Synthesis of Tetrahydrospectinomycin

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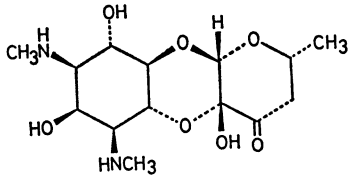
Condensation of 1,3-bis-*N*-(benzyloxycarbonyl)actinamine (**2**) with 2-*O*-chloroacetyl-4,6-dideoxy-3-*O*-*p*-nitrobenzoyl-α-D-xylohexopyranosyl chloride (**8**), followed by deacylation and catalytic hydrogenation afforded 5-*O*-(4,6-dideoxy-β-D-xylohexopyranosyl)actinamine (**11**). Compound **11** was found to be identical with one of the four tetrahydrospectinomycins. ^{1}H and ^{13}C NMR spectra were determined and analyzed.

Spectinomycin is an unique aminocyclitol antibiotic produced by the fermentation of *Streptomyces spectabilis*,[1,2] and is widely used in clinical treatment. Its structure was established by Wiley *et al.*,[3] the configuration being assigned by X-ray diffraction study,[4] as shown in Scheme 1.



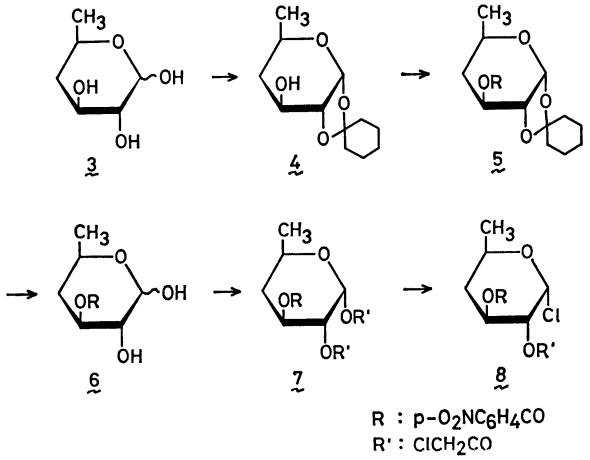
Spectinomycin

Scheme 1.

Reduction of spectinomycin with sodium borohydride or hydrogen in the presence of a catalyst gave two epimeric dihydrospectinomycins,[3] further reduction of the dihydrospectinomycins yielding four tetrahydrospectinomycins.[5]

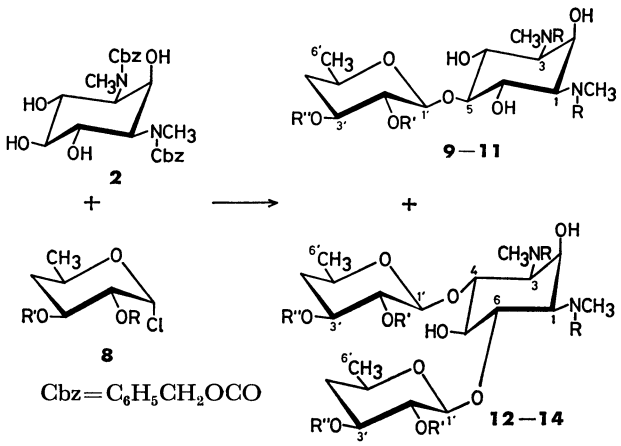
We have directed our studies toward a total synthesis of spectinomycin, and wish to report the synthesis of tetrahydrospectinomycin by the following reaction route (Schemes 2 and 3).

Actinamine dihydrochloride (**1**) was prepared by the hydrolysis of hexa-*N*,*O*-acetylactinamine[6] in 6 M hydrochloric acid. Treatment of **1** with benzyl chloroformate gave 1,3-bis-*N*-(benzyloxycarbonyl)actinamine (**2**).



R : p-$O_2NC_6H_4CO$
R' : $ClCH_2CO$

Scheme 2.



Cbz=$C_6H_5CH_2OCO$

8 R=$ClCH_2CO$, R'=*p*-$O_2NC_6H_4CO$
9 R=Cbz, R'=$ClCH_2CO$, R''=*p*-$O_2NC_6H_4CO$
10 R=Cbz, R'=R''=H
11 R=R'=R''=H
12 R=Cbz, R'=$ClCH_2CO$, R''=*p*-$O_2NC_6H_4CO$
13 R=Cbz, R'=R''=H
14 R=R'=R''=H

Scheme 3.

