Chirospecific Synthesis of (-)-Polyoxamic Acid and Its Stereoisomer

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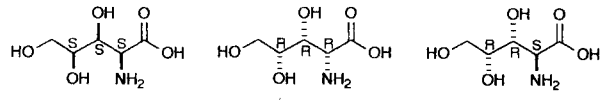
The (-)-polyoxamic acid **2** and its stereoisomer **3** have been prepared from D-glucono-δ-lactone which has three available stereocenters as required for **2** and **3**. Key transformations included the selective cleavage of the terminal isopropylidene group.

Introduction

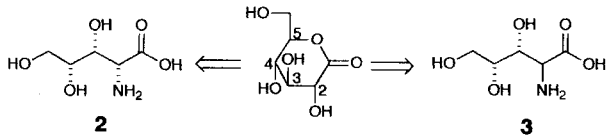
The family of polyoxin from *Streptomyces cacaoi* var. *asones* is widely used in Japan against phytopathogenic fungi, acting as competitive inhibitors of the chitin synthetase, leading to blockable of the biosynthesis of chitin, an essential component of the fungal cell wall.[1] The (+)-polyoxamic acid **1** is component of important polyoxin family, and has been synthesized starting from carbohydrates and noncarbohydrates.[2] Though stereo modified analogs of (+)-polyoxamic acid might provide more potent and selective chitin synthetase inhibitors, its stereoisomers have not been studied much.[3] Our objective was to develop an efficient route for the preparation of enantomerically pure (-)-polyoxamic acid **2** and 2-amino-2-deoxy-D-lysonic acid **3**, which have never reported, from D-glucono-δ-lactone.

As our chiral educt we chose D-glucono-δ-lactone which



1 **2** **3**

Scheme 1



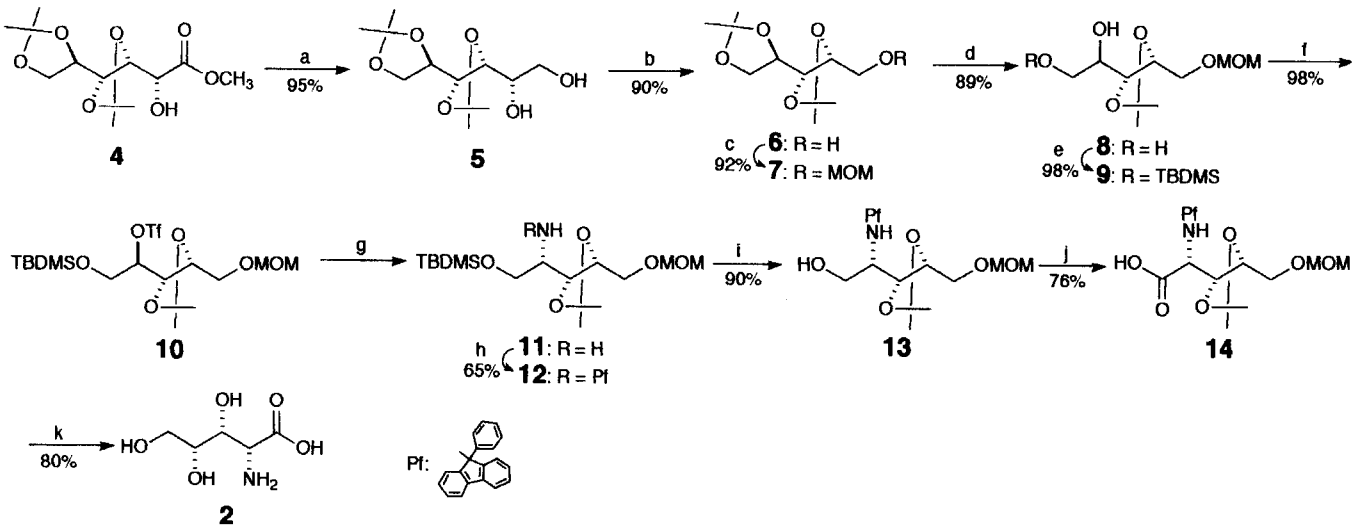
2 **3**

Scheme 2

has three available stereocenters required for the target molecules **2** and **3**. The stereochemistry of C3, C4 and C5 in starting material was used for compound **2**, while C2, C3 and C4 for compound **3** (Scheme 2).

