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Branched-chain Sugars. XXI. Synthesis of New Branched-chain Cyclitols Having *neo*-, *myo*-, and *chiro*-Configurations from 3-*O*-Benzyl-5,6-dideoxy-5-*C*-(1,3-dithian-2-yl)-6-nitro-D-galactofuranose and -L-altrofuranose[1)]

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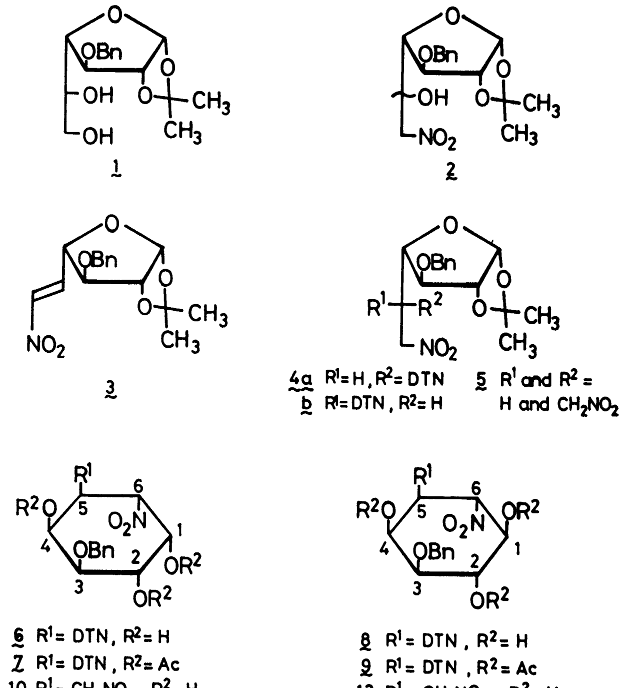
The Michael addition of 2-lithio-1,3-dithiane to 3-*O*-benzyl-5,6-dideoxy-1,2-*O*-isopropylidene-6-nitro-β-L-*arabino*-hex-5-enofuranose afforded a 1 : 1.8 mixture of 3-*O*-benzyl-5,6-dideoxy-5-*C*-(1,3-dithian-2-yl)-1,2-*O*-isopropylidene-6-nitro-α-D-galactofuranose and -β-L-altrofuranose. Removal of the isopropylidene group and intramolecular cyclization under weakly basic conditions afforded a mixture of branched-chain cyclitols having *neo*-, *myo*-, and *chiro*-configuration. A similar cyclization of the *O*-deisopropylidenated product of 3-*O*-benzyl-5,6-dideoxy-1,2-*O*-isopropylidene-6-nitro-5-*C*-(nitromethyl)-β-L-*arabino*-hexofuranose also afforded a mixture of cyclitols having *neo*-, *myo*-, and *chiro*-configuration. The results confirm the importance of two bulky groups such as benzyloxy at C-3 and 1,3-dithiane residue at C-5 in determining the stereodirection of cyclization.

In previous papers[2–4)] it was reported that the intramolecular cyclization of 3-*O*-benzyl-5,6-dideoxy-5-*C*-(1,3-dithian-2-yl)-6-nitrohexoses gives stereoselectively a few nitro cyclitols in which bulky substituents at C-5 and C-6 exclusively occupy *trans*-orientation and the newly formed hydroxyl group substantially occupies equatorial orientation when 3-*O*-benzyl group takes an axial orientation. Thus, the corresponding D-*gluco* derivatives[2,4)] gave *muco*-nitro cyclitols exclusively, and L-*ido* derivative[2)] *scyllo*- and *myo*-nitroinositols in a 1 : 1 ratio. The validity of this hypothesis was confirmed by the fact that the corresponding L-*talo* derivative gave only *myo*-nitroinositol, and the D-*allo* derivative gave *epi*- and *allo*-nitroinositols in a 1 : 1 ratio.[3)] We have examined our hypothesis by the intramolecular cyclization of D-*galacto*- and L-*altro*-derivatives (**4a** and **4b**).