2-*O*-Chloroacetyl-4,6-dideoxy-3-*O*-*p*-nitrobenzoyl-α-D-xylohexopyranosyl chloride (**8**) was prepared from 4,6-dideoxy-D-xylohexopyranose[7] (**3**) in five steps. A chloroacetyl group was used as protecting group on the hydroxyl group of C-2 because of relative ease of removal under milder conditions as compared with the *p*-nitrobenzoyl group.[8] This was demonstrated by the preparation of methyl 4,6-dideoxy-3-*O*-*p*-nitrobenzoyl-β-D-xylohexopyranoside (**17**) from methyl 2-*O*-chloroacetyl-4,6-dideoxy-3-*O*-*p*-nitrobenzoyl-β-D-xylohexopyranoside (**16**) in an aqueous pyridine solution.

Condensation of **2** with **8** in dry benzene in the presence of mercury(II) cyanide and "Drierite" gave a mixture of three products (R_f 0.28, 0.34, and 0.38) which were detectable on TLC. The mixture was fractionated on a silica gel column with benzene–ethanol as an eluant. Fractions showing a single spot at R_f 0.28 on TLC were combined and evaporated to give the desired compound: 1,3-bis-*N*-(benzyloxycarbonyl)-5-*O*-(2-*O*-chloroacetyl-4,6-dideoxy-3-*O*-*p*-nitrobenzoyl-β-D-xylohexopyranosyl)actinamine (**9**) as crystals in 7.8% yield.

Besides compound **9**, 1,3-bis-*N*-(benzyloxycarbonyl)-4,6-bis-*O*-(2-*O*-chloroacetyl-4,6-dideoxy-3-*O*-*p*-nitrobenzoyl-β-D-xylohexopyranosyl)actinamine (**12**) was obtain-

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ed from the fractions (R_f 0.38) in 13% yield. From the fractions (R_f 0.34), an isomer of **9** (**15**) was obtained in 1.7% yield, the structure of which has not been clarified.

By removing the protecting group, **9** gave 5-*O*-(4,6-dideoxy-β-D-xylohexopyranosyl)actinamine (**11**) which was found to be identical with one of the four tetrahydrospectinomycins described by Knight and Hoeksema.[5]

By removing the protecting group, **12** gave 4,6-bis-*O*-(4,6-dideoxy-β-D-xylohexopyranosyl)actinamine (**14**). The β-anomeric configuration of the two glycosidic linkages in **14** were established by ^{1}H NMR spectroscopic study, and their positions attached to the actinamine were confirmed by carbon-13 NMR spectrum in connection with that of **11**.

The normal proton-decoupled natural-abundance carbon-13 Fourier transform spectra of **11** and **14** were determined. The resonances were separated into those originating from an actinamine moiety and those from 4,6-dideoxy-β-D-xylohexopyranosyl group.

When the spectra were determined at pD<1, the resonances arising from the actinamine moiety shifted more or less from those determined in a free base by the effect of protonation on an amino group.[9]

The spectrum of **11** revealed the presence of 14 carbon atoms. The resonance at 33.3 ppm (2 carbons) was attributed to the two *N*-methyl carbons shifted to 31.6 ppm at pD<1, the resonance at 62.9 ppm (2 carbons) being ascribed to C-1 and C-3 which shifted to 62.0 and 61.7 ppm respectively, at pD<1. The resonance at 63.7 ppm is due to C-2, since a large upfield shift (3.6 ppm) was observed at pD<1. These assignments were established in connection with those of spectinomycin.[10] The resonance at 88.0 ppm was assigned to C-5, since methylation of a hydroxyl group causes a large downfield shift of the carbon bearing this hydroxyl group,[11] the result being extended to the glycosidation of a hydroxyl group.[12] C-5 of hyosamine in hygromycin B_2 revealed its resonance at 86.4 ppm[13] and that of 2-deoxystreptamine in ribostamycin at 85.0 ppm.[14] The two resonances at 71.3 and 72.0 ppm were ascribed to the remaining C-4 and C-6, respectively, owing to a large upfield shift at pD<1.