Results and Discussion

Starting from **4** we planned to synthesize diol **5** which would allow the introduction of C_5 unit *via* bis-diol cleavage. We also anticipated the selectivity in removal of terminal isopropylidene protecting group to give compound **8** as the key intermediate of the synthesis. By forming the new chiral center C2 in target compound **2**, we expected completely inversion of chiral center *via* S_N2 azidation. The D-gluconate **4** was synthesized from D-gluconolactone as described.[4] Reduction of ester **4** with $LiAlH_4$ gave diol **5** in 95% yield. The diol **5** was oxidized with $NaIO_4$, followed

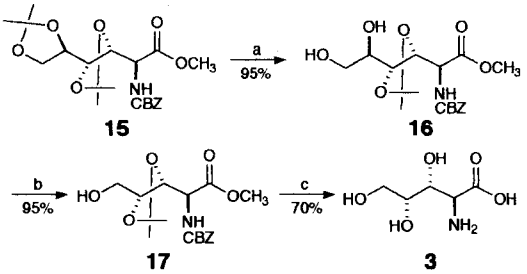


4 **5** **10** **13** **14** **2**

Scheme 3. (a) LAH, THF, 0 °C. (b) $NaIO_4$, EtOH-water (2/1), $NaBH_4$, rt. (c) MOMCl, i-Pr_2NEt, CH_2Cl_2, rt. (d) Dowex-50W (H^+), 90% MeOH, rt. (e) TBDMSCl, imidazole, DMF, rt. (f) Tf_2O, pyridine, CH_2Cl_2, −10 °C. (g) NaN_3, DMF and Pd/C, H_2, rt. (h) PfBr, $Pb(NO_3)_2$, Et_3N, CH_2Cl_2, rt. (i) Bu_4NF, THF, rt. (j) Swern oxidation, $KMnO_4$, K_2CO_3, THF-water (2/1), rt. (k) Pd/C, H_2, MeOH and Dowex-50W, reflux.

by sodium borohydride reduction of the resulting aldehyde to afford the formation of alcohol **6** in quantitative yield. The hydroxy group of alcohol **6** was protected with methylchloromethyl ether (MOMCl) in presence of diisopropylethylamine to give compound **7** in 92% yield. The terminal isopropylidene group of diisopropylidene **7** was selectively cleaved by treatment of compound **7** with Dowex 50W-X8 resin (H^+-form) in 90% methanol to give the diol **8** in 89% yield.[5] The primary hydroxy group of diol **8** was selectively protected with *t*-butyldimethylsilyl chloride (TBDMSCl) followed by triflation of corresponding silylate **9** gave triflate **10** in 98% yield from diol **8**. The triflate **10** was transformed the azide by treatment of **10** with sodium azide, and the corresponding azide was then hydrogenated in presence of palladium on charcoal. The free amine **11** was protected with 9-phenylfluorenyl group (Pf) which has been shown to inhibit deprotonation at α-position of the α-amino ester.[6] The TBDMS group of compound **12** was removed with Bu_4NF to give alcohol **13** in 90% yield and then hydroxy group of **13** was easily converted to aldehyde by Swern oxidation. The corresponding aldehyde was easily oxidized with $KMnO_4$ to give the acid **14** in 76% yield from silylate **11**. The Pf group of acid **14** was removed with palladium on charcoal, and remaining isopropylidene and MOM groups were removed by treatment of corresponding amine with Dowex 50W-8X in methanol to give free base form of target compound **2** without the need for additional ion exchange chromatography.

The diisopropylidenemannonate **15** was synthesized in four high-yielding steps from D-glucono-δ-lactone as described[7]; the overall yield for this conversion was 75% (Scheme 4). The terminal isopropylidene group was selectively cleaved by treatment of mannonate **15** with Dowex 50W-X8 resin (H^+-form) with 90% methanol to give the diol **16**. The diol **16** was oxidized with $NaIO_4$, followed by sodium borohydride reduction of the resulting aldehyde to give the formation of alcohol **17** in quantitative yield. The benzyloxycarbonyl group (CBZ) of ester **17** was removed with palladium on charcoal, and remaining isopropylidene, MOM and methyl ester groups were removed by treatment of corresponding amine with Dowex 50W-8X in aqueous THF to give free base form of target compound **3** without the need for additional ion exchange chromatography. We have first achieved enantiomerically pure (-)-polyoxamic acid **2** and 2-amino-2-deoxy-D-lyxonic acid **3** from D-gluconolactone.



