Branched-chain Sugars. XVII. Stereoselectivity in the Oxidation of Several Methyl 4,6-*O*-Benzylidene-2-*C*- or -3-*C*-methylene-α- and -β-D-hexopyranosides with *m*-Chloroperbenzoic Acid[1]

Juji YOSHIMURA,* Ken-ichi SATO, and Masuo FUNABASHI

Laboratory of Chemistry for Natural Products, Faculty of Science, Tokyo Institute of Technology, Nagatsuta, Midoriku, Yokohama 227

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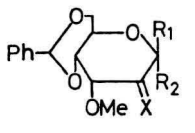
Stereoselectivity in the peroxy acid oxidation of methyl 4,6-*O*-benzylidene-3-*O*-methyl-2-*C*-methylene-α-D-*ribo*-hexopyranoside (**1b**), its 3-epimer (**2b**), β-anomer of **1b** and **2b**, methyl 4,6-*O*-benzylidene-2-*O*-methyl-3-*C*-methylene-α-D-*arabino*-hexopyranoside and its 2-epimer was examined. The results were compared with those of rigid methylenecyclohexane systems.

In previous papers reports were given on the stereoselectivity examined in the reaction of methyl 4,6-*O*-benzylidene-α- and -β-D-hexopyranosid-2-uloses and -3-uloses with nucleophiles.[2-5] It was found that in the reaction of diazomethane stereoselectivity is mainly controlled by the electrostatic attractive interaction between neighboring axial oxygens and diazomethyl cation in the zwitterionic intermediates.[4,5] The interaction sometimes resulted in a complemental stereoselectivity of diazomethane reaction to that of usual nucleophiles such as hydride anions and carbanions, valuable for a stereospecific synthesis of a proper branched-chain sugar.[6] However, the diazomethane reaction of uloses is sometimes accompanied by ring-expansion reaction, even when the stereoselectivity is the desired one.[7-9] For such cases, it was found that the peroxy acid oxidation of the corresponding methylene derivative provides a reliable pathway to obtain the spiro epoxide which is also afforded by the diazomethane reaction of the ulose.[10,11]

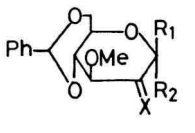
We have examined the stereoselectivity in the peroxy acid oxidation of several 2- or 3-methylen-α- and β-D-hexopyranosides in comparison with that of the diazomethane reaction of the corresponding uloses.

Results and Discussion

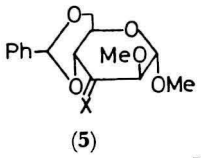
As the substrates, methyl 4,6-*O*-benzylidene-3-*O*-methyl-2-*C*-methylene-α-D-*ribo*-hexopyranoside (**1b**), its 3-epimer (**2b**), β-anomer of **1b**(**3b**) and **2b**(**4b**), methyl 4,6-*O*-benzylidene-2-*O*-methyl-3-*C*-methylene-α-D-*arabino*- (**5b**) -β-D-*ribo*-hexopyranosides (**6b**) were



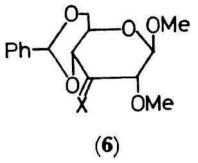
(**1**) R_1=H, R_2=OMe
(**3**) R_1=OMe, R_2=H



(**2**) R_1=H, R_2=OMe
(**4**) R_1=OMe, R_2=H



(**5**)



(**6**)

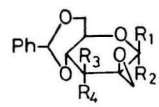
a: X=O
b: X=CH_2

synthesized from the corresponding uloses[12] and methyltriphenylphosphonium bromide by the usual method. In the case of **3b**, the corresponding ulose (**3a**)[13] was synthesized by the dimethyl sulfoxide–trifluoroacetic anhydride oxidation[12] of methyl 4,6-*O*-benzylidene-3-*O*-methyl-β-D-altropyranoside (**7**) obtained by the preferential ring-opening of the corresponding 2,3-epoxide of D-*manno* configuration with methanol. The 2,3-epoxide was synthesized by an improved method.[14]

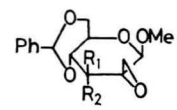
m-Chloroperbenzoic acid oxidation of methylene derivatives was carried out in dry 1,2-dichloroethane at 60 °C, until the starting material disappeared on TLC.