The other 6 resonances were attributed to 6 carbon atoms of the 4,6-dideoxy-β-D-xylohexopyranosyl group. The resonances at 20.6 and 40.6 ppm were clearly due to C-6′ and C-4′, respectively. The resonances at 104.5 and 76.2 ppm were ascribed to C-1′ and C-2′, respectively, since those of methyl β-D-glucopyranoside resonate at 104.2 and 74.1 ppm.[15] The resonance at 69.7 ppm was ascribed to C-5′, since the corresponding carbon atom of spectinomycin revealed its resonance at 69.2 ppm.[10] Thus, the remaining resonance at 71.1 ppm is attributable to C-3′. The assignment was rationalized by the fact that C-4′ of nebramine shows its resonance with a large upfield shift (5.2 ppm) as compared to C-4′ of neamine.[16]

The assignments of the resonances are given in Table 1.

The resonances of the spectrum of **14** were assigned in connection with those of **11**. In the spectrum of **14**, resonances originating from 4,6-dideoxy-β-D-xylohexopyranosyl groups were readily recognized by the formation of pairs of signals at the same position observed in the spectrum of **11**. The two glycosyloxy groups were linked to C-4 and C-6 of the actinamine, since two resonances at 82.7 and 84.8 ppm were ascribed to the carbon atoms where the glycosyloxy groups attached[12] and the resonances of C-4 and C-6 (71.3 and 72.0 ppm) in the spectrum of **11** were not observed in the spectrum of **14**, C-5 showing its resonance at 75.5 ppm instead.

Table 1. ^{13}C NMR chemical shifts[a] of **11**, **14**, and spectinomycin hydrate

	11		**14**		Spectinomycin hydrate[10]
	base	pD<1	base	pD<1	pD 4.6
C-1	62.9	62.0	62.7[c]	61.5	62.5
C-2	63.7	60.1	62.9[c]	59.8	60.7
C-3	62.9	61.7	61.9	60.8	59.5
C-4	71.3[b]	68.2	82.7[d]	77.1	66.5
C-5	88.0	84.2	75.5	73.4	70.7
C-6	72.0[b]	69.0	84.8[d]	79.3	66.9
1-NCH_3	33.3	31.6	33.1	32.1	31.8
3-NCH_3	33.3	31.6	32.8	31.7	31.3
C-1′	104.5	104.2	104.5 105.7	103.8 103.8	94.4
C-2′	76.2	76.1	76.2 76.7	75.8 76.0	94.4
C-3′	71.1	71.1	71.3 71.5	71.1 71.1	92.6
C-4′	40.6	40.6	40.5 40.7	40.4 40.6	42.3
C-5′	69.7	69.8	69.7 69.8	69.8 70.2	69.2
C-6′	20.6	20.6	20.7 20.7	20.7 20.7	20.5

a) In parts per million downfield from tetramethylsilane.
b), c), d) The signals may be reversed.

Experimental

General Methods. Melting points were determined in capillary tubes and are uncorrected. Solutions were evaporated under reduced pressure below 40 °C. Opitcal rotations were recorded on a Japan Spectroscopic DIP-SL polarimeter. IR spectra were measured on a Hitachi 225 spectrophotometer in KBr disks. ^{1}H NMR spectra were recorded on a Varian A-60D spectrometer at 60 MHz or a Varian XL-100 spectrometer at 100 MHz in deuteriochloroform or deuterium oxide with tetramethylsilane or sodium 4,4-dimethyl-4-silapentane-1-sulfonate as an internal standard. The peak positions are given in δ-values. ^{13}C NMR spectra were recorded for solutions in deuterium oxide with an internal dioxane reference, the chemical shifts being reported in ppm downfield from tetramethylsilane (δ_C for dioxane= −67.4). The spectra were obtained on a Varian XL-100 transform with Varian VFT-100 computer. TLC was performed on Wakogel B-10 (Wako Pure Chemical Co. Ltd.) plates, silica gel (Wakogel C-300) being employed for column chromatography. Elemental analyses were performed by Mr. Saburo Nakada.

Actinamine Dihydrochloride (1). A 5.63 g portion of hexa-*N*,*O*-acetylactinamine[6] was heated in 6M hydrochloric acid (40 ml) for 6 h under reflux. The solution was evaporated to dryness and the residue was recrystallized from aqueous

acetone giving 3.38 g (99%) of **1**, mp above 250 °C.