Scheme 4. (a) Dowex 50W (H^+-form), MeOH, rt. (b) $NaIO_4$, EtOH-water (2/1), $NaBH_4$, rt. (c) Pd/C, H_2, MeOH, rt and Dowex 50W (H^+-form), THF-water (2 : 1), reflux.

Experimental

General. Dowex 50W-X8 was purchased from Sigma Chemical Co. All non-aqueous reaction were carried out under an inert nitrogen atmosphere. Tetrahydrofuran (THF) was distilled from Na/benzophenone; acetonitrile, 2,2-dimethoxypropane, dimethylformamide (DMF), and methylene chloride were distilled from CaH_2. Column chromatography was carried out using 230-400 mesh silica gel. Mps were measured on Thomas-Hoover Capillary Apparatus and are uncorrected. Specific rotation values were measured on JASCO DIP-370 polarimeter. Proton and carbon nmr spectra were measured down field relative to tetramethyl silane in $CDCl_3$ unless otherwise noted (value in ppm); ^1H NMR, ^{13}C NMR were conducted on 500 MHz spectrometer. Final solutions before evaporation were dried over anhydrous Na_2SO_4.

1,2;3,4-di-*O*-isopropylidene-D-glucitol (5). To an ice-cooled suspension of $LiAlH_4$ (0.59 g, 15.5 mmol) in THF (50 mL) was added a solution of **4** (3 g, 10.3 mmol). The reaction mixture was warmed to room temperature, stirred for 1 h, and then quenched by the sequential addition of water (0.59 mL), 15% aq. NaOH (0.59 mL), and water (1.77 mL). The mixture was filtered and evaporated. The residue was chromatographed (hexane/EtOAc, 3/1) to give 2.6 g (95%) of **5** as an oil: $[\alpha]^{20}_D$ +12.7 (c 1.0, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$): δ 1.33 (s, 3H), 1.36 (s, 3H), 1.40 (s, 3H), 1.41 (s, 3H), 2.75 (m, 1H, OH), 2.83 (m, 1H, OH), 3.72-3.78 (m, 2H), 3.94-3.99 (m, 3H), 4.03 (m, 1H), 4.15 (dd, J_1=8.5, J_2=6.0, 1H); ^{13}C NMR (125 MHz): δ 25.6, 26.9, 27.2, 27.5, 65.2, 68.3, 70.9, 77.7, 77.8, 81.9, 110.1, 110.3.

1,2;3,4-di-*O*-isopropylidene-D-lyxitol (6). To a solution of **5** (2.57 g, 9.8 mmol) in EtOH (25 mL) was added $NaIO_4$ (2.5 g, 11.8 mmol) and water (10 mL), and then stirred for 2 h. To reaction mixture was added $NaBH_4$ (446 mg, 11.8 mmol) and more stirred for 10 min. The reaction mixture was evaporated, then added water (50 mL), and extracted with EtOAc (50 mL×3). The combined organic phase was washed with brine, dried and concentrated under reduced pressure. The residue was chromatographed (hexane/EtOAc, 4/1) to give 2.05 g (90%) as an oil: $[\alpha]^{20}_D$ − 2.1 (c 1.0, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$): δ 1.28 (s, 3H), 1.32 (s, 3H), 1.33(s, 3H), 1.35 (s, 3H), 2.58 (m, 1H, OH), 3.63-3.67 (m, 2H), 3.74 (m, 1H), 3.90 (dd, J_1=8.6, J_2=4.7, 1H), 3.95 (m, 1H), 4.00 (m, 1H), 4.09 (dd, J_1=8.6, J_2=6.2, 1H); ^{13}C NMR (125 MHz): δ 24.9, 26.4, 26.6, 26.7, 62.6, 67.6, 76.6, 78.3, 80.6, 109.2, 109.6.

