the later interations which converged to $R = 0.042$ ($R_w = 0.054$).[12,13] The maximum and minimum values in a final difference map were 0.14 e $\text{Å}^{-3}$ and -0.17 e $\text{Å}^{-3}$ respectively. Neutral atom scattering factors used in the structure-factor calculations were taken from ref. 14. In the least-squares iterations, $\Sigma w\Delta^2$ [$w = 1/\sigma^2(|F_o|)$, $\Delta = |F_o| - |F_c|$] was minimized.

Cleavage of tert-butyldimethylsilyl ethers. A solution of the silyl ether (1.0 g/100 mL) in dry THF was stirred with 1 equivalent of tetra-n-butylammonium fluoride until the cleavage was complete (TLC). The solvent was then evaporated and the residue was purified by column chromatography.

Epoxidation of olefins with meta-chloroperoxybenzoic acid (MCPBA). The olefin (1.0 mmol) was dissolved in methylene chloride (10 mL). Saturated aqueous sodium bicarbonate (5 mL) was added followed by MCPBA (4 mmol). The two-phase mixture was stirred vigorously at room temperature for several hours until reaction was complete (TLC). Diethyl ether (20 mL) was added and the aqueous phase partitioned. The organic phase was washed with 10% aqueous potassium hydroxide (2 x 5 mL) and saturated brine (5 mL) successively, dried over sodium sulfate, and evaporated to give the desired epoxide.

Swern's oxidation[15] of alcohols. A solution of dimethyl sulfoxide (4.0 mmol) in dry methylene chloride (50 mL) was cooled to -78 °C under an atmosphere of argon and to this was added trifluoroacetic anhydride (4.0 mmol) dropwise. The resulting mixture was stirred at -78 °C for an additional 15 min. The alcohol (1.0 mmol), dissolved in dry methylene chloride (5.0 mL), was added dropwise and the mixture stirred at -78°C for an additional 30 min. Dry triethylamine (8.0 mmol) was added slowly and the resulting mixture warmed to room temperature, washed with saturated brine, dried over sodium sulfate, and evaporated to give the desired ketone.

1,5-Anhydro-4,6-O-benzylidene-2-O-(tert-butyldimethylsilyl)-3-deoxy-3-C-methyl-3-C-vinyl-D-allitol (2a). Compound 1[9] (1.2 g, 2.9 mmol) was dissolved in benzonitrile (20 mL), 5% palladium on carbon (0.12 g) was added and the reaction vessel was evacuated and flushed with argon several times. The resulting mixture was heated to reflux with vigorous stirring under an atmosphere of argon for 24 h. After cooling to room temperature, the reaction mixture was filtered through a bed of Celite and the solvent was evaporated under vacuum to give 2a (1.0 g, 89%) as a syrup; TLC $R_f$ 0.49 (B); $[\alpha]_D$ -13.6° (c 2.67, $CHCl_3$); $^1H$ NMR δ0.06 (s, 3, $CH_3Si$), 0.10 (s, 3, $CH_3Si$), 0.90 (s, 9, $(CH_3)_3CSi$), 1.27 (s, 3, 3-$CH_3$), 3.26 (d, 1, $J_{4,5}$=9.0 Hz, H4), 3.45-3.75 (m, 5, H1, H1', H2, H5, H6a), 4.28 (dd, 1, $J_{5,6e}$=5.0 Hz, $J_{6a,6e}$=10 Hz, H6e), 5.29 (dd, 1, $J_{7,8}$=12 Hz, $J_{8,8'}$=2 Hz, H8), 5.45 (s, 1, PhCH), 5.49 (dd, 1, $J_{7,8'}$=18 Hz, H8'), 6.10 (dd, 1, H7), 7.30-7.50 (m, 5, Ph).

Anal. calcd for $C_{22}H_{34}O_4Si$: C, 67.65; H, 8.77. Found: C, 67.86; H, 8.68.

1,5-Anhydro-4-6-O-benzylidene-3-deoxy-3-C-methyl-3-C-vinyl-D-allitol (2b). Compound 2a (1.0 g, 2.6 mmol) was desilylated in 2 h according to standard procedure to give 2b (0.68 g, 96%) as a syrup: TLC $R_f$ 0.44 (A); $[\alpha]_D$ -31.5° (c 2.13, $CHCl_3$); $^1H$ NMR δ1.37 (s, 3, 3-$CH_3$), 1.6 (bs, 1, OH), 3.26-3.83 (m, 6, H1, H1', H2, H4, H5, H6a), 4.31 (dd, 1, $J_{5,6e}$=4.0 Hz,

$J_{6a,6e}$=10.0 Hz, H6e), 5.37 (dd, 1, $J_{7,8}$=17.0 Hz, $J_{8,8'}$=2.0 Hz, H8), 5.47 (s,1, PhC<u>H</u>), 5.47 (dd, 1, $J_{7,8'}$=10.0 Hz, H8'), 6.23 (dd, 1, H7), 7.30-7.50 (m, 5, Ph).