Found: C, 34.24; H, 7.08; N, 9.93; Cl, 25.49%. Calcd for $C_8H_{18}N_2O_4 \cdot 2HCl$: C, 34.42; H, 7.22; N, 10.03; Cl, 25.40%.

*1,3-Bis-*N*-(benzyloxycarbonyl)actinamine (2).* A 3.57 g portion of **1** was suspended in 60% aqueous acetone (550 ml) containing sodium carbonate (13.8 g). 30% Benzyl chloroformate in toluene (43.5 g) was added to the suspension under ice cooling with agitation. After being left to stand overnight at room temperature, the reaction mixture was evaporated to dryness and the residue was extracted with warm acetone. The acetone extracts were evaporated and the residue was triturated with ether. The crude product was recrystallized from ethanol–ether to give 5.11 g (84%) of **2**, mp 161—163.5 °C. An analytically pure sample was obtained by further recrystallizartion fom water, mp 164—165 °C.

Found: C, 61.01; H, 6.30; N, 5.98%. Calcd for $C_{24}H_{30}N_2O_8$: C, 60.75; H, 6.37; N, 5.90%.

*4,6-Dideoxy-*D*-xylohexopyranose (3).* The compound was prepared by the method of Jones and his co-workers.[7]

*1,2-*O*-Cyclohexylidene-4,6-dideoxy-*α*-*D*-xylohexopyranose (4).* Compound **3** (2.10 g) was suspended in cyclohexanone (74 ml) containing *p*-toluenesulfonic acid (60 mg) and "Drierite" (2.0 g). After being stirred overnight at room temperature, the reaction mixture was added with sodium hydrogencarbonate (5.5 g). The mixture was filtered and the filtrate was evaporated. The residue was purified by silica gel column chromatography with 1:3 (v/v) 2-butanone-toluene as an eluant. Fractions showing a single spot at R_f 0.42 on TLC in the same solvent were combined and evaporated to give 2.45 g (76%) of **4** as a syrup, $[\alpha]_D^{22}$ +35.3 ° (*c* 5.8, chloroform). ^{1}H NMR ($CDCl_3$): δ 1.23 (d, 3, J=6.5 Hz, C$\underline{H}_3$), 2.74 (broad s, 1, OH), 5.56 (d, 1, J=4.5 Hz, H-1).

Found: C, 62.84; H, 8.65%. Calcd for $C_{12}H_{20}O_4$: C, 63.13; H, 8.83%.

*1,2-*O*-Cyclohexylidene-4,6-dideoxy-3-*O*-p-nitrobenzoyl-*α*-*D*-xylohexopyranose (5).* To a suspension of *p*-nitrobenzoyl chloride (4.96 g) in pyridine (90 ml) was added a solution of **4** (2.33 g) in pyridine (5 ml) under ice cooling with agitation. After being stirred overnight at room temperature, the reaction mixture was poured into ice cold water (700 ml) and extracted with chloroform (50 ml×3). The combined chloroform layers were washed with sodium hydrogencarbonate solution and water. After being dried over anhydrous sodium sulfate, the solution was evaporated to give 3.13 g of a syrup. The product was recrystallized twice from ether–pentane to give 2.49 g (65%) of **5**, mp 94—97 °C; $[\alpha]_D^{24}$ +72 ° (c 1.1, chloroform). ^{1}H NMR ($CDCl_3$): δ 1.29 (d, 3, J=6.5 Hz, C$\underline{H}_3$), 5.68 (d, 1, $J_{1,2}$=2.5 Hz, H-1).

Found: C, 60.35; H, 6.06; N, 3.51%. Calcd for $C_{19}H_{23}NO_7$: C, 60.47; H, 6.14; N, 3.71%.

*4,6-Dideoxy-3-*O*-p-nitrobenzoyl-*D*-xylohexopyranose (6).* Compound **5** (1.51 g) was heated in 80% aqueous acetic acid (30 ml) for 1 h under reflux. The solution was evaporated and the residue was dissolved in ethanol. Petroleum ether was added to the ethanolic solution to give 1.01 g (85%) of **6** as amorphous powder, $[\alpha]_D^{22}$ +148.8 °→+142.1 ° (*c* 1.45, pyridine).

Found: C, 52.29; H, 5.27; N, 4.49%. Calcd for $C_{13}H_{15}NO_7$: C, 52.53; H, 5.27; N, 4.71%.