Results and Discussion

3-*O*-Benzyl-5,6-dideoxy-5-*C*-(1,3-dithian-2-yl)-6-nitro-D-galactofuranose (**4a**) and -L-altrofuranose (**4b**) were prepared in the same manner as reported.[2–4)] 3-*O*-Benzyl-1,2-*O*-isopropylidene-α-D-galactofuranose (**1**)[5)] was at first oxidized with sodium periodate in aqueous methanol, and the resulting aldehyde was treated with nitromethane in methanol in the presence of sodium methoxide to give C-5 epimeric nitro alcohols (**2**)[6)] in a good yield. Direct dehydration of the compound **2** with acetic anhydride–sodium acetate[7)] afforded 3-*O*-benzyl-5,6-dideoxy-1,2-*O*-isopropylidene-6-nitro-β-L-*arabino*-hex-5-enofuranose (**3**) in 95% yield. Addition of 2-lithio-1,3-dithiane to **3** in dry tetrahydrofuran at −45 to −50 °C gave a syrupy mixture of **4a** and **4b** in 50% yield after being subjected to silica gel column chromatography. The ratio of **4a** to **4b** was estimated to be 1 : 1.8 by comparison of intensities of H-1 protons. Addition of nitromethane to **3** also gave 3-*O*-benzyl-5,6-dideoxy-1,2-*O*-isopropylidene-6-nitro-5-*C*-nitromethyl-β L-*arabino*-hexofuranose (**5**) in 65% yield.



Scheme 1.

From a theoretical point of view, D-*galacto* isomer **4a** should give branched-chain *chiro*- and/or *muco*-inositol derivatives, whereas L-*altro* isomer **4b** should give *myo*- and *neo*-inositol derivatives. However, stereo-

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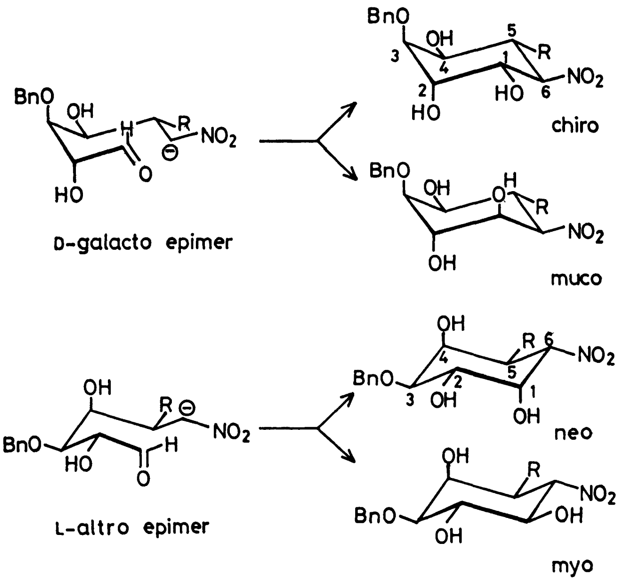
Table 1. NMR parameters of branched-chain nitro cyclitols[a)]

	H_1 ($J_{1,2}$)	H_2 ($J_{2,3}$)	H_3 ($J_{3,4}$)	H_4 ($J_{4,5}$)	H_5 ($J_{5,6}$)	H_6 ($J_{6,1}$)	$H_{1'}$ ($J_{5,1'}$)	Acetyl
7 (*neo*)	5.98t (3.5)	5.16dd (10.0)	3.78dd (3.0)	6.02t (3.0)	3.14oct (12.0)	5.28dd (3.0)	4.24d (5.0)	2.00 2.06 2.16
9 (*myo*)	5.53t (9.5)	5.30t (9.5)	3.56dd (3.0)	5.95t (3.0)	2.8m (11.0)	5.24dd (9.5)	4.12d (4.0)	1.97 2.03 2.10
11 (*neo*)	6.06t (3.7)	5.17dd (10.5)	3.88dd (3.5)	5.83t (2.5)	3.53m (11.5)	4.98dd (3.5)	4.50d (6.0)	2.00 2.07 2.10
13 (*myo*)	5.59t (10.0)	5.25t (9.5)	3.70dd (2.5)	5.73t (2.5)	3.21m (12.0)	4.84dd (10.0)	4.32dd 4.48dd, (5.0) (8.0)	1.98 2.02 2.20
15 (*chiro*)	5.81dd (3.0)	5.55dd (5.0)	3.84dd (3.5)	5.24dd (11.0)	3.30dt (10.5)	5.16t (10.0)	4.08d (2.5)	2.00 2.06 2.12
17 (*chiro*)	5.79dd (3.0)	5.59t (4.0)	3.97dd (3.0)	5.08dd (12.0)	3.44tt (12.0)	5.08dd (11.0)	4.52d (3.5)	1.96 2.00 2.15

