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Note

Synthesis of some valienamine epoxides: on the structure of the alpha-amylase inhibitor NS-504*†

SEIICHIRO OGAWA†, NOBUO IKEDA,
Department of Applied Chemistry, Faculty of Science and Technology, Keio University, Hiyoshi, Kohoku-ku, Yokohama, 223 (Japan)

HARUKI TAKEDA, AND YOSHIO NAKAGAWA
R&D Division, Tokyo Tanabe Seiyaku Co. Ltd., Akabanekita, Kita-ku, Tokyo, 115 (Japan)

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The complex NS-504 (**1**), isolated[2] from culture broths of *Streptomyces flavocromogenus*, is an inhibitor of alpha-amylase and is a member of the pseudo-oligosaccharidic class of glucosidase inhibitor[3]. The structures **1** have been established[2], except for the configuration of the epoxide group, by conventional methods[3,4].

We now describe a synthesis of two stereoisomers of valienamine epoxide, in order to confirm the configuration of the epoxide group in the inhibitor-complex, and their transformation into three branched-chain aminocyclitols of biological interest.

First, the ^{1}H-n.m.r. spectrum ($CDCl_3$) of the deca-acetate (**3**) of the lowest homologue[2] (**2**) of **1** could be interpreted by comparison with the data[5] for the corresponding amylostatin XG deca-acetate[6]. The signal of the epoxide proton (H-2″) at δ 3.40 (d, J 5.1 Hz) strongly suggested[7] the epoxide and imino functions to be *cis*.

Epoxidation of DL-(1,3/2,6)-4-*C*-acetoxymethyl-1,2,3-tri-*O*-acetyl-6-azido-4-cyclohexene-1,2,3-triol[8] (**4**) and its 6-acetamido derivative[8] (**6**) with *m*-chloroperbenzoic acid (MCPBA) in 1,2-dichloroethane in the presence of phosphate buffer (pH 8) gave the crystalline epoxides **9** (26%) and **10** (60%), respectively, the ^{1}H-n.m.r. spectra of which contained singlets (δ 3.49 and 3.48) due to the epoxide proton which indicated both the azido and acetamido, and epoxide groups to be *trans*. In contrast, under similar conditions, the corresponding 6-epimer[8] (**5**) was

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†Author for correspondence.

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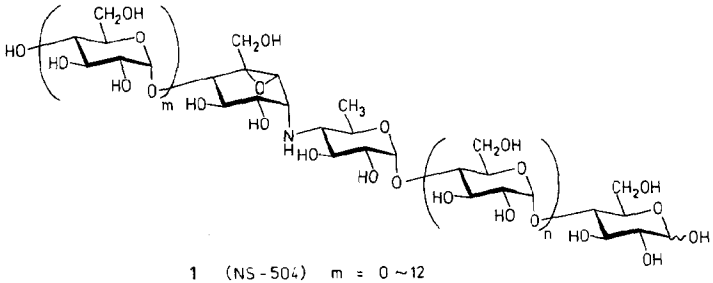
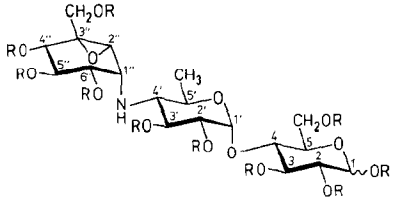
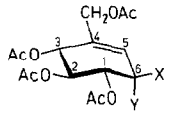


1 (NS-504) m = 0 ~ 12
n = 0 ~ 12

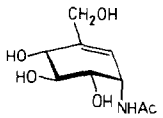


2 R = H
3 R = Ac

recovered unchanged, and penta-*N,O*-acetyl-DL-valienamine[8] (**7**) gave 37% of the epoxide **11**. In order to take advantage of the *cis*-directing effect[9] of HO-3, **7** was first converted into the *N*-acetyl derivative **8** by treatment with methanolic sodium methoxide and then treated with MCPBA in acetic acid, affording, after acetylation, 56% of the epoxide **11**. The ^{1}H-n.m.r. spectrum of **11** contained a doublet (δ 3.49, J 4 Hz) due to the epoxide proton, indicating that the acetamido and epoxide groups are *cis*, and the other resonances accord with the corresponding data of the cyclohexene moiety of **3**.