Anal. calcd. for $C_{16}H_{20}O_4$: C, 69.55; H, 7.30. Found: C, 69.35; H, 7.24.

<u>1,5-Anhydro-4,6-O-benzylidene-3-deoxy-3-C-(1,2-[s]-epoxyethyl)-3-C-methyl-D-allitol</u> (<u>3</u>). Compound <u>2b</u> (0.4 g, 1.45 mmol) was epoxidized according to standard procedure to give <u>3</u> (0.34 g, 80%) as a syrup: TLC $R_f$ 0.40 (A); $[\alpha]_D$ -24.8° (c 2.77, $CHCl_3$); $^1H$ NMR δ1.18 (s, 3, 3-$CH_3$), 2.66 (bs, 1, OH), 2.74 (t, 1, $J_{7,8}$= $J_{8,8'}$=4.0 Hz, H8), 2.80 (dd, 1, $J_{7,8'}$=3.0 Hz, H8'), 3.32 (d, 1, $J_{4,5}$=10.0 Hz, H4), 3.53 (dd, 1, H7), 3.60 (t, 1, $J_{5,6a}$= $J_{6a,6e}$=10.0 Hz, H6a), 3.60 (m, 1, H2), 3.74 (t, 1, $J_{1a,1e}$= $J_{1a,2}$=10.0 Hz, H1a), 3.77 (dt, 1, $J_{5,6e}$=5.0 Hz, H5), 3.90 (dd, 1, $J_{1e,2}$=6.0 Hz, H1e), 4.33 (dd, 1, H6e), 5.47 (s, 1, PhC<u>H</u>), 7.30-7.50 (m, 5, Ph).

Anal. calcd for $C_{16}H_{20}O_5$: C, 65.74; H, 6.90. Found: C, 65.74; H, 6.74.

<u>1,5-Anhydro-2-O-(tert-butyldimethylsilyl)-3-deoxy-3-C-methyl-3-C-vinyl-D-allitol</u> (<u>4</u>). Compound <u>2a</u> (3.9 g, 10.0 mmol) was dissolved in dry methanol (100 mL) with a trace of camphorsulfonic acid and the mixture was stirred at room temperature for 8 h. The solution was neutralized with a few drops of saturated aqueous sodium bicarbonate and concentrated to a syrup. The syrup was chromatographed (solvent A) to give <u>4</u> (2.80 g, 93%) as a white solid which was recrystallized from ethanol: mp 50-51 °C; TLC $R_f$ 0.38 (B); $[\alpha]_D$ +24.2° (c 3.21, $CHCl_3$); $^1H$ NMR δ0.01 (s, 3, $CH_3Si$), 0.03 (s, 3, $CH_3Si$), 0.83 (s, 9, $(CH_3)_3CSi$), 1.23 (s, 3, 3-$CH_3$), 1.78 (bs, 1, OH), 2.22 (bs, 1, OH), 3.20-3.90 (m, 7, H1, H1', H2, H4, H5, H6, H6'), 5.23 (dd, 1, $J_{7,8}$=18.0 Hz, $J_{8,8'}$=2.0 Hz, H8), 5.40 (dd, 1, $J_{7,8'}$=12.0 Hz, H8'), 6.15 (dd, 1, H7).

Anal. calcd for $C_{15}H_{30}O_4Si$: C, 59.56; H, 10.00. Found: C, 59.45; H, 10.03.