a) d=doublet, m=multiplet, oct=octet, t=triplet, dd=double doublet, dt=double triplet, tt=triple triplet.
b) $J_{1'a,1'b}$=14.0.



Scheme 2.

direction of the cyclization is rather limited,[2,3)] since it depends on whether or not the benzyloxy group at C-3 can occupy an axial orientation. The failure to form a *muco*-isomer would be anticipated since it would generate a 1,3-diaxial non-bonded interaction. This would destabilize the system.

Since the separation of **4a** and **4b** was unsuccessful, the mixture was refluxed in 75% acetic acid for 2 h to remove the 1,2-*O*-isopropylidene group. The free sugars obtained were treated with 2 equivalent sodium hydrogen-carbonate in aqueous methanol for 20 h to give a mixture of cyclitols, showing two main spots having R_f values of 0.43 and 0.32 on TLC (solvent C). The two components were separated by preparative TLC. From the less polar component *neo*-inositol derivative (**6**) was obtained in 27% yield as white needles. Acetylation of **6** with acetic anhydride in the presence of *p*-toluenesulfonic acid gave a crystalline triacetate (**7**) in 88% yield. Its configuration was demonstrated by NMR spectrum data (Table 1). However, recrystallization (from ethanol-hexane) or purification with preparative TLC caused a partial degradation of **7** to the corresponding nitro olefin (**18**). Such a transformation is usually observed in the cases of similar nitro cyclitols in which the nitro group and the newly formed, vicinal hydroxyl group occupy the *cis*-orientation.[2)]

A mixture of other inositol derivatives (other than *neo*-configuration) was obtained from a more polar component in 54% yield as a syrup, from which *chiro*-isomer (**14**) crystallized out as prisms in 20% yield. The structure of **14** is supported by the NMR spectrum of its triacetate (**15**). The mother liquor of **14** was evaporated and the residue was treated with acetone in the presence of anhydrous copper(II) sulfate and a few drops of concentrated sulfuric acid to remove trace of **14** from the mixture.

After separation of **14** by means of preparative TLC, compound (**8**) (*myo*-configuration) was isolated, its structure being confirmed by means of the NMR parameters of its crystalline tri-*O*-acetate (**9**).

Similar cyclization of **5** was achieved by treating **5** with 70% acetic acid and sodium hydrogencarbonate in aqueous methanol successively, three isomers of nitro cyclitols having *neo*- (**10**), *myo*- (**13**), and *chiro*- (**16**) configuration being isolated in 18, 10, and 10% yields, respectively. Each structure was confirmed by the analysis of NMR spectra of their acetates. *O*-acetyl derivatives of these nitro cyclitols were also very labile and could not be obtained in the pure state except for *myo*-isomer. In the case of *neo*-isomer **10**, its tri-*O*-acetate **11** was readily transformed into the corresponding nitro olefin (**19**) during the course of recrystallization. The formation of three isomeric nitro cyclitols is of interest as compared with the results in which only two out of four possible isomers were formed in the case of 3-*O*-benzyl-5,6-dideoxy-1,2-*O*-isopropylidene-5-*C*-(nitromethyl)-6-nitro-α-D-*ribo*-hexofuranose.[3)]

Such bulky groups as benzyloxy group, 1,3-dithian-2-yl group and nitromethyl group have decisive influence on the stereodirection of the intramolecular cyclization of **4** and **5** to afford branched-chain nitro cyclitols.