	X	Y
4	N_3	H
5	H	N_3
6	NHAc	H
7	H	NHAc



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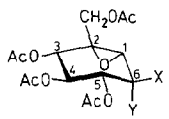
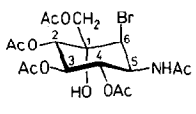


	X	Y
9	N_3	H
10	NHAc	H
11	H	NHAc

All synthetic compounds described in this paper are racemic, but, for convenience, only single enantiomers are depicted.



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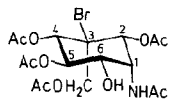

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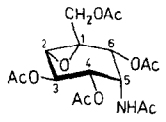

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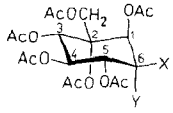
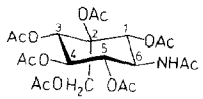


	X	Y
15	NHAc	H
16	H	NHAc



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Attempts were made also to introduce the epoxide function *via* a bromohydrin. Treatment of **6** with a slight excess of *N*-bromosuccinimide in aqueous *N,N*-dimethylformamide at room temperature gave 36% of the bromohydrin **12**, the structure of which was evident from its ^{1}H-n.m.r. spectrum. The intermediate bromonium ion seemed to be cleaved by participation of AcO-3. On the other hand, 51% of a crystalline bromide **13** was derived similarly from **7**. The structure was tentatively assigned on the basis of the ^{1}H-n.m.r. spectrum (in $CDCl_3$), which contained signals at δ 3.31 (d, *J* 7.5 Hz), 3.98 (dt, *J* 5, 7.5, 7.5 Hz), 4.93 (dt, *J* 5, 5, 10 Hz), 5.24 (t, *J* 7.5 Hz), 5.60 (d, *J* 7.5 Hz), and 5.62 (d, *J* 5 Hz), which were attributed to HO, H-6, H-1, H-5, H-4, and H-2, respectively. When CD_3OD was added, the signals due to H-1 and H-6 collapsed to a triplet (*J* 5 Hz) and a doublet of doublets (*J* 5.5, 9 Hz), respectively. Cleavage of the intermediate bromonium ion involved the participation of AcNH-6 followed by the O-1→N acetyl migration.

Treatment of **12** with potassium carbonate in methanol at room temperature, followed by acetylation, afforded 84% of **10**. Similar treatment of **13** gave two epoxides **11** and **14**, which were expected to be formed *via* intramolecular attack of HO-2 and HO-4. The ^{1}H-n.m.r. spectrum of **14** contained signals at δ 3.29 (s), 4.88 (dd, *J* 3.4, 5.6 Hz), 4.98 (dd, *J* 3.4, 9.3 Hz), 5.20 (d, *J* 9.3 Hz), and 5.61 (d, *J* 5.6 Hz), which were ascribable to H-2, H-5, H-4, and H-6, respectively, indicative of the structure assigned, thereby confirming the structures of **11** and **13**. Therefore, the proposed structure of **2** was established.

When **10** was treated with 2 equiv. of sodium acetate in aqueous 10% 2-methoxyethanol at 80°, reaction proceeded through participation of AcNH-6 and AcO-7 to afford, after acetylation, the acetylated branched-chain aminocyclitols **15** (42%) and **17** (11%), respectively, the ^{1}H-n.m.r. spectra of which contained a signal at δ 4.57 (ddd, *J* 3, 6, 9 Hz) and 4.85 (dt, *J* 10.5, 11.5, 11.5 Hz), due to H-6. Compound **15** was also obtained by opening of the epoxide group by an intramolecular attack of an acetate ion *via* diaxial cleavage. Under similar conditions, **11** reacted preferentially through the latter mechanism to give 44% of **16**, the hydroxyl derivative of valiolamine[10]. The signal due to H-6 appeared at δ 4.70 (ddd, *J* 4, 5, 9 Hz).