*1,2-Bis-*O*-chloroacetyl-4,6-dideoxy-3-*O*-p-nitrobenzoyl-*α*-*D*-xylohexopyranose (7).* Compound **6** (456 mg) was dissolved in a mixture of dioxane (5 ml) and pyridine (0.4 ml). To the solution was added chloroacetyl chloride (0.4 ml) under ice cooling with agitation. After 1 h, the reaction mixture was poured into ice cold water (30 ml) and extracted with chloroform (30 ml×3). The combined chloroform layer was washed with sodium hydrogensulfate solution, sodium hydrogencarbonate solution and water. After being dried over anhydrous sodium sulfate, the solution was evaporated to give 778 mg of a crude product. Recrystallization from ethanol gave 382 mg (55%) of **7**, mp 136—138 °C; $[\alpha]_D^{23}$ +128 ° (*c* 0.5, chloroform). ^{1}H NMR ($CDCl_3$): δ 1.14 (d, 3, J=6.0 Hz, C$\underline{H}_3$), 3.95 (s, 2, C$\underline{H}_2$Cl), 4.15 (s, 2, C$\underline{H}_2$Cl), 6.43 (d, 1, $J_{1,2}$=3.0 Hz, H-1).

Found: C, 45.53; H, 3.84; N, 3.06; Cl, 15.44%. Calcd for $C_{17}H_{17}NO_9Cl_2$: C, 45.35; H, 3.81; N, 3.11; Cl, 15.75%.

*2-*O*-Chloroacetyl-4,6-dideoxy-3-*O*-p-nitrobenzoyl-*α*-*D*-xylohexopyranosyl Chloride (8).* Hydrogen chloride was bubbled into a solution of **7** (610 mg) in dry ether (150 ml) until saturated and the solution was left to settle overnight in a refrigerator. The solution was evaporated and the residue was dissolved in chloroform (30 ml). The chloroform solution was washed with sodium hydrogencarbonate solution and water. After being dried over anhydrous sodium sulfate, the solution was evaporated. The residue was recrystallized from chloroform–ether to give 364 mg (69%) of **8**, mp 147—149 °C; $[\alpha]_D^{15}$ +216 ° (*c* 0.5, chloroform). ^{1}H NMR ($CDCl_3$): δ 1.26 (d, 3, J=6.5 Hz, C$\underline{H}_3$), 3.98 (s, 2, C$\underline{H}_2$Cl), 6.34 (d, 1, $J_{1,2}$=4.0 Hz, H-1).

Found: C, 45.82; H, 3.81; N, 3.46; Cl, 18.11%. Calcd for $C_{15}H_{15}NO_7Cl_2$: C, 45.94; H, 3.86; N, 3.57; Cl, 18.08%.

Condensation of 2 and 8. A mixture of **2** (3.08 g, 6.5 mmol) and **8** (4.82 g, 12.3 mmol) in dry benzene (60 ml) containing mercury(II) cyanide (3.5 g) and "Drierite" (3.1 g) was heated for 41 h under reflux. The mixture was filtered and the filtrate was evaporated. The residue was fractionated on a silica gel column with 20:1 (v/v) benzene–ethanol as an eluant.

Fractions showing a single spot at R_f 0.28 on TLC in the same solvent system were combined and evaporated. The residue was recrystallized from chloroform–ethanol to give 421 mg (7.8%) of 1,3-bis-*N*-(benzyloxycarbonyl)-5-*O*-(2-*O*-chloroacetyl-4,6-dideoxy-3-*O*-*p*-nitrobenzoyl-*β*-D-xylohexopyranosyl)actinamine (**9**) as crystals, mp 143—144 °C; $[\alpha]_D^{20}$ +45.4 ° (*c* 1.0, chloroform). ^{1}H NMR ($CDCl_3$): δ 1.35 (d, 3, J=6.0 Hz, C$\underline{H}_3$), 3.06 (s, 3, NC$\underline{H}_3$), 3.10 (s, 3, NC$\underline{H}_3$), 4.03 (s, 2, C$\underline{H}_2$Cl).

Found: C, 56.15; H, 5.26; N, 5.05; Cl, 4.39%. Calcd for $C_{39}H_{44}N_3O_{15}Cl$: C, 56.42; H, 5.34; N, 5.06; Cl, 4.27%.