Experimental

Melting points were determined with a YANACO micro melting-point apparatus and are uncorrected. IR spectra were recorded on a Hitachi 260-10 spectrophotometer. Proton magnetic resonance (100 MHz) were recorded on a JNM-PS-100 spectrometer in chloroform-*d* with tetramethylsilane as an internal standard. Chemical shifts and coupling constants were recorded in δ and Hz units, respectively, and IR frequencies in $\mathrm{cm^{-1}}$. Optical rotations were determined on a JASCO DIP-4 digital polarimeter or a Karl Zeiss LEP Al polarimeter. TLC and preparative TLC were performed with silica gel (E. Merck type 60) as an adsorbent in the following solvent systems (v/v): A, hexane–ethyl acetate, 3 : 1; B, 2 : 1; C, 1 : 1, D, 1 : 2. Solvents were evaporated under reduced pressure below 40 °C.

*A Mixture (2) of 3-*O*-Benzyl-6-deoxy-1,2-*O*-isopropylidene-6-nitro-α-D-galactofuranose and -β-L-altrofuranose.* Sodium periodate (1.90 g, 8.9 mmol) was added to an ice-cooled solution of 3-*O*-benzyl-1,2-*O*-isopropylidene-α-D-galactofuranose (**1**)[5)] (2.54 g, 8.2 mmol) in aqueous methanol (methanol: water = 70 : 35 v/v). The reaction mixture was stirred at the same temperature for 30 min, and then at room temperature for 1.5 h. The mixture was filtered and the solid washed with methanol. The filtrate and washings were combined, concentrated to remove as much methanol as possible, and extracted several times with dichloromethane (*ca.* 150 ml). The organic layer was washed with brine, dried over anhydrous magnesium sulfate, and concentrated to afford aldehyde as a clear syrup.

To an ice-cooled solution of the aldehyde obtained above and nitromethane (35 ml) in absolute methanol (70 ml) was added 1 M sodium methoxide in methanol (8.2 ml), and the mixture was kept at room temperature for 15 h. Acetic acid (1.5 ml) was added to the light brown solution thus obtained, the solvent being removed by evaporation. The residue was partitioned between dichloromethane (100 ml) and water (50 ml), and the water layer further extracted with dichloromethane (20 ml × 2). Combined dichloromethane layer was washed with brine, dried over anhydrous magnesium sulfate, and concentrated to dryness to afford an epimeric mixture of nitro aclohols as a thick syrup. One of the epimers crystallized from ethanol–hexane (1.38 g, 50%): mp 94°; $[\alpha]_{\mathrm{D}}^{17.5}$ −8.7° (*c* 0.74, $\mathrm{CH_2Cl_2}$). Purification of the mother liquor on a silica gel column (solvent A) afforded a mixture of epimers as a syrup (1.35 g, 37%): IR 3450 (OH), 1550, 1575 (–$\mathrm{NO_2}$); NMR (after the addition of $\mathrm{D_2O}$), 1.31, 1.51 (s, 3H each), 3.95—4.48 (m, 7H), 4.66 (d, H-2), 5.92 (d, 1H, $J_{1,2}$=4.0, H-1), 7.33 (s, 5H, Ph). Found: C, 56.59; H, 7.25; N, 4.28%. Calcd for $\mathrm{C_{16}H_{21}NO_7}$: C, 56.63; H, 6.24; N, 4.13%.

*3-*O*-Benzyl-5,6-dideoxy-1,2-*O*-isopropylidene-6-nitro-β-L-arabino-hex-5-enofuranose (3).* A mixture of **2** (1.23 g, 3.63 mmol) and anhydrous sodium acetate (2.20 g) in acetic anhydride (7.1 ml) was stirred at room temperature for 48 h and poured into aqueous sodium hydrogencarbonate (50 ml). The oil precipitated was extracted with dichloromethane (50 ml × 3), washed with aqueous sodium hydrogencarbonate and brine and dried with anhydrous sodium sulfate. The solvent was evaporated to afford **3** as a light yellow syrup (1.12 g, 95%), sufficiently pure for further preparation; purification on a silica gel column and/or preparative TLC was not successful: IR 1530, 1350 (C=C–$\mathrm{NO_2}$).