Oxidation of **1b** exclusively gave methyl 2,2′-anhydro-4,6-*O*-benzylidene-2-*C*-hydroxymethyl-3-*O*-methyl-α-D-altropyranoside (**8**) in 82% yield, the product being identical with that obtained by the diazomethane reaction of the corresponding ulose (**1a**).[5] Similarly, oxidation of **2b** exclusively gave the corresponding spiro epoxide (**9**) of D-*manno* configuration in 86% yield, the main product in the reaction of diazomethane with **2a**.[5] Oxidation of **3b** gave an epimeric mixture of the corresponding spiro epoxides (**10**) and (**11**) in 79% yield. Separation of the mixture on preparative TLC gave pure **10** and **11** in the ratio 2:1. In order to determine the configuration of these epimers, they were reduced with lithium aluminum hydride to give the corresponding 2-*C*-methyl derivatives (**12** and **13**), subsequent acetolysis afforded the corresponding tetra-*O*-acetates (**14** and **15**), respectively. By comparison of these α,β-acetates with those obtained from methyl 4,6-*O*-benzylidene-2-*C*-methyl-3-*O*-methyl-α-D-altro- and -allopyranoside,[5] the configuration of the main products (**10**, **12**, and **14**) was determined to be D-*altro* (H_1 protons of **14** appeared at δ 6.41 and 6.22), and that of the minor product D-*allo* (**15**; δ 6.37 and 5.86).

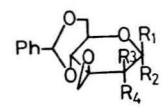
Oxidation of **4b** also gave an epimeric mixture of the corresponding spiro epoxides (**16** and **17**) in 84% yield in the ratio 1.2:1. The configuration of the main product was determined to be D-*gluco* by comparison with that obtained by the diazomethane reaction of **4a**.[5] Similarly the oxidation of **5b** and **6b** gave an epimeric mixture of the corresponding spiro epoxides (**18** and **19**, and **20** and **21**), respectively. The configurations of these compounds were also determined by comparison with those obtained by the diazomethane reaction of **5a** and **6a**.[4] The results are summarized



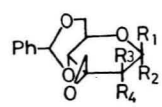
	R_1	R_2	R_3	R_4
(**8**)	H	OMe	H	OMe
(**9**)	H	OMe	OMe	H
(**10**)	OMe	H	H	OMe
(**17**)	OMe	H	OMe	H



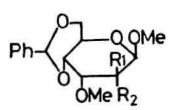
	R_1	R_2
(**11**)	H	OMe
(**16**)	OMe	H



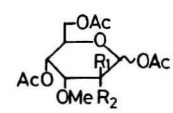
	R_1	R_2	R_3	R_4
(**18**)	H	OMe	OMe	H
(**20**)	OMe	H	H	OMe



	R_1	R_2	R_3	R_4
(**19**)	H	OMe	OMe	H
(**21**)	OMe	H	H	OMe



	R_1	R_2
(**7**)	OH	H
(**12**)	OH	Me
(**13**)	Me	OH



	R_1	R_2
(**14**)	OAc	Me
(**15**)	Me	OAc

Table 1. Comparison of stereoselectivity in the peroxy acid oxidation of methyl 4,6-*O*-benzylidene-2- or -3-methylene-α- and -β-D-hexopyranosides and in the diazomethane reaction of the corresponding uloses

Substrates		Yields (%) of spiro epoxides in the reaction of uloses with diazomethane[a] (a series) and that of methylene derivatives with *m*-chloroperbenzoic acid (b series)	
		Axial attack product	Equatorial attack product
1	a		83.5 (**8**)
	b	82.0 (**8**)	
2	a	31.1	63.7 (**9**)
	b	86.0 (**9**)	
3	a	21.8 (**11**)	65.3 (**10**)
	b	52.7 (**10**)	26.3 (**11**)
4	a	92.5 (**16**)	
	b	38.2 (**17**)	45.2 (**16**)
5	a		41.0 (**19**)[b]
	b	39.5 (**19**)	47.5 (**18**)
6	a	17.6 (**20**)	76.5 (**21**)
	b	42.0 (**21**)	30.0 (**20**)

a) The results are cited from Refs. 4 and 5, except those of **3a**. b) The ring-expansion product of **19** was obtained in 36.9% yield.

in Table 1.

The reaction of **3a** and diazomethane in ethanol was carried out in order to confirm our hypothesis on stereoselectivity. Separation of the products (87% yield) on preparative TLC gave **10** and **11** in the ratio 3:1. Since **4a** exclusively gave an axial attack product in the diazomethane reaction,[4] the predominant equatorial attack also supports our hypothesis, in which the electrostatic attractive force of axial oxygen at C-3 position is stronger than that of lone pair electron of ring oxygen at β-position of the carbonyl group.