EXPERIMENTAL

General methods. — Melting points were determined with a MEL-TEMP capillary melting-point apparatus and are uncorrected. ^{1}H-N.m.r. spectra were

recorded for solutions in $CDCl_3$ (internal Me_4Si) with Varian EM-390 (90 MHz), Jeol FX-200 (200 MHz), and Jeol GX-400 (400 MHz) instruments. T.l.c. was performed on Silica Gel 60 GF (Merck) with detection by charring with sulfuric acid. Column chromatography was conducted on Wakogel C-300 (300 Mesh, Wako Co., Osaka). Organic solutions were dried over anhydrous Na_2SO_4 and concentrated at <50° under diminished pressure.

1,2,3,6,2',3'-Hexa-O-acetyl-4',6'-dideoxy-4'-[(1R)-(1,2,3,4,6/5)-4,5,6-tri-acetoxy-3-C-acetoxymethyl-2,3-epoxycyclohexylamino]maltose (**3**). — 4',6'-Dideoxy-4'-[(1*R*)-(1,2,3,4,6/5)-2,3-epoxy-4,5,6-trihydroxy-3-*C*-hydroxymethylcyclohexyl-amino]maltose[8] (**2**) was acetylated with acetic anhydride and pyridine in the usual way to give **3** as an amorphous powder, m.p. 185–185.5°. ^{1}H-N.m.r. data ($CDCl_3$, 200 MHz): δ 5.74 (d, 1 H, $J_{1,2}$ 8.2 Hz, H-1β), 5.49 (d, 1 H, $J_{4'',5''}$ 8.3 Hz, H-4''), 5.29 (dd, 1 H, $J_{5'',6''}$ 9.3 Hz, H-5''), 5.21 (d, 1 H, $J_{1',2'}$ 3.8 Hz, H-1'), 5.18 (dd, 1 H, $J_{2',3'}$ 10.7, $J_{3',4'}$ 7.8 Hz, H-3'), 5.15 (dd, 1 H, $J_{2,3}$ 9.5, $J_{3,4}$ 8.5 Hz, H-3), 4.98 (dd, 1 H, H-2), 4.76 (dd, 1 H, H-2'), 4.74 (dd, 1 H, $J_{1'',6''}$ 5.8 Hz, H-6''), 4.50 (dd, 1 H, $J_{5,6a}$ 2, $J_{6,6}$ 12.3 Hz, H-6a), 4.30 (d, 1 H, $J_{7'',7''}$ 12.2 Hz, H-7''a), 4.20 (dd, 1 H, $J_{5,6b}$ 4.4 Hz, H-6b), 4.00 (dd, 1 H, $J_{4,5}$ 9.8 Hz, H-4), 3.83 (d, 1 H, H-7''b), 3.83 (bd, 1 H, H-5), 3.70 (bt, H-1''), 3.60 (dq, $J_{4',5'}$ 9.8, J_{5',CH_3} 6.4 Hz, H-5'), 3.40 (d, 1 H, $J_{1'',2''}$ 5.1 Hz, H-2''), 2.58 (bdd, 1 H, H-4'), 2.13, 2.11, 2.105, 2.10, 2.08, 2.03, 2.01, and 1.98 (8 s, 3, 3, 3, 3, 3, 3, 6, 6, and 3 H, 10 OAc), 1.37 (d, 3 H, Me).

Anal. Calc. for $C_{39}H_{53}NO_{24}$: C, 50.93; H, 5.81; N, 1.52. Found: C, 50.43; H, 5.86; N, 1.71.