1,2;3,4-di-*O*-isopropylidene-5-*O*-methoxymethyl-D-lyxitol (7). To a solution of **6** (1.7 g, 7.3 mmol) in methylenechloride (30 mL) was added diisopropylethylamine (1.8 g, 14.5 mmol) and chloromethylmethyl ether (1.2 g, 14.5 mmol) at 0. After stirring for 4 h at rt, the reaction mixture was quenched with sat. NH_4Cl solution (40 mL) and extracted with EtOAc (30 mL×3). The combined extracts were washed with brine, dried, and evaporated, and the residue was chromatographed (hexane/EtOAc, 10/1) to give 1.9 g (92%) of **7** as a colorless oil; $[\alpha]_D^{23}$ +11.8 (c 3.5, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$): δ 1.35 (s, 3H), 1.40 (s, 3H), 1.42 (s, 3H), 1.45 (s, 3H), 3.39 (s, 3H), 3.64 (dd, J_1= 10.6, J_2=6.4, 1H), 3.73 (t, 1H), 3.83 (dd, J_1=10.7, J_2=7.7, 1H), 3.96 (dd, J_1=8.5, J_2=4.9, 1H), 4.08 (m, 1H), 4.13-4.16 (m, 2H), 4.70 (s, 2H) ^{13}C NMR (125 MHz): δ 25.6, 27.0, 27.4,

27.4, 55.6, 68.0, 68.5, 77.1, 78.2, 80.0, 97.1, 110.0, 110.1.

3,4-*O*-isopropylidene-5-*O*-methoxymethyl-D-lyxitol (8). To a solution of **7** (1.2 g, 4.3 mmol) in 90% MeOH (20 mL) was added Dowex 50W-X8 resin (240 mg). The reaction mixture was stirred for 9 h at rt, then was filtered, and filtrate was evaporated. The crude residue was chromatographed on silica gel [hexane/EtOAc (4/1, then 1/1)] to give 904 mg (89%) of **8** as a sticky oil; $[\alpha]^{26}_{D}$ +0.68 (c 4.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.39 (s, 3H), 1.40 (s, 3H), 3.38 (s, 3H), 3.68-3.81 (m, 6H), 4.15 (m, 1H), 4.67 (s, 2H); ^{13}C NMR (125 MHz): δ 27.2, 27.3, 55.9, 64.3, 68.8, 73.0, 78.7, 79.4, 97.1, 110.0.

1-*O*-*tert*-butyldimethylsilyl-3,4-*O*-isopropylidene-5-*O*-methoxymethyl-D-lyxitol (9). To a solution of **8** (0.8 g, 3.5 mmol) in dry DMF (20 mL) was added imidazole (470 mg, 6.9 mmol) and *tert*-butyldimethylchlorosilane (0.7 g, 5.2 mmol) at rt. The reaction mixture was stirred for 20 min at rt, then 30 mL of sat. $NaHCO_3$ solution was added followed by extraction with EtOAc (50 mL×3). The combined organic layer was washed with brine, dried, and evaporated, and the crude residue was chromatographed on silica gel [hexane/EtOAc, 4/1] to give 1.2 g (98%) of **9** as a sticky oil: $[\alpha]^{26}_{D}$ +11.6 (c 3.4, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$): δ 0.00 (s, 6H), 0.81 (s, 9H), 1.31 (m, 6H), 3.29 (s, 3H), 3.54-3.65 (m, 4H), 3.71-3.75 (m, 2H), 4.13 (m, 1H), 4.60 (s, 2H); ^{13}C NMR (125 MHz): δ −7.3, −7.2, 16.4, 24.0, 25.2, 53.4, 62.4, 66.7, 71.2, 75.4 77.5, 94.8, 107.7.