*3-*O*-Benzyl-5,6-dideoxy-5-*C*-(1,3-dithian-2-yl)-1,2-*O*-isopropylidene-6-nitro-β-L-altrofuranose and -α-D-galactofuranose (4).* To a cooled (−45— −50 °C) solution of **3** (2.22 g, 6.9 mmol) in dry tetrahydrofuran (THF, 10 ml) was added all at once a solution of 2-lithio-1,3-dithiane prepared at −45 °C from 1,3-dithiane (1.22 g, 10.2 mmol) and butyllithium (15% hexane solution, 6.2 ml, 9.68 mmol) in dry THF (14 ml). The reaction mixture was stirred at the same temperature for 45 min, then at room temperature for 30 min, and acidified with acetic acid (1 ml). The light brown solution was concentrated to a residue which was partitioned between water (50 ml) and dichloromethane (50 ml). The water layer was extracted with dichloromethane (25 ml × 2). The dichloromethane layers were combined, washed with brine, dried ($\mathrm{MgSO_4}$), and concentrated to a syrup (3.32 g); TLC (solvent A) revealed the presence of a major component having the R_f value 0.40. Isolation of the major component by means of silica gel column chromatography afforded a mixture of 5-*C*-epimers **4** as a syrup (1.51 g, 50%). In a NMR spectrum of **4** taken in benzene-d_6 in the presence of tris(1,1,1,2,2,3,3-heptafluoro-7,7-dimethyl-4,6-octanedionato)-praseodymium were observed two anomeric protons with a coupling constant of 3.75 at 5.36 and 5.48. Since *neo*-(**6**) and *myo*-nitro cyclitol (**9**) were isolated to a greater extent (the sum of 44%) than *chiro*-isomer (**14**) (20%), the peak at 5.36 was assigned to $\mathrm{H_1}$ of D-*galacto*-isomer (**4a**) and the one at 5.48 to H-1 of L-*altro*-isomer (**4b**). The ratio D-*galacto*: L-*altro* was estimeted to be 1 : 1.8. Found: C, 54.70; H, 6.08; N, 2.91; S, 14.43%. Calcd for $\mathrm{C_{20}H_{27}NO_6S_2}$: C, 54.40; H, 6.16; N, 3.17; S, 14.52%.

*3-*O*-Benzyl-5,6-dideoxy-1,2-*O*-isopropylidene-6-nitro-5-*C*-nitromethyl-β-L-arabino-hexofuranose (5).* A solution of nitro olefin **3** (642 mg, 2 mmol) in methanol (6 ml) was added to an ice-cooled solution of nitromethane (3 ml, 55 mmol) in dry methanol (15 ml) containing 1.6 ml of 1 M sodium methoxide in absolute methanol. The reaction mixture was kept at room temperature for 1 h, acidified with acetic acid (1 ml), and concentrated to dryness. The residue was partitioned between dichloromethane (70 ml) and water (20 ml). The dichloromethane layer was washed with brine, dried ($\mathrm{MgSO_4}$), and concentrated to a syrup. TLC (solvent A) showed a presence of a major component having the R_f value 0.45. Isolation ol the major component by means of preparative TLC afforded **5** as a syrup (501 mg, 66%): $[\alpha]_{\mathrm{D}}^{26}$ −34.4° (*c* 0.72 chloroform); IR 1560, 1380 (–$\mathrm{NO_2}$); NMR 1.36, 1.52 (3Hs each, C–$\mathrm{CH_3}$), 3.26 (m, 1H, $J_{5,6}$=5.9, $J_{5,6'}$=4.3, H-5), 3.94 (d, 1H, $J_{3,4}$=3.8, H-3), 4.06 (dd, 1H, $J_{4,5}$=9.7, H-4), 4.4—4.8 (6H, –$\mathrm{CH_2NO_2}$×2, –$\mathrm{CH_2}$–Ph), 4.68 (d, 1H, $J_{1,2}$=3.75, H-2), 5.86 (d, 1H, H-1), 7.36 (s, 5H, Ph), Found: C, 53.82; H, 5.65; N, 7.10%. Calcd for $\mathrm{C_{17}H_{22}N_2O_8}$: C, 53.40; H, 5.80; N, 7.33%.