Fractions showing a single spot at R_f 0.34 on TLC were combined and evaporated. The residue was recrystallized from chloroform–ethanol giving 92 mg (1.7%) of 1,3-bis-*N*-(benzyloxycarbonyl)-*O*-(2-*O*-chloroacetyl-4,6-dideoxy-3-*O*-*p*-nitrobenzoyl-D-xylohexopyranosyl)actinamine (**15**), mp 172—173.5 °C; $[\alpha]_D^{22}$ +87.5 ° (*c* 1.0, chloroform). ^{1}H NMR ($CDCl_3$): δ 1.24 (d, 3, J=6.0 Hz, C$\underline{H}_3$), 3.09 (s, 3, NC$\underline{H}_3$), 3.11 (s, 3, NC$\underline{H}_3$), 4.04 (s, 2, C$\underline{H}_2$Cl).

Found: C, 56.37; H, 5.32; N, 5.01; Cl, 4.39%. Calcd for $C_{39}H_{44}N_3O_{15}Cl$: C, 56.42; H, 5.34; N, 5.06; Cl, 4.27%.

Fractions showing a single spot at R_f 0.38 on TLC were combined and evaporated. The residue was recrystallized from chloroform–ether giving 989 mg (13%) of 1,3-bis-*N*-(benzyloxycarbonyl)-4,6-bis-*O*-(2-*O*-chloroacetyl-4,6-dideoxy-3-*O*-*p*-nitrobenzoyl-*β*-D-xylohexopyranosyl)actinamine (**12**), mp 152—153 °C; $[\alpha]_D^{22}$ +14.0 ° (*c* 1.0, chloroform). ^{1}H NMR ($CDCl_3$): δ 1.21 (d, 3, J=6.5 Hz, C$\underline{H}_3$), 1.40 (d, 3, J=6.5 Hz, C$\underline{H}_3$), 3.05 (s, 6, 2×NC$\underline{H}_3$), 4.02 (s, 4, 2×C$\underline{H}_2$Cl).

Found: C, 54.51; H, 4.93; N, 4.55; Cl, 6.28%. Calcd for $C_{54}H_{58}N_4O_{22}Cl_2$: C, 54.69; H, 4.93; N, 4.72; Cl, 5.98%.

*1,3-Bis-*N*-(benzyloxycarbonyl)-5-*O*-(4,6-dideoxy-β-D-xylohexo-*

*pyranosyl)actinamine (**10**).* Compound **9** (290 mg) was deacylated in saturated methanolic ammonia (20 ml) overnight at ambient temperature with gentle agitation. The solution was evaporated and the residue was recrystallized from methanol giving 206 mg (98%) of **10**, mp 244—246 °C; $[\alpha]_D^{18}$ −1.1 ° (*c* 1.0, pyridine).

Found: C, 59.37; H, 6.53; N, 4.83%. Calcd for $C_{30}H_{40}N_2O_{11}$: C, 59.59; H, 6.67; N, 4.63%.

*5-O-(4,6-Dideoxy-β-D-xylohexopyranosyl)actinamine (**11**).* A solution of **10** (115 mg) in 50% aqueous methanol (20 ml) was hydrogenated in the presence of palladium black (20 mg) overnight in a Parr apparatus in hydrogen atmosphere (3.4 kg/cm²). The filtrate was evaporated after the catalyst had been filtered off. The residue was purified by Amberlite CG-50 (H^+) resin column chromatography with 0.05 M ammonia as an eluant. The product was recrystallized from ethanol to give 59 mg (92%) of **11** as needles, mp 222—225 °C; $[\alpha]_D^{21}$ −21.8 ° (*c* 1.0, water). ^{1}H NMR (D_2O): δ 1.28 (d, 3, *J*=6.5 Hz, $C\underline{H}_3$), 2.41 (s, 6, 2×$NC\underline{H}_3$), 4.58 (d, 1, *J*=7.5 Hz, H-1). IR and ^{1}H NMR spectra of **11** were superimosable on those of an authentic sample of tetrahydrospectinomycin prepared by the method of Knight and Hoeksema.[5] [Lit,[5] mp 227—231 °C; $[\alpha]_D$−22 ° (*c* 1.0, water)].

Found: C, 49.79; H, 8.19; N, 8.35%. Calcd for $C_{14}H_{28}N_2O_7$: C, 49.99; H, 8.39; N, 8.33%.