1-*O*-*tert*-butyldimethylsilyl-2-*O*-trifluoromethanesulfonyl-3,4-*O*-isopropylidene-5-*O*-methoxymethyl-D-lyxitol (10). A solution of **9** (1.0 g, 2.9 mmol) in methylenechloride (10 mL) was cooled to −10 °C, and precooled pyridine (0.67 g, 8.5 mmol) was added. A solution of trifluoromethanesulfonic anhydride (1.2 g, 4.3 mmol) in methylenechloride (3 mL) was added over 10 min under vigorous stirring. After stirring 30 min, the reaction mixture was neutralized at 0 with sat. aq. $NaHCO_3$ solution, washed with sat. $CuSO_4$ (20 mL×3). The organic layer was seperated, and aqueous layer was extracted with methylenechloride (20 mL×3). The combined organic layer was washed with brine, dried, and evaporated. The residue was co-evaporated repeatedly (5 times) with toluene. The remaining yellowish crystal (1.4 g, 98%) were pure enough for a futher transformation.

1-*O*-*tert*-butyldimethylsilyl-2-deoxy-2-[(9-phenylfluorenyl)amino]-3,4-*O*-isopropylidene-5-*O*-methoxymethyl-D-xylitol (12). To a sololution of **10** (1.5 g, 3.1 mmol) in DMF (15 mL) was added sodium azide (0.4 g, 6.1mmol) at rt. After stirring for 2 h at 50 °C, the reaction mixture was quenched with water and extracted with EtOAc (30 mL×3). The combined extracts were washed with brine, dried, and evaporated to give corresponding azide (0.9 g, 2.5 mmol) which was not purified for next step. A solution of azide in EtOAc (15 mL) was hydrogenated at atomosphere pressure with Pd/C (10%, 80 mg) for 7 h. The mixture was filtered, the filtrate was evaporated, and oily residue was dissolved CH_2Cl_2 (20 mL). 9-Phenylfluoren-9-yl bromide (1.1 g, 3.3 mmol), lead nitrate (1.1 mg, 3.3 mmol), and triethylamine (446 mg, 4.4 mmol) were added. The mixture was stirred for 24 h at rt, and then it was filtered and chromatographed on silica gel [hexane/EtOAc, 30/1] to give 1.2 g (65%) of **12** as sticky oil: $[\alpha]^{25}_{D}$ +115.7 (c 1.4, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$): δ −0.02-0.01 (d, 6H), 0.94 (s, 9H), 1.46 (s, 3H), 1.66 (s, 3H), 2.45 (m, 1H), 3.17 (dd, J_1= 9.9, J_2=8.3, 1H), 3.18 (dd, J_1=10.0, J_2=3.5, 1H), 3.57 (s, 3H), 3.67 (dd, J_1=10.6, J_2=7.0, 1H), 3.83 (dd, J_1=10.6, J_2=2.8, 1H), 4.03 (m, 1H), 4.67 (m, 1H), 4.85 (s, 2H), 7.37-7.89 (m, 13H); ^{13}C NMR (125 MHz): δ 17.8, 25.5, 26.8, 27.1, 52.7, 54.9, 62.5, 68.3, 71.8, 77.0, 77.5, 96.4, 108.2, 119.6, 119.8, 124.7, 125.3, 125.8, 126.8, 127.5, 127.6, 128.0, 139.9, 140.2, 145.2, 148.8, 151.7; Anal. Calcd for $C_{35}H_{47}NO_5Si$: C, 71.3; H, 8.0; N, 2.4 Found: C, 71.7; H, 8.2; N, 2.2.

2-Deoxy-2-[(9-phenylfluorenyl)amino]-3,4-*O*-isopropylidene-5-*O*-methoxymethyl-D-xylitol (13). To a solution of **12** (500 mg, 0.85 mmol) in THF (5 mL) was added 1.0 M Bu_4NF (1.6 mL, 1.6 mmol, in THF). After stirring for 5 h at rt., the reaction mixture was quenched with water and extracted with EtOAc (25 mL×3). The combined extracts were washed with brine, dried, and evaporated. The crude residue was chromatographed (hexane/EtOAC, 8/1) to give 320 mg (90%) of **13** as an oil: $[\alpha]^{25}_{D}$ +58.0 (c 4.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.41 (s, 3H), 1.49 (s, 3H), 2.26 (m, 1H), 2.74 (m, 1H), 3.14 (d, J= 10.7, 1H), 3.35 (s, 3H), 3.44 (dd, J_1=10.8, J_2=6.3, 1H), 3.49 (dd, J_1=10.8, J_2=3.4, 1H), 3.79 (m, 1H), 4.39 (m, 1H), 4.62 (s, 2H), 7.24-7.72 (m, 13H); ^{13}C NMR (125 MHz): δ 27.5, 27.6, 53.9, 55.7, 63.1, 68.3, 72.8, 77.7, 81.3, 97.1, 109.7, 120.4, 125.5, 126.0, 127.7, 128.2, 128.8, 128.9, 140.4, 141.0, 145.6, 149.2, 151.1; Anal. Calcd for $C_{29}H_{33}NO_5$: C, 73.2; H, 7.0; N, 3.0 Found: C, 73.4; H, 7.1; N, 2.8.