Hydrolysis of 4 and Intramolecular Cyclization. A solution of **4** (0.6815 g) in 75% acetic acid (35 ml) was heated to reflux for 2 h. The light brown solution was concentrated to dryness. A trace of acetic acid was codistilled with toluene. The residue was then dissolved in methanol (30 ml) and treated with sodium hydrogencarbonate (260 mg) in water (15 ml) at room temperature for 20 h. The solution was neutralized by the addition of ion exchange resin (Dowex

50 W×8, H+ form, 4 ml). Evaporation of the solvent afforded a crude mixture of nitrocyclitols as light brown foam (567 mg, 94.2%). TLC (solvent C) indicated the presence of two components having the R_f values 0.43 and 0.32, respectively. Preparative TLC (solvent C) afforded a less polar component having the R_f value 0.43 (168.5 mg, 27%), and a more polar component having the R_f value 0.32 (334.4 mg, 54%).

1D-(1,2,6/3,4,5)-3-O-Benzyl-5-(1,3-dithian-2-yl)-6-nitro-1,2,3,4-cyclohexanetetrol (6).[8] Recrystallization of the component having the R_f value 0.43 from ethanol afforded **6** as needles: mp 166—169 °C; $[\alpha]_D^{18}$ −5.7° (*c* 2.1, methanol); IR 3420 (OH), 1545, 1370 (–NO_2). Found: C, 50.80; H, 6.10; N, 3.13%. Calcd for $C_{17}H_{23}O_6NS_2$: C, 50.86; H, 5.77; N, 3.49%.

1D-(1,2,6/3)-1,3-Di-O-acetyl-2-O-benzyl-6-(1,3-dithian-2-yl)-5-nitrocyclohex-4-ene-1,2,3-triol (18). Acetylation of **6** in acetic anhydride in the presence of catalytic amount of *p*-toluenesulfonic acid gave crude tri-*O*-acetate **7**, in 88% yield, which gradually decomposed into nitro olefin (**18**) which was isolated with preparative TLC as yellow syrup: $[\alpha]_D^{27}$ +129.7° (*c* 3.38, methanol–dichloromethane: 1 : 3 v/v); NMR 2.07, 2.10 (s, 3H each, OAC), 2.91 (m, 4H), 3.79 (m, 1H, H-6), 4.15 (dd, 1H, $J_{2,3}$=8.0, $J_{1,2}$=2.5, H-2), 4.36 (d, 1H, $J_{1',6}$=7.5, H-1′), 4.56 and 4.72 (ABq, 2H, J_{AB}=12.0, –CH_2–), 5.65 (ddd, 1H, $J_{3,6}$=1.5, $J_{3,4}$=3.5, H-3), 6.03 (t, 1H, $J_{1,6}$=2.5), 7.10 (d, 1H, H-4), 7.35 (m, 5H, Ph). Found: C, 54.56; H, 5.64; N, 2.82%. Calcd for $C_{21}H_{25}O_7NS_2$: C, 53.95; H, 5.39; N, 3.00%.