1,5-Anhydro-2-O-(tert-butyldimethylsilyl)-3-deoxy-3-C-(1,2-[R]-epoxyethyl)-3-C-methyl-D-allitol (5). Compound 4 (1.2 g, 4.0 mmol) was epoxidized according to the standard procedure to give 5 (1.05 g, 83%) as a syrup: TLC $R_f$ 0.29 (A); $[\alpha]_D$ +23.9° (c 2.80, $CHCl_3$); $^1H$ NMR δ0.02 (s, 3, $CH_3Si$), 0.04 (s, 3, $CH_3Si$), 0.83 (s, 9, $(CH_3)_3CSi$), 1.05 (s, 3, 3-$CH_3$), 2.27 (bs, 1, OH), 2.68 (t, 1, $J_{7,8}=J_{8,8'}=4.0$ Hz, H8), 2.73 (dd, 1, $J_{7,8'}=3.0$ Hz, H8'), 3.02 (bs, 1, OH), 3.29 (d, 1, $J_{4,5}=10.0$ Hz, H4), 3.44 (dd, 1, H7), 3.53-3.90 (m, 6, H1, H1', H2, H5, H6, H6').

Anal. calcd for $C_{15}H_{30}O_5Si$: C, 56.57; H, 9.49. Found: C, 56.36; H, 9.25.

1,5-Anhydro-4,6-O-benzylidene-3-C-(1,2-[R]-epoxyethyl)-3-C-methyl-D-allitol (6b). Compound 5 (100 mg, 0.33 mmol) was dissolved in dry methylene chloride (10 mL). α,α-Dimethoxytoluene (0.06 mL, 0.4 mmol) was added followed by a trace of camphorsulfonic acid. After stirring at room temperature for 15 min, the reaction mixture was neutralized with triethylamine and evaporated to dryness to give compound 6a which was desilylated according to the standard procedure to 6b (80 mg, 88%) as a syrup: TLC $R_f$ 0.40 (A); $[\alpha]_D$ +19.3° (c 0.15, $CHCl_3$); $^1H$ NMR δ1.34 (s, 3, 3-$CH_3$), 2.76 (t, 1, $J_{7,8}=J_{8,8'}=4.0$ Hz, H8), 3.25 (dd, 1, $J_{7,8'}=3.0$ Hz, H8'), 3.30 (d, 1, $J_{4,5}=10.0$ Hz, H4), 3.30 (m, 1, H7), 3.51 (t, 1, $J_{5,6a}=J_{6a,6c}=10.0$ Hz, H6a), 3.60-3.86 (m, 3, H1a, H1e, H2), 3.91 (dt, 1, $J_{5,6e}=5.0$ Hz, H5), 4.28 (dd, 1, H6e), 5.42 (s, 1, PhCH), 7.30-7.50 (m, 5, Ph).

1,5-Anhydro-4,6-di-O-benzyl-3-deoxy-3-C-(1,2-[R]-epoxyethyl)-3-C-methyl-D-ribo-2-hexulose (9c). Compound 9b (0.77 g, 2.0 mmol) was oxidized according to the standard procedure to give 9c (0.73 g, 95%) as a syrup: TLC $R_f$ 0.36 (B); $[\alpha]_D$ -44.3° (c 5.20, $CHCl_3$); IR $\gamma_{CO}$ 1730 $cm^{-1}$; $^1H$ NMR δ1.08 (s, 3, 3-$CH_3$), 2.72 (dd, 1, $J_{7,8}=3.0$ Hz, $J_{8,8'}=4.0$ Hz, H8), 2.83 (t, 1, $J_{7,8}=4.0$ Hz, H8'), 3.43 (dd, 1, H7), 3.62 (dd, 1, $J_{5,6}=5.0$ Hz, $J_{6,6'}=10.0$ Hz, H6), 3.69 (dd, 1, $J_{5,6}=5.0$ Hz, H6'), 3.77 (d, 1, $J_{4,5}=5.0$ Hz, H4), 3.99

(q, 1, H5), 4.06 (d, 1, $J_{1,1'}$=18.0 Hz, H1), 4.25 (d, 1, H1'), 4.50-4.65 (m, 4, $PhCH_2O$), 7.20-7.40 (m, 10, Ph).

Anal. calcd for $C_{23}H_{26}O_5$: C, 72.23; H, 6.85. Found: 72.14; H, 6.67.