DL-*(1,2,3,5/4,6)-2-C-Acetoxymethyl-3,4,5-tri-O-acetyl-1,2-anhydro-6-azido-1,2,3,4,5-cyclohexanepentol* (**9**). — A stirred mixture of DL-(1,3/2,6)-4-*C*-acetoxymethyl-1,2,3-tri-*O*-acetyl-6-azido-4-cyclohexene-1,2,3-triol[8] (**4**; 113 mg, 0.31 mmol), *m*-chloroperbenzoic acid (115 mg, ~0.47 mmol), 1,2-dichloroethane (3 mL), and a phosphate buffer (pH 8, 3 mL) was heated overnight at reflux. More peroxy acid (115 mg) was added, heating was continued overnight, and the mixture was then diluted with 1,2-dichloroethane (20 mL), successively washed with aqueous 10% sodium thiosulfate, aqueous sodium hydrogencarbonate, and water, dried, and concentrated. The residue (103 mg) was eluted from a column of silica gel (15 g) with 2-butanone–toluene (1:10) to give **4** (60 mg) and **9** (14 mg, 26% based on **4** consumed) as needles, m.p. 99.5–100.5° (from ethanol). ^{1}H-N.m.r. data ($CDCl_3$, 90 MHz): δ 5.50–4.95 (m, 3 H, H-3,4,5), 4.62 (d, 1 H, $J_{7,7'}$ 12 Hz, H-7), 3.90 (d, 1 H, $J_{5,6}$ 9 Hz, H-6), 3.75 (d, 1 H, H-7'), 3.49 (s, 1 H, $J_{1,6}$ ~0 Hz, H-1), 2.10 and 2.00 (2 s, 9 and 3 H, 4 OAc).

Anal. Calc. for $C_{15}H_{19}N_3O_9$: C, 46.76; H, 4.97; N, 10.90. Found: C, 46.63; H, 5.03; N, 11.01.

DL-*(1,2,3,5/4,6)-6-Acetamido-2-C-acetoxymethyl-3,4,5-tri-O-acetyl-1,2-anhydro-1,2,3,4,5-cyclohexanepentol* (**10**). — A mixture of DL-(1,3/2,6)-6-acetamido-4-*C*-acetoxymethyl-1,2,3-tri-*O*-acetyl-4-cyclohexene-1,2,3-triol[8] (**6**; 350 mg, 0.91 mmol), *m*-chloroperbenzoic acid (340 mg, ~1.3 mmol), 1,2-dichloroethane (8 mL), and a phosphate buffer (pH 8, 8 mL) was heated overnight at reflux. The reaction

mixture was processed as described in the preparation of **9**, and the product was crystallised from ethanol to give **10** (220 mg, 60%) as needles, m.p. 176–177.5°. ^{1}H-N.m.r. data ($CDCl_3$, 200 MHz): δ 6.25 (d, 1 H, $J_{6,NH}$ 9 Hz, NH), 5.44 (d, 1 H, $J_{3,4}$ 8 Hz, H-3), 5.16 (dd, 1 H, $J_{4,5}$ Hz, H-4), 5.04 (t, 1 H, $J_{5,6}$ 9 Hz, H-5), 4.85 (d, 1 H, $J_{7,7'}$ 12 Hz, H-7), 4.68 (t, 1 H, H-6), 3.83 (d, 1 H, H-7'), 3.48 (s, 1 H, $J_{1,6}$ ~0 Hz, H-1), 2.06–1.99 (cluster of singlets, 15 H, NAc and 4 OAc).

Anal. Calc. for $C_{17}H_{23}NO_{10}$: C, 50.87; H, 5.78; N, 3.49. Found: C, 50.71; H, 5.73; N, 3.33.

DL-*(1,2,3,5,6/4)-6-Acetamido-2-*C*-acetoxymethyl-3,4,5-tri-*O*-acetyl-1,2-anhydro-1,2,3,4,5-cyclohexanepentol* (**11**). — (*a*) DL-(1,3,6/2)-6-Acetamido-4-*C*-acetoxymethyl-1,2,3-tri-*O*-acetyl-4-cyclohexene-1,2,3-triol (penta-*N,O*-acetyl-DL-valienamine)[8] (**7**; 61 mg, 0.16 mmol) was stirred with *m*-chloroperoxybenzoic acid (59 mg, 1.5 equiv.) in chloroform (2 mL), 1,2-dichloroethane (2 mL), and a phosphate buffer (pH 8, 4 mL) overnight at 50°. Column chromatography (benzene–ethanol, 12:1) of the product gave **7** (25 mg) and **11** (14 mg, 37% based on **7** consumed) as needles, m.p. 161–163° (from ethanol). ^{1}H-N.m.r. data ($CDCl_3$, 200 MHz): δ 5.90 (d, 1 H, $J_{6,NH}$ 8 Hz, NH), 5.58 (d, 1 H, $J_{3,4}$ 8 Hz, H-3), 5.18 (dd, 1 H, $J_{4,5}$ 10.5 Hz, H-4), 5.07–4.95 (m, 1 H, H-6), 4.93 (dd, 1 H, $J_{5,6}$ 6 Hz, H-5), 4.26 and 3.85 (2 d, each 1 H, $J_{7,7}$ 12 Hz, CH_2OAc), 3.49 (d, 1 H, $J_{1,6}$ 4 Hz, H-1), 2.11, 2.09, 2.05, 2.00, and 1.97 (5 s, each 3 H, NAc and 4 OAc).