1D-(1,2,5/3,4,6)-3-O-Benzyl-5-(1,3-dithian-2-yl)-6-nitro-1,2,3,4-cyclohexanetetrol (14). The more polar component obtained above was tritulated and recrystallized from ethanol–hexane to afford **14** as prisms (20%): mp 191.5—193.5° (dec); $[\alpha]_D^{26.5}$ +5.7° (*c* 1.06, methanol); IR 3550, 3400, 3330 (OH), 1550 (–NO_2). Found: C, 50.59; H, 5.71; N, 3.31%. Calcd for $C_{17}H_{23}NO_6S_2$: C, 50.86; H, 5.77; N, 3.49%. Tri-*O*-acetate **15** was prepared by treatment **14** with acetic anhydride-*p*-toluenesulfonic acid.

1L-(1,3,4,5/2,6)-1,2,4-Tri-O-acetyl-3-O-benzyl-5-(1,3-dithian-2-yl)-6-nitro-1,2,3,4-cyclohexanetetrol (9). The mother liquor left from the isolation of **14** was concentrated to dryness and treated with acetone and anhydrous copper(II) sulfate in the presence of a catalytic amount of sulfuric acid for one week. The reaction mixture was then passed through a short column of silica gel and concentrated to dryness.

TLC of the mixture (solvent C) indicated the presence of two components, which were separated by means of preparative TLC.

The more polar component was treated with acetic anhydride in the presence of *p*-toluenesulfonic acid to afford crystalline **9** in 17% yield (from **4**): mp 215—217°; $[\alpha]_D^{18}$ +48.6° (*c* 0.5, dichloromethane); IR 1755 (–$OCCH_3$), 1560, 1370 (–NO_2). Found: C, 52.58; H, 5.72; N, 2.62%. Calcd for $C_{23}H_{29}NO_9S_2$: C, 52.36; H, 5.54; N, 2.65%.

The less polar component was treated with boiling 75% acetic acid for 2 h and acetylated with acetic anhydride-*p*-toluenesulfonic acid to give **15**.

Hydrolysis of 5 and Intramolecular Cyclization. A solution of **5** (1.15 g) in 70% acetic acid (50 ml) was heated to reflux for 2 h. The dark brown solution was concentrated to dryness and a trace of acetic acid was removed by codistillation with toluene. The residue was dissolved in methanol (50 ml) and treated with sodium hydrogencarbonate (427 mg) in water (25 ml) at room temperature for 16 h. The light brown solution was neutralized with Dowex 50 W×8 (H+) (5 ml) and concentrated to dryness to afford a half crystalline residue (0.9825 g, 95%). TLC indicated the presence of two major components having R_f values 0.29 and 0.22 (solvent C).

1D-(1,2,6/3,4,5)-3-O-Benzyl-6-nitro-5-nitromethyl-1,2,3,4-cyclohexanetetrol (10). To the residue obtained above (983 mg) was added ethanol (*ca.* 20 ml) and the mixture was kept in a refrigerator overnight. Crystals precipitated were collected (194 mg, 18.8% from **5**) and recrystallized from ethanol to afford **10** as prisms: mp 225—228° (dec); R_f 0.29 (solvent C); $[\alpha]_D^{27.5}$ −46.1° (*c* 0.77, acetone); IR 3540, 3350, 3300 (OH), 1555, 1570, 1340, 1380 (–NO_2). Found: C, 48.89; H, 5.21; N, 8.19%. Calcd for $C_{14}H_{18}N_2O_8$: C, 49.12; H, 5.30; N, 8.18%.