1,5-Anhydro-4,6-di-O-benzyl-2-O-(tert-butyldimethylsilyl)-3-deoxy-3-C-methyl-3-C-vinyl-D-allitol (7a). Compound 4 (1.7 g, 5.6 mmol) was dissolved in dry THF (50 mL). Sodium hydride (50% in oil, 0.8 g, 16.6 mmol) was added slowly and the resulting suspension was stirred at room temperature for 15 min. Tetrabutylammonium iodide (200 mg, 0.56 mmol) was added followed by benzyl bromide (2.0 mL, 16.8 mmol). The resulting mixture was stirred at room temperature for 8 h, after which the reaction mixture was diluted with diethyl ether (50 mL), washed with saturated brine (3 x 20 mL), dried over sodium sulfate, and concentrated to a syrup which was chromatographed (solvent D) to give 7a (2.6 g, 96%) as a syrup: TLC $R_f$ 0.31 (D); $[\alpha]_D$ +28.8° (c 6.0, $CHCl_3$); $^1H$ NMR δ0.03 (s, 3, $CH_3Si$), 0.07 (s, 3, $CH_3Si$), 0.87 (s, 9, $(CH_3)_3CSi$), 1.23 (s, 3, 3-$CH_3$), 3.34 (d, 1, $J_{4,5}$=10.0 Hz, H4), 3.42-3.72 (m, 6, H1, H1', H2, H5, H6, H6'), 4.50-4.66 (m, 4, $PhCH_2O$), 5.25 (dd, 1, $J_{7,8}$=12.0 Hz, $J_{8,8'}$=2.0 Hz, H8), 5.36 (dd, 1, $J_{7,8'}$=18.0 Hz, H8'), 6.10 (dd, 1, H7), 7.17-7.36 (m, 10, Ph).

Anal. calcd for $C_{29}H_{42}O_4Si$: C, 72.16; H, 8.77. Found: C, 72.42; H, 8.79.

1,5-Anhydro-4,6-di-O-benzyl-3-deoxy-3-C-methyl-3-C-vinyl-D-allitol (7b). Compound 7a (2.4 g, 5.0 mmol) was desilylated according to the standard procedure to give 7b (1.7 g, 93%) as a syrup: TLC $R_f$ 0.44 (A); $[\alpha]_D$ +26.4° (c 3.27, $CHCl_3$); $^1H$ NMR δ1.30 (s, 3, 3-$CH_3$), 1.45 (d, 1, $J_{2,OH}$=10.0 Hz, OH), 3.26 (t, 1, $J_{1,2}=J_{1,1'}$=11.0 Hz, H1), 3.42 (d, 1, $J_{4,5}$=10.0 Hz, H4), 3.50 (m, 1, $J_{1',2}$=5.0 Hz, H2), 3.63-3.73 (m, 3, H5, H6, H6'), 3.80 (dd, 1, H1'), 4.47-4.66 (m, 4, $PhCH_2O$), 5.30 (dd, 1, $J_{7,8}$=18.0 Hz, $J_{8,8'}$=2.0 Hz, H8), 5.45 (dd, 1, $J_{7,8'}$=12.0 Hz, H8'), 6.21 (dd, 1, H7), 7.13-7.37 (m, 10, Ph).

Anal. calcd. for $C_{23}H_{28}O_4$: C, 74.97; H, 7.66. Found: C, 74.81; H, 7.44.

1,5-Anhydro-4,6-di-O-benzyl-3-deoxy-3-C-(1,2-[S]-epoxyethyl)-3-C-methyl-D-allitol (8a). Compound 7b (1.84 g, 5.0 mmol) was epoxidized according to standard procedure to give 8a (1.6 g, 83%) as a white solid which exhibited the following characteristics: mp 98-99 °C; TLC $R_f$ 0.38 (B); $[\alpha]_D$ +23.2° (c 2.44, $CHCl_3$); $^1H$ NMR δ1.10 (s, 3, 3-$CH_3$), 2.70 (t, 1, $J_{7,8}=J_{8,8'}=$ 4.0 Hz, H8), 2.72 (d, 1, $J_{2,OH}$=10.0 Hz, OH), 2.74 (dd, 1, $J_{7,8'}$=3.0 Hz, H8'), 3.43 (d, 1, $J_{4,5}$=10.0 Hz, H4), 3.47 (dd, 1, H7), 3.55 (m, 1, $J_{1,2}$=10.0 Hz, $J_{1',2}$=5.0 Hz, H2), 3.62-3.76 (m, 3, H5, H6, H6'), 3.68 (t, 1, $J_{1,1'}$=10.50 Hz, H1), 3.92 (dd, 1, H1'), 4.50-4.68 (m, 4, $PhCH_2O$), 7.10-7.35 (m, 10, Ph).

Calcd mass for $C_{23}H_{28}O_5$: 384.1937. Found (HRMS): 384.1936.