Anal. Calc. for $C_{17}H_{23}NO_{10}$: C, 50.87; H, 5.78; N, 3.49. Found: C, 50.85; H, 5.72; N, 3.20.

(*b*) Compound **7** (100 mg, 0.26 mmol) was treated with methanolic M sodium methoxide (0.1 mL) in methanol (4 mL) for 0.5 h at room temperature. The mixture was neutralised with Amberlite 120B (H^+) resin and concentrated to give **8** (54 mg, 96%) as a white solid. Without purification, this compound was treated with *m*-chloroperbenzoic acid (93 mg, ~1.5 equiv.) in acetic acid (6 mL) for 2 days at room temperature. The mixture was concentrated, the residue was acetylated in the usual way, and elution of the product from a column of silica gel (10 g) with benzene–ethanol (12:1) gave **7** (50 mg) and **11** (29 mg, 56% based on **7** consumed) as needles, m.p. 161–163° (from ethanol).

DL-*(1,2,4/3,5,6)-5-Acetamido-1-*C*-acetoxymethyl-2,3,4-tri-O-acetyl-6-bromo-1,2,3,4-cyclohexanetetrol* (**12**). — A mixture of **6** (270 mg, 0.70 mmol), *N*-bromosuccinimide (160 mg, 1.2 mol), and aqueous 99% *N,N*-dimethylformamide (7.1 mL) was stirred for 2 days at room temperature. T.l.c. (benzene–ethanol, 10:1) then indicated the formation of new component (R_F 0.28), together with **6** (R_F 0.32). The mixture was concentrated, and the residue was eluted from a column of silica gel (20 g) with benzene–ethanol (12:1) to give **6** (80 mg) and **12** (84 mg, 36% based on **6** consumed) as needles, m.p. 195–196.5° (from ethanol). ^{1}H-N.m.r. data ($CDCl_3$, 200 MHz): δ 6.35 (d, 1 H, $J_{5,NH}$ 10.5 Hz, NH), 5.65 (t, 1 H, $J_{2,3} = J_{3,4}$ = 10 Hz, H-3), 5.41 (d, 1 H, H-2), 5.26 (t, 1 H, $J_{4,5}$ 10 Hz, H-4), 4.92 (btd, 1 H, $J_{5,6}$ 5 Hz, H-5), 4.92 (d, 1 H, $J_{7,7'}$ 12.5 Hz, H-7), 4.61 (d, 1 H, H-6), 3.95 (d, 1 H, H-7'), 3.90 (bs, OH), 2.17, 2.10, 2.02, and 1.99 (4 s, 3, 3, 6, and 3 H, NAc and 4 OAc).

Anal. Calc. for $C_{17}H_{24}BrNO_{10}$: C, 42.34; H, 5.02; N, 2.90. Found: C, 42.30; H, 4.96; N, 2.72.

Compound **12** (40 mg, 0.08 mmol) was treated with anhydrous potassium carbonate (14 mg, 1.2 mol) in methanol (4 mL) for 6 h at room temperature. After neutralisation with M hydrochloric acid, the mixture was concentrated and the residue was acetylated in the usual way. The product was recrystallised from ethanol to give **10** (28 mg, 84%), m.p. 175.5–177°.