1D-(1,2,6/3)-1,3-Di-O-acetyl-2-O-benzyl-5-nitro-6-nitromethylcyclohex-4-ene-1,2,3-triol (19). A solution of **10** (26.2 mg) in acetic anhydride containing a catalytic amount of *p*-toluenesulfonic acid was kept overnight at room temperature. The solution was poured into ice water, extracted with dichloromethane, washed with water, dried (Na_2SO_4), and concentrated to afford crude tri-*O*-acetate **11** (29.6 mg, 82.5%) sufficiently pure for NMR analysis. Purification of crude tri-*O*-acetate **11** was performed on preparative TLC (solvent system A). The major fraction was isolated and recrystallized from ethanol–hexane to afford cyclohexene derivative **19** as prisms (20.1 mg, 78% from **11**): mp 138—139°; $[\alpha]_D^{27}$ +57.9° (*c* 0.88, methanol: dichloromethane=5 : 1 v/v); IR 1755, 1740 (esters), 1575, 1370 (aliph–NO_2), 1535, 1340 (vinyl–NO_2); NMR 1.96, 2.10 (s, 3H each –OAc), 3.83 (dt, 1H, $J_{2,4}$=1.0, $J_{1,2}$=$J_{2,3}$=2.5, H-2), 4.34 (m, 1H, H-6), 4.46 (dd, 1H, $J_{1',1''}$=14.0, $J_{1',6}$=3.0, H-1′), 4.66 and 4.73 (ABq, 2H, J=12.5, –CH_2–), 5.22 (dd, 1H, $J_{1'',6}$=7.0, H-1″), 5.32 (dd, 1H, $J_{1,6}$=6.5, H-1), 5.62 (dd, 1H, $J_{3,6}$=1.0, $J_{3,4}$=4.0, H-3), 7.30 (dd, 1H, H-4), 7.37 (m, 5H, Ph). Found: C, 52.43; H, 4.98; N, 6.91%. Calcd for $C_{18}H_{20}N_2O_9$: C, 52.94; H, 4.94; N, 6.86%.

1L-(1,3,4,5/2,6)-1,2,4-Tri-O-acetyl-3-O-benzyl-6-nitro-5-nitromethyl-1,2,3,4-cyclohexanetetrol (13). To a suspension of an intramolecular cyclization mixture of **5** (315 mg) in dry acetone (3 ml) and 2,2-dimethoxypropane (6 ml) was added a catalytic amount *p*-toluenesulfonic acid monohydrate, and the clear solution obtained immediately was kept at room temperature overnight. The mixture was then diluted with dichloromethane (100 ml) and washed twice with aqueous sodium hydrogenecarbonate (10 ml). The water layer was extracted with dichloromethane (20 ml). Dichloromethane layers were combined, washed with brine, and dried (anhydrous sodium sulfate). Evaporation of the solvent afforded a syrupy mixture. TLC indicated the presence of two major components having R_f values 0.73 and 0.63 (solvent C).

The component having the R_f value 0.73 was isolated by preparative TLC as syrup (76.0 mg, 22%) dissolved in 80% acetic acid and heated to reflux 1.5 h. The reaction mixture was concentrated to a solid residue. The residue was acetylated with acetic anhydride (1 ml) containing a catalytic amount of *p*-toluenesulfonic acid, and the usual work-up of the acetylation mixture afforded a solid mass which recrystallized from ethanol to give **13** as prisms (44.7 mg, 10.3% from **5**): mp 141—143°; $[\alpha]_D^{30}$ +111.2° (*c* 1.0, dichloromethane); IR 1750 (ester), 1575, 1560, and 1375 (aliph–NO_2). Found: C, 51.20; H, 5.30; N, 6.14%. Calcd for $C_{20}H_{24}N_2O_{11}$: C, 51.28; H, 5.16; N, 5.98%.

1D-(1,2,5/3,4,6-)-3-O-Benzyl-6-nitro-5-nitromethyl-1,2,3,4-cyclohexanetetrol (16). The component having the R_f value 0.63 was isolated with preparative TLC as a syrup (62.4 mg, 18%), dissolved in 80% acetic acid (10 ml) and heated to reflux for 1.5 h. The reaction mixture was concentrated to a solid mass, and recrystallized from ethanol–

hexane to afford **16** as needles (38.9 mg, 10.2% from **5**): mp 187—189°; $[\alpha]_D^{27}$ −36.8° (*c* 1.0, methanol); IR 3500, 3400 (OH), 1560, 1550, 1380, 1360 (NO_2). Found: C, 49.10; H, 5.26; N, 8.17%. Calcd for $C_{14}H_{18}N_2O_8$: C, 49.12; H, 5.30; N, 8.18%.

1,2,4-Tri-*O*-acetyl derivative **7** was prepared by the treatment of **16** with acetic anhydride and *p*-toluenesulfonic acid.

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