1,5-Anhydro-4,6-di-O-benzyl-3-deoxy-3-C-(1,2-[S]-epoxyethyl)-3-C-methyl-D-ribo-2-hexulose (8b). Compound 8a (1.54 g, 4.0 mmol) was oxidized according to standard procedure to give 8b (1.50 g, 98%) as a syrup: TLC $R_f$ 0.47 (B); $[\alpha]_D$ -23.0° (c 4.31, $CHCl_3$); IR $\gamma_{CO}$ 1720 $cm^{-1}$; $^1H$ NMR δ1.20 (s, 3, 3-$CH_3$), 2.28 (dd, 1, $J_{7,8}$=3.0 Hz, $J_{8,8'}$=4.0 Hz, H8), 2.60 (t, 1, $J_{7,8'}$=4.0 Hz, H8'), 3.53 (dd, 1, H7), 3.74-3.86 (m, 3, H4, H6, H6'), 4.11 (ABq, 2, H1, H1'), 4.14 (dt, 1, $J_{4,5}$=9.0 Hz, $J_{5,6}=J_{5,6'}$=3.0 Hz, H5), 4.53-4.73 (m, 4, $PhCH_2O$), 7.20-7.36 (m, 10, Ph).

Anal. calcd for $C_{23}H_{26}O_5$: C, 72.23; H, 6.85. Found: C, 71.97; H, 6.86.

1,5-Anhydro-4,6-di-O-benzyl-2-O-(tert-butyldimethylsilyl)-(1,2-[R]-epoxyethyl)-3-C-($3^1$,$3^2$-epoxy-L-glycero-dihydroxyethyl)-3-C-methyl-D-allitol (9a). Compound 5 (0.95 g, 3.0 mmol) was dissolved in dry THF (50 mL) and sodium hydride (50% in oil, 0.36 g, 7.5 mmol) was added slowly. The suspension was stirred at room temperature for 15 min and tetrabutylammonium iodide (110 mg, 0.3 mmol), followed by benzyl bromide (0.9 mL, 7.5 mmol) was added. The resulting mixture was stirred at room temperature for

12 h. The resulting white suspension was diluted with diethyl ether (50 mL), washed with saturated brine (3 x 20 mL), dried over sodium sulfate, and concentrated to a syrup which was chromatographed (solvent C) to give 9a (1.30 g, 87%) as a syrup: TLC $R_f$ 0.36 (C); $[\alpha]_D$ +31.4° (c 4.40, $CHCl_3$); $^1H$ NMR δ0.05 (s, 3, $CH_3Si$), 0.08 (s, 3, $CH_3Si$), 0.87 (s, 9, $(CH_3)_3CSi$), 1.07 (s, 3, 3-$CH_3$), 2.57 (dd, 1, $J_{7,8}$=4.0 Hz, $J_{8,8'}$=5.0 Hz, H8), 2.98 (dd, 1, $J_{7,8'}$=3.0 Hz, H8'), 3.30 (dd, 1, H7), 3.39 (d, 1, $J_{4,5}$=10.0 Hz, H4), 3.50-3.75 (m, 5, H1, H1', H2, H6, H6'), 3.99 (dt, 1, $J_{5,6}$=$J_{5,6'}$=3.0 Hz, H5), 5.45-5.65 (m, 4, $PhCH_2O$), 7.17-7.35 (m, 10, Ph).

Anal. calcd for $C_{29}H_{42}O_5Si$: C, 69.84; H, 8.49. Found: C, 69.86; H, 8.44.

1,5-Anhydro-4,6-di-O-benzyl-3-deoxy-3-C-(1,2-[R]-epoxyethyl)-3-C-methyl-D-allitol (9b). Compound 9a (1.0 g, 2.0 mmol) was desilylated according to the standard procedure to give 9b (0.73 g, 95%) as a syrup: TLC $R_f$ 0.33 (A); $[\alpha]_D$ +52.1° (c 3.49, $CHCl_3$); $^1H$ NMR δ1.20 (s, 3, 3-$CH_3$); 2.20 (bs, 1, OH), 2.69 (dd, 1, $J_{7,8}$=4.5 Hz, $J_{8,8'}$=5.0 Hz, H8), 3.08 (dd, 1, $J_{7,8'}$=3.0 Hz, H8'), 3.28 (dd, 1, H7), 3.39 (d, 1, $J_{4,5}$=10.0 Hz, H4), 3.60-3.90 (m, 6, H1, H1', H2, H5, H6, H6'), 4.47-4.65 (m, 4, $PhCH_2O$), 7.20-7.35 (m, 10, Ph).

Calcd mass for $C_{23}H_{28}O_5$: 384.1937. Found (HRMS): 384.1936.

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