DL-*(1,2,4,6/3,5)-1-Acetamido-3-*C*-acetoxymethyl-2,4,5-tri-*O*-acetyl-3-bromo-2,4,5,6-cyclohexanetetrol* (**13**). — Compound **7** (200 mg, 0.52 mmol) was treated with an equimolar amount of *N*-bromosuccinimide in aqueous *N,N*-dimethylformamide at 40° as described in the preparation of **12**. Column chromatography (benzene–ethanol, 12:1) of the products gave **7** (59 mg) and **13** (89 mg, 51% based on **7** consumed) as needles, m.p. 189–191° (from ethanol). ^{1}H-N.m.r. data ($CDCl_3$, 200 MHz): δ 6.56 (d, 1 H, $J_{1,NH}$ 10 Hz, NH), 5.62 (d, 1 H, $J_{1,2}$ 5 Hz, H-2), 5.60 (d, 1 H, $J_{4,5}$ 7.5 Hz, H-4), 5.24 (t, 1 H, $J_{5,6}$ 7.5 Hz, H-5), 4.93 (dt, $J_{1,6}$ 5 Hz, H-1), 4.82 (d, 1 H, $J_{7,7'}$ 12.5 Hz, H-7), 4.25 (d, 1 H, H-7'), 3.98 (dt, 1 H, $J_{6,OH}$ 7.5 Hz, H-6), 3.31 (d, 1 H, OH), 2.22, 2.15, 2.13, 2.11, and 2.04 (5 s, each 3 H, 5 OAc); [$CDCl_3$–CD_3OD (5:1)] δ 5.55 (d, 1 H, $J_{4,5}$ 9 Hz, H-4), 5.49 (d, 1 H, $J_{1,2}$ 5.5 Hz, H-2), 5.29 (t, 1 H, $J_{5,6}$ 9 Hz, H-5), 4.85 (d, 1 H, $J_{7,7'}$ 12.5 Hz, H-7), 4.82 (t, 1 H, $J_{1,6}$ 5.5 Hz, H-1), 4.35 (d, 1 H, H-7'), 3.98 (dd, 1 H, H-6), 2.25, 2.15, 2.13, 2.10, and 2.05 (5 s, each 3 H, 5 OAc).

Anal. Calc. for $C_{17}H_{24}BrNO_{10}$: C, 42.34; H, 5.02; N, 2.90. Found: C, 42.23; H, 4.90; N, 2.76.

DL-*(1,2,4,5,6/3)-5-Acetamido-3,4,6-tri-*O*-acetyl-1-*C*-acetoxymethyl-1,2-anhydro-1,2,3,4,6-cyclohexanepentol* (**14**). — Compound **13** (46 mg, 0.09 mmol) was treated with anhydrous potassium carbonate as described in the preparation of **10** from **12**. The products were acetylated in the usual way and column chromatography (benzene–ethanol, 15:1) then gave, first, **14** (8 mg, 22%) as a syrup. ^{1}H-N.m.r. data ($CDCl_3$, 400 MHz): δ 6.09 (d, 1 H, $J_{5,NH}$ 9.7 Hz, NH), 5.61 (d, 1 H, $J_{5,6}$ 5.6 Hz, H-6), 5.20 (d, 1 H, $J_{2,3}$ 0, $J_{3,4}$ 9.3 Hz, H-3), 4.98 (dd, 1 H, $J_{4,5}$ 3.4 Hz, H-4), 4.88 (ddd, 1 H, H-5), 4.35 (d, 1 H, $J_{7,7'}$ 12.2 Hz, H-7), 3.96 (d, 1 H, H-7'), 3.29 (s, 1 H, H-2), 2.14, 2.10, and 2.02 (3 s, 3, 6, and 6 H, 5 OAc). Mass spectrum: *m/z* 402 (M^+ + H).

Eluted second was **11** (10 mg, 28%), isolated as needles, m.p. 161–163° (from ethanol).