By considering both steric (non-bonded interactions) and electrostatic (attractive or repulsive) factors (Table 1), the stereoselectivity in the diazomethane reaction of uloses could be explained by the electrostatic attractive interaction between neighboring axial oxygen atom and diazomethyl cation in the transition state.

Peroxy acid oxidation is known to involve an electrophilic attack of the reagent from the less hindered side of the alkene to give the less hindered epoxide, through a highly ordered transition state.[15,16]

In the *m*-chloroperbenzoic acid oxidation of rigid methylenecyclohexane systems, Carlson and Behn showed that the axial attack percentage[17] is 59—69% due to stronger steric hindrance of axial hydrogen on α-carbon than that of β-carbon in the transition state.[18] From the results obtained here, the axial attack percentage in the case of **4b** (46%) and **6b** (58%) can be considerd as standards for 2-methylene and 3-methylene pyranosides, respectively, since they have no axial substiuents. The lower percentage of axial attack in the case of **4b** than that of cyclohexane systems suggests "the product development control"[18] of C_2–O dipole bisecting C_1–O_1 and C_1–O_5 torsional angle in axial attack epoxide formation of β-anomers. The higher percentage in the case of **3b** (68%) than that of **4b** is estimated as the steric factor of the axial 3-methoxyl group. The predominant axial attack in the case of α-anomer of 2-methylene derivatives (**1b** and **2b**) is attributed to the strong steric factor of the axial methoxyl group at C-1 position, as is known in the reduction of 2-uloses with hydride anions.[5,19]

The lower percentage in the case of **5b** (45%) than that of **6b** should be attributed to the balance of steric factors between axial 1- and 2-methoxyl groups. However, the hindrance of the former seems to be larger than the latter, since the percentage of methyl 4,6-*O*-benzylidene-2-deoxy-3-methylene-α-D-*erythro*-hexopyranoside having no 2-methoxyl group is 25%.[11]

Experimental

General Methods. All melting points were determined on a Yanagimoto micro melting point apparatus and are uncorrected. Solvents were evaporated under reduced pressure at a bath temperature not exceeding 50 °C. Optical rotations were measured in a 0.2 dm tube with a Carl Zeiss LEP-Al polarimeter in chloroform unless otherwise stated. IR spectra were recorded with a Hitachi Model EPI-G2 spectrometer, and NMR spectra with a JNM-PS-100 spectrometer in deuteriochloroform containing tetramethylsilane as an internal standard. Chemical shifts and coupling constants were recorded in δ and Hz units, and IR frequencies in cm^{-1}.

*Methyl-4,6-O-benzylidene-3-O-methyl-β-D-ribo-hexopyranosid-2-ulose (**3a**).* Mesylation of methyl 4,6-*O*-benzylidene-3-*O*-benzoyl-β-D-glucopyranoside in pyridine with methanesulfonyl chloride gave the concesponding 2-*O*-mesylate in 82% yield, which was recrystallized from ethanol–hexane. Mp 194—197 °C; $[\alpha]_D^{22}$ −81.5° (*c* 1.1). IR: 1735 (ester); NMR: 8.20—8.00 and 7.60—7.20 (Ph: m), 5.65 (H_3: t, $J_{2,3}=J_{3,4}=9.0$), 4.80—4.50 (H_2 and H_1: m), 4.38 (H_6: q, $J_{5,6}=4.4$, $J_{6,6'}=10.2$), 3.93—3.44 (H_4, H_5, and $H_{6'}$: m), 3.57 (OMe), 2.99 (OMs).

Found: C, 56.75; H, 5.19; S, 6.26%. Calcd for $C_{22}H_{24}O_9S$: C, 56.89; H, 5.21; S, 6.90%.

A solution of the above mesylate (1 g, 2.2 mmol) and sodium (60.7 mg, 2.6 mmol) in absolute methanol (50 ml) was refluxed for 1 h until the starting material and its de-*O*-benzoylated product disappeared on TLC. The reaction mixture was poured into water, and then extracted with chloroform. The usual work-up of the extract gave methyl 4,6-*O*-benzylidene-2,3-anhydro-β-D-mannopyranoside, which was recrystallized from ethanol–hexane in 83% yield. Mp 181—183 °C; $[\alpha]_D^{22}$ −30.2° (*c* 0.7), [lit,[13] mp 182 °C; $[\alpha]_D^{22}$ −30.4° (*c* 0.82)].