*1,3-Bis-N-(benzyloxucarbonyl)-4,6-bis-O-(4,6-dideoxy-β-D-xylohexopyranosyl)actinamine (**13**).* Compound **12** (0.4 g) was deacylated by a procedure analogous to that described for **10**. The product was purified by column chromatography with 15:1 (v/v) benzene–ethanol. Fractions showing a single spot at R_f 0.58 on TLC in 5:1 (v/v) benzene–ethanol were combined and evaporated. The residue was dissolved in benzene. Hexane was added to the solution giving 190 mg (75%) of **13** as amorphous powder, mp 111—128 °C; $[\alpha]_D^{22}$ −25.0 ° (*c* 1.0, pyridine).

Found: C, 57.52; H, 6.68; N, 3.62%. Calcd for $C_{36}H_{50}N_2O_{14}\cdot H_2O$: C, 57.44; H, 6.96; N, 3.72%.

*4,6-Bis-O-(4,6-dideoxy-β-D-xylohexopyranosyl)actinamine (**14**).* Hydrogenolysis of **13** (124 mg) was carried out by a procedure analogous to that described for **11**. The product was recrystallized from ethanol to give 63 mg (82%) of **14**, mp 243—247 °C; $[\alpha]_D^{22}$ −26.0 ° (*c* 1.0, water). ^{1}H NMR (D_2O): δ 1.28 (d, 6, *J*=6.0 Hz, 2×$C\underline{H}_3$), 2.44 (s, 6, 2×$NC\underline{H}_3$), 4.50 (d, 1, *J*=7.5 Hz, anomeric proton), 4.62 (d, 1, *J*=7.5 Hz, anomeric proton).

Found: C, 51.61; H, 8.02; N, 6.01%. Calcd for $C_{20}H_{38}N_2O_{10}$: C, 51.49; H, 8.21; N, 6.00%.

*Methyl 2-O-Chloroacetyl-4,6-dideoxy-3-O-p-nitrobenzoyl-β-D-xylohexopyranoside (**16**).* A solution of **8** (340 mg) in dichloromethane (1.5 ml) was added to methanol (5 ml) containing mercury(II) cyanide (340 mg). The mixture was stirred at ambient temperature for 2 h and filtered. The filtrate was evaporated, and the residue was dissolved in chloroform. The chloroform solution was filtered and the filtrate was evaporated. The residue was recrystallized from ethanol to give 238 mg (71%) of **16**, mp 122—123 °C; $[\alpha]_D^{16}$ + 58 ° (*c* 0.5, chloroform). ^{1}H NMR ($CDCl_3$): δ 1.34 (d, 3, *J*=6.0 Hz, $C\underline{H}_3$), 3.50 (s, 3, $OC\underline{H}_3$), 3.98 (s, 2, $C\underline{H}_2Cl$), 4.44 (d, 1, *J*=8.0 Hz, H-1).

Found: C, 49.36; H, 4.70; N, 3.69; Cl, 8.97%. Calcd for $C_{16}H_{18}NO_8Cl$: C, 49.56; H, 4.68; N, 3.61; Cl, 9.14%.

*Methyl 4,6-dideoxy-3-O-p-nitrobenzoyl-β-D-xylohexopyranoside (**17**).* Water (4 ml) was added to a solution of **16** (158 mg) in pyridine (7 ml), and the pH of the mixture was adjusted to 7 by addition of 6M hydrochloric acid. The mixture was settled at ambient temperature for 5 h. The mixture was diluted with chloroform, and the solution was washed successively with sodium hydrogensulfate solution, sodium hydrogencarbonate solution and water. After being dried over anhydrous sodium sulfate, the solution was evaporated. The residue was recrystallized from ethanol–petroleum ether to give 103 mg (81%) of **17**, mp 133—134 °C; $[\alpha]_D^{22}$ +30° (*c* 0.5, chloroform). ^{1}H NMR ($CDCl_3$): δ 1.32 (d, 3, *J*=6.0 Hz, $C\underline{H}_3$), 2.66 (broad s, 1, OH), 3.57 (s, 3, $OC\underline{H}_3$), 4.26 (d, 1, *J*=8.0 Hz, H-1).

Found: C, 54.19; H, 5.50; N, 4.56%. Calcd for $C_{14}H_{17}NO_7$: C, 54.02; H, 5.51; N, 4.50%.

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