DL-*(1,6/2,3,4,5)-* (**15**) *and* DL-*(1,3,5/2,4,6)-6-Acetamido-2-*C*-acetoxymethyl-1,2,3,4,5-penta-*O*-acetyl-1,2,3,4,5-cyclohexanepentol* (**17**). — A mixture of **10** (110 mg, 0.27 mmol), anhydrous sodium acetate (45 mg, 0.54 mmol), and aqueous 10% 2-methoxyethanol (3.3 mL) was heated for 8 h at 80°, and for a further 12 h after the addition of sodium acetate (45 mg). The mixture was concentrated and the residue was treated with acetic anhydride (3 mL) and pyridine (3 mL) for 3 days at 70°. The products were eluted from a column of silica gel (15 g) with benzene–ethanol (10:1) to give, first, **15** (57 mg, 42%) as needles, m.p. 208–210° (from ethanol). ^{1}H-N.m.r.

data ($CDCl_3$, 200 MHz): δ 6.04 (d, 1 H, $J_{1,6}$ 3 Hz, H-1), 5.60 (d, 1 H, $J_{6,NH}$ 9 Hz, NH), 5.55–5.45 (m, 2 H, H-3,4), 5.21 (ddd, 1 H, $J_{3,5}$ 4, $J_{4,5}$ 6, $J_{5,6}$ 11.2 Hz, H-5), 4.70 (d, 1 H, $J_{7,7'}$ 12.5 Hz, H-7), 4.57 (ddd, 1 H, H-6), 4.52 (d, 1 H, H-7'), 2.24, 2.20, 2.05, 2.04, 2.01, 1.98, and 1.90 (7 s, each 3 H, NAc and 6 OAc).

Anal. Calc. for $C_{21}H_{29}NO_{13}$: C, 50.10; H, 5.80; N, 2.78. Found: C, 50.04; H, 5.83; N, 2.70.

Eluted second was **17** (15 mg, 11%), obtained as needles, m.p. 188–189° (from ethanol). ^{1}H-N.m.r. data ($CDCl_3$, 200 MHz): δ 6.26 (d, 1 H, $J_{1,6}$ 11.5 Hz, H-1), 6.24 (d, $J_{3,4}$ 10.5 Hz, H-3), 5.72 (d, 1 H, $J_{6,NH}$ 10.5 Hz, NH), 5.65 (t, 1 H, $J_{4,5}$ 10.5 Hz, H-4), 5.17 (dd, 1 H, $J_{5,6}$ 11.5 Hz, H-5), 4.85 (dt, 1 H, H-6), 4.38 (s, 2 H, CH_2OAc), 2.32, 2.09, 2.07, 2.04, 2.00, 1.96, and 1.90 (7 s, each 3 H, NAc and 6 OAc).

Anal. Found: C, 50.13; H, 5.73; N, 2.57.

DL-*(1,4/2,3,5,6)-6-Acetamido-2-C-acetoxymethyl-1,2,3,4,5-penta-O-acetyl-1,2,3,4,5-cyclohexanepentol* (**16**). — A mixture of **11** (52 mg, 0.13 mmol), anhydrous sodium acetate (23 mg, 0.26 mmol), and aqueous 10% 2-methoxyethanol (3.3 mL) was heated for 6 h at 80° and then concentrated. The residue was acetylated as described in the preparation of **15** and **17**, and the product was crystallised from ethanol to give **16** (29 mg, 44%) as needles, m.p. 189.5–190.5°. ^{1}H-N.m.r. data ($CDCl_3$, 200 MHz): δ 5.94 (d, 1 H, $J_{6,NH}$ 9 Hz, NH), 5.66 (d, 1 H, $J_{1,6}$ 4 Hz, H-1), 5.52 (d, 1 H, $J_{3,4}$ 8.5 Hz, H-3), 5.45 (t, 1 H, $J_{4,5}$ 8.5 Hz, H-4), 5.25 (dd, 1 H, $J_{5,6}$ 5 Hz, H-5), 4.78 (d, 1 H, $J_{7,7'}$ 12.5 Hz, H-7), 4.70 (ddd, 1 H, H-6), 4.52 (d, 1 H, H-7'), 2.19, 2.16, 2.05, 2.04, 2.02, and 2.01 (6 s, 3, 3, 3, 3, 6, and 3 H, NAc and 6 OAc).

Anal. Calc. for $C_{21}H_{29}NO_{13}$: C, 50.10; H, 5.80; N, 2.78. Found: C, 49.80; H, 5.73; N, 2.56.

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