Found: C, 63.91; H, 6.22%. Calcd for $C_{14}H_{16}O_5$: C, 63.62; H, 6.10%.

A solution of the above 2,3-anhydro-mannopyranoside (500 mg) and sodium methoxide (700 mg sodium) in methanol (20 ml) was refluxed for 24 h, poured into water, and then extracted with chloroform. The chloroform layer was evaporated to give a mixture of crystals which were separated on preparative TLC (ether–hexane=1:1, Merck type 60 Kieselgel). Lower R_f product was methyl 4,6-*O*-benzylidene-2-*O*-methyl-β-D-glucopyranoside. Yield, 38%; mp 172—175 °C (ethanol–hexane); $[\alpha]_D^{22}$ −69.6° (*c* 1.5), [lit,[20] mp 175—176 °C; $[\alpha]_D^{14}$ −67.3° (*c* 1.6)].

Found: C, 60.86; H, 7.02%. Calcd for $C_{15}H_{20}O_6$: C, 60.80; H, 6.80%.

Higher R_f product was methyl 4,6-*O*-benzylidene-3-*O*-methyl-β-D-altropyranoside (**7**). Yield, 41%, mp 94—96 °C (ethanol–hexane); $[\alpha]_D^{22}$ −63.0° (*c* 1.2). IR: 3536 (OH); NMR: 7.60—7.30 (Ph: m), 5.57 (PhCH: s), 4.77 (H_1: d, $J_{1,2}=1.2$), 4.38 (H_6: q, $J_{5,6}=4.0$, $J_{6,6'}=7.0$), 4.15—3.67 (H_2, H_3, H_4, H_5, and $H_{6'}$: m), 3.60 (2×OMe), 2.66 (OH: d, $J_{2,OH}=2.0$).

Found: C, 61.10; H, 6.85%. Calcd for $C_{15}H_{20}O_6$: C, 60.80; H, 6.80%. Coupling constants ($J_{1,2}=1.6$, $J_{2,3}=3.6$) in the NMR spectrum of the corresponding 2-acetate support the structure.

Oxidation of the above β-D-altropyranoside with dimethyl sulfoxide–trifluoroacetic anhydride, under similar conditions to those reported,[12] afforded **3a** in 87% yield, which was recrystallized from ethanol–water. Hydrate of **3a**: Mp 85—90 °C; $[\alpha]_D^{22}$ −56.8° (*c* 0.8). IR: 3500 and 3380 (OH); NMR 7.60—7.25 (Ph: m), 5.50 (PhCH: s), 4.52 (H_1: s), 4.37 (H_6: q, $J_{5,6}=3.0$, $J_{5,6'}=7.8$), 4.15—3.50 (H_4, H_5, and OH: m), 3.86 ($H_{6'}$: t, $J_{6,6'}=7.8$), 3.70 (H_3: d, $J_{3,4}=2.0$), 3.67 and 3.63 (2×OMe).

Found: C, 57.76; H, 6.60%. Calcd for $C_{15}H_{18}O_6\cdot H_2O$: C, 57.68; H, 6.46%.

*Wittig Reaction of Uloses (**1a**—**6a**).* A solution of butyllithium (10%; 2.9 ml, 4.5 mmol) in hexane was added dropwise with stirring to a suspension of methyltriphenylphosphonium bromide (2.9 g, 5.6 mmol) in dry tetrahydrofuran (7 ml) cooled in an ice–water bath. A solution of methyl 4,6-*O*-benzylidene-3-*O*-methyl-α-D-*ribo*-hexopyranosid-2-ulose (**1a**)[5] (1 g, 3.4 mmol) in tetrahydrofuran (30 ml) was then rapidly added with vigorous stirring to the resulting yellowish orange suspension. The reaction mixture was kept at room temperature for 30 min until **1a** disappeared on TLC. After addition of ether (70 ml) to the mixture, the precipitate was collected by filtration. The filtrate was evaporated, and the residue was placed on a silica-gel column (Wako-gel C-200: 30 g) followed by elution with benzene to give white crystals (437 mg, 44%), methyl 4,6-*O*-benzylidene-3-*O*-methyl-2-*C*-methylene-α-D-*ribo*-hexopyranoside (**1b**) which were recrystallized from ether–hexane. Mp 82—84 °C; $[\alpha]_D^{22}$ +40.3° (*c* 0.6). NMR: 7.64—7.20 (Ph: m), 5.51 (PhCH: s), 5.30 and 5.25 (exo-CH_2: each s), 4.38 (H_5: m), 4.34 (H_6: q, $J_{5,6}=4.8$), 4.07 (H_3: d, $J_{3,4}=3.2$), 3.66 ($H_{6'}$: t, $J_{5,6'}=J_{6,6'}=11.0$), 3.65 (H_4: q, $J_{4,5}=8.0$), 3.40 and 3.35 (2×OMe).