2-Deoxy-2-[(9-phenylfluorenyl)amino]-3,4-*O*-isopropylidene-5-*O*-methoxymethyl-D-xylonic acid (14). DMSO (0.2 mL, 2.7 mmol) was added dropwise to a cold (−78 °C), magnetically stirred solution of oxalyl chloride (212 mg, 1.7 mmol) in CH_2Cl_2 (6 mL) under nitrogen. After 20 min, a solution of **13** (320 mg, 0.67 mmol) in CH_2Cl_2 (6 mL) was added to reaction mixture. After a further 20 min, triethylamine (542 mg, 5.4 mmol) was added and the reaction mixture was kept at −78 °C for 30 min, allowed to warm slowly to rt., and quenched with water (20 mL) and extracted with CH_2Cl_2 (20 mL×3). The combined extracts were washed , dried, and evaporated, and the oilyl residue was dissolved in THF/water (2/1, 20 mL). $KMnO_4$ (159 mg, 1.0 mmol) and K_2CO_3 (185 mg, 1.3 mmol) were added. The mixture was stirred for 5 h at rt, and then it was filtered, filtrate was washedwith diethylether (20 mL× 3). The aqueous layer was adjusted pH 2, and extracted with EtOAc (30 mL×3). The combined extracts were washed with brine, dried, and evaporated, and the residue was chromatographed (hexane/EtOAC, 1/1) to give 250 mg (76%) of **14** as an oil: $[\alpha]^{25}_{D}$ +30.0 (c 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.28 (s, 3H), 1.36 (s, 3H), 2.60 (m, 1H), 3.18 (m, 1H), 3.21 (s, 3H), 3.31 (dd, J_1=10.9, J_2=3.3, 1H), 3.77 (m, 1H), 3.94 (m, 1H), 4.45 (s, 2H), 7.16-7.61 (m, 13H); ^{13}C NMR (125 MHz): δ 27.3, 27.4, 55.7, 56.5, 72.9, 76.8, 77.7, 78.1, 96.9, 110.2, 120.5, 125.7, 126.3, 126.9, 127. 9, 128.5, 129.3, 141.0, 143.8, 147.2, 148.8, 175.0 ; Anal. Calcd for $C_{29}H_{31}NO_6$: C, 71.15; H, 6.38; N, 2.86 Found: C, 71.3; H, 6.5; N, 2.7.

(-)-polyoxamic acid (2). A solution of **14** (200 mg, 0.4 mmol) in EtOAc (4 mL) was hydrogenated at atomosphere pressure with Pd/C (10%, 30 mg) for 6 h at 50 °C. The reaction mixture was filtered, filtrate was evaporated,

and oily residue was dissolved in 90% MeOH (6 mL). The mixture was refluxed for 24 h, and then it was washed with MeOH. The remaining residue was eluted with 2 M NH_3 solution. The ammoniacal solution was evaporated, then co-evaporated with toluene to give 55 mg (82%) of **2** as a solid: mp 170-180 dec; $[\alpha]^{25}_D$ −2.4 (c 1.5, H_2O); IR (KBr) 3500, 2950, 1648, 1520; ^{1}H NMR (500 MHz, $CDCl_3$): δ 3.62-3.70 (m, 2H), 3.86 (d, J=2.7, 1H), 3.90 (m, 1H), 4.21 (m, 1H); ^{13}C NMR (125 MHz): δ 58.4, 62.9, 68.5, 73.5, 173.0; Anal. Calcd for $C_5H_{11}NO_5$: C, 36.4; H, 6.7; N, 8.5 Found: C, 35.9; H, 6.9; N, 8.6.