Found: C, 65.82; H, 6.83%. Calcd for $C_{16}H_{20}O_5$: C, 65.74; H, 6.90%.

A similar reaction of methyl 4,6-*O*-benzylidene-3-*O*-methyl-α-D-*arabino*-hexopyranosid-2-ulose (**2a**) gave the corresponding 2-*C*-methylene derivative (**2b**) in 52% yield, which was recrystallized from ether–hexane. Mp 149—151 °C; $[\alpha]_D^{22}$ +55.4° (*c* 0.9). NMR: 7.60—7.20 (Ph:m), 5.54 (H_1: s), 5.35 and 5.17 (exo-CH_2: each q, $J_{4,CH_2}=1.0$, $J_{gem}=2.0$), 4.23 (H_5: sex), 4.26 (H_4: t, $J_{3,4}=J_{4,5}=9.2$), 3.97 (H_6: q, $J_{5,6}=4.0$), 3.73 ($H_{6'}$: t, $J_{5,6'}=J_{6,6'}=9.4$), 3.58 (H_3: dd), 3.58 and 3.38 (2×OMe).

Found: C, 65.77; H, 6.90%. Calcd for $C_{16}H_{20}O_5$: C, 65.74; H, 6.90%.

A similar reaction of **3a** gave methyl 4,6-*O*-benzylidene-3-*O*-methyl-2-*C*-methylene-β-D-*ribo*-hexopyranoside (**3b**) in 57% yield, which was recrystallized from ethanol. Mp 95—97 °C; $[\alpha]_D^{22}$ −95.5° (*c* 2.8). NMR: 7.60—7.20 (Ph: m), 5.52 (PhCH and H_1: superimposed s), 5.18 and 5.01 (exo-CH_2: each broad s), 4.37 (H_6: q, $J_{5,6}=5.0$, $J_{6,6'}=9.8$), 4.13 (H_5: m), 4.12 (H_3: d, $J_{3,4}=3.0$), 3.73 ($H_{6'}$: t, $J_{5,6'}=9.8$), 3.67 (H_4:q, $J_{4,5}=9.0$), 3.60 and 3.36 (2×OMe).

Found: C, 65.66; H, 7.03%. Cacld for $C_{16}H_{20}O_5$: C, 65.74; H, 6.90%.

A similar reaction of methyl 4,6-*O*-benzylidene-3-*O*-methyl-β-D-*arabino*-hexopyranosid-2-ulose (**4a**)[5] gave the corresponding 2-*C*-methylene derivative (**4b**) in 67% yield, which was recrystallized from ethanol. Mp 156—157 °C; $[\alpha]_D^{22}$ −71.2° (*c* 1.2). NMR: 7.60—7.25 (Ph: m), 5.56 (PhCH: s), 5.50 and 5.42 (exo-CH_2: each broad s), 4.80 (H_1: s), 4.35 (H_6: q, $J_{5,6}=4.0$, $J_{6,6'}=10.0$), 4.00—3.45 (H_3, H_4, and H_5: m), 3.80 ($H_{6'}$:t, $J_{6,6'}=J_{5,6'}=10.0$), 3.62 and 3.60 (2×OMe).

Found: C, 65.49; H, 6.99%. Calcd for $C_{16}H_{20}O_5$: C, 65.74; H, 6.90%.

A similar reaction of methyl 4,6-*O*-benzylidene-2-*O*-methyl-α-D-*arabino*-hexopyranosid-3-ulose (**5a**)[4] gave the corresponding 3-*C*-methylene derivative (**5b**) in 72% yield, which was recrystallized from ethanol. Mp 88—90 °C; $[\alpha]_D^{22}$ +108.7° (*c* 1.1). NMR: 7.70—7.20 (Ph: m), 5.60 (PhCH: s), 5.38 and 5.14 (exo-CH_2: each t, $J_{gem}=J_{4,CH_2}=1.6$), 4.73 (H_1: d, $J_{1,2}=1.2$), 4.40—4.05 (H_5 and H_6: m), 4.00—3.70 (H_4 and $H_{6'}$:m), 3.75 (H_2: d), 3.40 and 3.32 (2×OMe).

Found: C, 66.15; H, 6.86%. Calcd for $C_{16}H_{20}O_5$: C, 65.74; H, 6.90%.

A similar reaction of methyl 4,6-*O*-benzylidene-2-*O*-methyl-β-D-*ribo*-hexopyranosid-3-ulose (**6a**)[4] gave the corresponding 3-*C*-methylene derivative (**6b**) in 60% yield, which was recrystallized from ethanol. Mp 160—161 °C; $[\alpha]_D^{22}$ −61.9° (*c* 1.0). NMR: 7.60—7.20 (Ph: m), 5.60 (PhCH: s), 5.27 (exo-CH_2: t, $J_{4,CH_2}=J_{gem}=2.0$), 4.34 (H_6: q, $J_{5,6}=5.0$), 4.23 (H_1: d, $J_{1,2}=7.6$), 3.94 (H_4: broad d, $J_{4,5}=9.0$), 3.78 ($H_{6'}$: t, $J_{5,6'}=J_{6,6'}=10.0$), 3.58 and 3.57 (2×OMe), *ca.* 3.57 (H_2: d), 3.30 (H_5: sex).

Found: C, 65.70; H, 7.00%. Calcd for $C_{16}H_{20}O_5$: C, 65.74; H, 6.90%.

Oxidation of exo-*Methylene Compounds* (***1b—6b***) *with* m-*Chloroperbenzoic Acid.* A solution of **1b** (300 mg, 1.0 mmol) and *m*-chloroperoxybenzoic acid (85% purity, 406 mg, 2.0 mmol) dissolved in 1,2-dichloroethane (15 ml) was heated at 60 °C overnight. The mixture was washed with 0.1 M sodium hydroxide and water, and dried with magnesium sulfate. The organic layer was evaporated to give crystalline methyl 2,2′-anhydro-4,6-*O*-benzylidene-2-*C*-hydroxymethyl-3-*O*-methyl-α-D-altropyranoside (**8**) in 82% yield which was recrystallized from ethanol–hexane. Mp 108—109 °C; $[\alpha]_D^{23}$ +85.0° (*c* 0.7). NMR spectrum was identical with that of the authentic sample.[5]

A similar reaction of **2b** gave methyl 2,2′-anhydro-4,6-*O*-benzylidene-2-*C*-hydroxymethyl-3-*O*-methyl-α-D-mannopyranoside (**9**) in 86% yield which was recrystallized from ethanol–hexane. All the physical constants were identical with those of the authentic sample derived from the reaction of **2a** and diazomethane. Mp 140—141 °C; $[\alpha]_D^{22}$ +76.5° (*c* 0.8).

A similar reaction of **3b** and separation of two products on preparative TLC (ether–hexane 1:1) gave the epimeric pair of spiro epoxides, methyl 2,2′-anhydro-4,6-*O*-benzylidene-2-*C*-hydroxymethyl-3-*O*-methyl-β-D-altropyranoside (**10**) and the corresponding β-D-allopyranoside (**11**), in 52.7 and 26.3% yields, respectively, which were recrystallized from ethanol–hexane.

10: Mp 114—115 °C; $[\alpha]_D^{22}$ −81.6° (*c* 0.8). NMR: 7.60—7.25 (Ph: m), 5.54 (PhCH: s), 5.00 (H_1: s), 4.40 (H_6: q, $J_{5,6}$=4.0), 4.10 (H_5: m), 3.95 (H_4: q, $J_{4,5}$=8.6), 3.83 ($H_{6'}$: t, $J_{5,6'}=J_{6,6'}$=9.0), 3.30 (H_3: d, $J_{3,4}$=2.4), 3.56 and 3.52 (2×OMe), 3.11 and 2.78 (epoxy CH_2: ABq, J=5.3).

Found: C, 61.89; H, 6.65%. Calcd for $C_{16}H_{20}O_6$: C, 62.32; H, 6.54%.