Methyl 2-benzyloxycarbonylamino-2-deoxy-3,4-*O*-isopropylidene-D-mannonate (16). To a solution of **15** (3.8 g, 9 mmol) in 90% MeOH was added Dowex 50W-X8 resin (4 g). The reaction mixture was stirred for 16 h at rt, then was filtered, and the filtrate was evaporated. The crude residue was chromatographed [hexane/EtOAc, (1/1 then 1/5)] to give 3.3 g (95%) of **16** as a solid: mp 101-103 °C; $[\alpha]_D^{20}$ +46.4 (c 1.65, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.33 (s, 3H), 1.35 (s, 3H), 3.58-3.87 (m, 3H), 3.79 (s, 3H), 4.09 (dd, J_1=7.8, J_2=7.6, 1H), 4.23 (dd, J_1=7.8, J_2=3.0, 1H), 4.68 (m, 1H), 5.12 (s, 2H), 6.0 (br s, 1H), 7.33 (m, 5H); ^{13}C NMR (125 MHz): δ 26.7, 27.1, 52.2, 56.3, 64.0, 67.3, 73.4, 77.5, 81.2, 110.4, 128.1, 128.3, 128.5, 136.0, 156.3, 169.8.; Anal. Calcd for $C_{18}H_{25}N_1O_8$: C, 56.4; H, 6.6; N, 3.6 Found: C, 56.6, H, 6.7; N, 3.5.

Methyl 2-benzyloxycarbonylamino-2-deoxy-3,4-*O*-isopropylidene-D-lyxonate (17). To a solution of diol **16** (2.1 g, 5.9 mmol) in EtOH (30 mL) was added $NaIO_4$ (1.5 g, 7.1 mmol) and water (10 mL), then stirred for 2 h. After alcohol spot disapeared in TLC, to reaction mixture was added $NaBH_4$ (0.247 g, 6.5 mmol) and more stirred for 10 min. The reaction mixture was evaporated, then added water (20 mL), and extracted with EtOAc (30 mL×3). The organic layer was washed with brine, dried, and concentrated under reduced pressure. The residue was chromatographed (hexane/EtOAc, 4/1) to give 2.0 g (95%) of **17** as a solid: $[\alpha]^{25}_D$ +40.6 (c 1.9, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.36 (s, 3H), 1.41 (s, 3H), 3.80 (s, 3H), 4.15 (m, 1H), 4.25 (m, 1H), 4.61 (m, 1H), 5.15 (s, 2H), 5.80 (d, J=7.5, 1H, NH), 7.36 (m, 5H); ^{13}C NMR (125 MHz): δ 27.2, 27.3, 27.5, 53.0, 56.0, 62.7, 67.7, 78.4, 79.3, 100.0, 110.5, 128.6, 128.7, 129.0, 136.4, 156.4, 170.0; Anal. Calcd for $C_{17}H_{23}NO_7$: C, 57.8; H, 6.6; N, 4.0 Found: C, 57.2; H, 6.7; N, 4.1.

2-Amino-2-deoxy-D-lyxonic acid (3). A solution of **17** (160 mg, 0.45 mmol) and Dowex 50W-X8 (0.3 g) in THF-water (3 : 1) was refluxed overnight. The mixture was filtered, and then was washed with MeOH. The remaining residue was eluted with 2 M NH_3 solution. The ammoniacial solution was evaporated, then co-evaporated with toluene to give 52 mg (70%) of **3** as a solid. mp 165 dec; $[\alpha]^{25}_D$ −4.2 (c 1.4, H_2O); IR (KBr) 3450, 2940, 1630, 1520; ^{1}H NMR (500 MHz, D_2O) δ 3.81-3.90 (m, 2H), 4.06 (m, 1H), 4.22 (m, 1H), 4.39 (m, 1H); ^{13}C NMR (125 MHz) δ 57.0, 60.6, 65.4, 69.9, 169.5; Anal. Calcd for $C_5H_{11}NO_5$: C, 36.36; H, 6.71; N, 8.48 Found: C, 36.5; H, 6.4; N, 8.6.

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