11: Mp 150—151 °C; $[\alpha]_D^{22}$ −61.2° (*c* 0.7). NMR: 7.60—7.25 (Ph: m), 5.50 (PhCH: s), 5.30 (H_1: s), 4.37 (H_6: q, $J_{5,6}$=5.0), 4.16 (H_5: sex), 3.76 ($H_{6'}$: t, $J_{5,6'}=J_{6,6'}$=10.0), 3.76 (H_4: q, $J_{3,4}$=2.2, $J_{4,5}$=9.0), 3.45 (H_3: d), 3.62 and 3.53 (2×OMe), 3.23 and 2.57 (epoxy CH_2: ABq, J=5.4).

Found: C, 62.21; H, 6.57%. Calcd for $C_{16}H_{20}O_6$: C, 62.32; H, 6.54%. Configutations of **10** and **11** were determined by conversions into **14** and **15**, respectively.

A similar reaction of **4b** gave the epimeric pair of spiro epoxide, methyl 2,2′-anhydro-4,6-*O*-benzylidene-2-*C*-hydroxymethyl-3-*O*-methyl-β-D-glucopyranoside (**16**) and the corresponding β-D-mannopyranoside (**17**). Separation of the mixture on preparative TLC (ether–hexane 1:1) gave pure **16** in 45.2% yield, which is identical with the authentic sample obtained by the diazomethane reaction of **4a**.[5] However, pure **17** could not be obtained in a pure state due to its instability on TLC plate. The yield and structure of **17** were estimated form the NMR spectrum of the mixture.

17: NMR 7.60—7.25 (Ph: m), 5.63 (PhCH: s), 4.75 (H_1: s), 4.40 (H_6: q), 3.60 and 3.52 (2×OMe), 3.06 and 2.99 (epoxy CH_2: ABq, J=5.8), H_3, H_4, H_5, and $H_{6'}$, could not be analyzed.

A similar reaction of **5b** and separation of two products on preparative TLC (ether–hexane 1:1) gave the epimeric pair of spiro epoxides, methyl 3,3′-anhydro-4,6-*O*-benzylidene-3-*C*-hydroxymethyl-2-*O*-methyl-α-D-mannopyranoside (**18**) and the corresponding α-D-altropyranoside (**19**) in 47.5 and 39.5% yields, respectively.

18: Sirup; $[\alpha]_D^{22}$ +62.0° (*c* 1.9). NMR: 7.55—7.20 (Ph: m) 5.56 (PhCH: s), 4.76 (H_1: d, $J_{1,2}$=1.8), 4.47—3.75 (H_4, H_5, H_6, and $H_{6'}$: m), 3.11 (H_2: d), 3.54 and 3.37 (2×OMe), 3.17 and 2.70 (epoxy CH_2: ABq, J=6.0).

Found: C, 62.21; H, 6.50%. Calcd for $C_{16}H_{20}O_6$: C, 62.32; H. 6.54%.

19: Mp 141—143 °C (from ether–hexane); $[\alpha]_D^{23}$ +75.3° (*c* 1.3). NMR and IR spectra were identical with those of the authentic sample[4] obtained by the diazomethane reaction of **5a**.

Oxidation of **6b** and separation of two products on preparative TLC (ether–hexane 1:1) gave the epimeric pair of methyl-**3,3′-a**nhydro-4,6-*O*-benzylidene-3-*C*-hydroxymethyl-2-*O*-methyl-β-D-glucopyranoside (**20**) and the corresponding β-D-allopyranoside (**21**) in 30.0% and 42.0% yields, respectively, which were recrystallized from ethanol–hexane.

20: Mp 150—151 °C; $[\alpha]_D^{23}$ −74.2° (*c* 0.8).

21: Mp 156—157 °C; $[\alpha]_D^{23}$ −62.9° (*c* 0.9).

NMR and IR spectra of both **20** and **21** were identical with those of the authentic samples[4] obtained by the diazomethane reaction of **6a**.

Reduction of ***10*** *and* ***11*** *with Lithium Aluminium Hydride.* Lithium aluminium hydride (50 mg) was added to a solution of **10** (150 mg, 0.52 mmol) in tetrahydrofurane (5 ml) and the mixture was then stirred at room temperature for 1 h. The excess hydride was carefully decomposed with water and then filtered. The filtrate was extracted with chloroform. The extract was washed with water, dried with anhydrous magnesium sulfate, and evaporated to give crystalline methyl 4,6-*O*-benzylidene-2-*C*-methyl-3-*O*-methyl-β-D-altropyranoside (**12**) in 91% yield which was recrystallized from ethanol–hexane. Mp 113—114 °C; $[\alpha]_D^{22}$ −64.4° (*c* 1.0). IR: 3520 (OH); NMR: 7.60—7.20 (Ph: m), 5.47 (PhCH: s), 4.44 (H_1: s), 4.34 (H_6: q, $J_{5,6}$=4.0, $J_{6,6'}$=9.0), 4.14 (H_4: q, $J_{3,4}$=2.0, $J_{4,5}$=10.0), 3.94 (H_5: sex), 3.77 ($H_{6'}$: t, $J_{5,6'}$=9.0), 3.47 (H_3: d), 3.56 and 3.47 (2×OMe), 2.70 (OH: broad s), 1.27 (CMe).

Found: C, 61.90; H, 7.30%. Calcd for $C_{16}H_{22}O_6$: C, 61.92; H, 7.15%.

A similar reduction of **11** (150 mg) in THF (5 ml) afforded methyl 4,6-*O*-benzylidene-2-*C*-methyl-3-*O*-methyl-β-D-allopyranoside (**13**) in 89% yield wihch was recrystallized from ethanol–hexane. Mp 118—119 °C; $[\alpha]_D^{22}$ −68.0° (*c* 1.1). NMR: 7.60—7.20 (Ph: m), 5.44 (PhCH: s), 4.43 (H_1: s), 4.35 (H_6: q, $J_{5,6}$=4.0, $J_{6,6'}$=10.4), 4.00—3.48 (H_3, H_4, H_5, and $H_{6'}$: m) 3.60 and 3.48 (2×OMe), 3.30 (OH: broad s), 1.27 (CMe).

Found: C, 61.82; H, 7.41%. Calcd for $C_{16}H_{22}O_6$: C, 61.92; H, 7.15%.

Determination of the Configuration of ***12*** *and* ***13***. A solution of **12** (100 mg) in acetic anhydride (3 ml) containing a drop of 60% perchloric acid was heated at 60 °C for 6 h. Since acetolysis was incomplete, the reaction was repeated at room temperature for 18 h, using *p*-toluenesulfonic acid as a catalyst. The reaction mixture was then poured into cold sodium hydrogencarbonate solution and the resulting solution was extracted with chloroform.

The extracts were washed with water, dried, and evaporated to give a mixture of sirupy 1,2,4,6-tetra-*O*-acetyl-2-*C*,3-*O*-dimethyl-α- and -β-D-altropyranoses (**14**). The configutation was determined without isolation of anomers by direct comparison of the R_f value and NMR spectrum with those of the authentic sample prepared by acetolysis of methyl 4,6-*O*-benzylidene-2-*C*,3-*O*-dimethyl-α-D-altropyranoside.[5]

Compound **13** was also converted into a mixture of sirupy 1,2,4,6-tetra-*O*-acetyl-2-*C*,3-*O*-dimethyl-α- and -β-D-*allo*-pyranoses (**15**), which was identical with that obtained by the acetolysis of methyl 4,6-*O*-benzylidene-2-*C*,3-*O*-dimethyl-α-D-allopyranoside.[5]

14: R_f values, 0.41 and 0.36 (on DC Fertigplatten Kieselgel 60, Merck AG; benzene–acetone 8:1). NMR: 6.37 and 5.86 (H_1:each s), 3.57 (2×OMe), 2.15—2.05 (8×OAc), 1.60 and 1.54 (CMe).

15: R_f values, 0.36 and 0.31 (under the same conditions as above). NMR: 6.41 and 6.22 (H_1: each s), 3.50 and 3.40 (OMe), 2.15—2.05 (8×OAc), 1.68 and 1.56 (CMe).

Reaction of ***3a*** *with Diazomethane.* To a solution of **3a** (294 mg, 1.0 mmol) in ethanol (30 ml) was added dropwise a solution of diazomethane (2.0 mmol) in ether (10 ml) at 0 °C. After the mixture had been left at room temperature for 12 h, the solution was evaporated to give a sirup. Separation of two products on preparative TLC (ether: hexane= 1:1) gave **10** and **11** in 65.3% and 21.8% yields, respectively. Both were respectively identical with authentic samples obtained *via* the peroxy acid oxidation of (**3b**).

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