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Total syntheses of (+)- and (−)-1-deoxynojirimycin (1,5-dideoxy-1,5-imino-D- and L-glucitol) and of (+)- and (−)-1-deoxyidonojirimycin (1,5-dideoxy-1,5-imino-D- and L-iditol) via furoisoxazoline-3-aldehydes

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Abstract

The isoxazoline obtained by 1,3-dipolar cycloaddition of 2,2-diethoxyacetonitrile *N*-oxide to furan was converted into enantiomerically pure (−)-(3a*S*,5*S*,6*S*,6a*R*)- and (+)-(3a*R*,5*R*,6*R*,6a*S*)-3a,5,6,6a-tetrahydro-5,6-isopropylidenedioxyfuro[2,3-*d*]isoxazole-3-carbaldehyde, (−)-**5** and (+)-**5**, respectively, through resolution with (1*S*,2*S*)-1,2-diphenylethylenediamine. The aldehydes **5** are required as latent 1,5-iminohexitol moieties in cross-aldolizations towards imino-*C*-disaccharides. In order to establish absolute configurations of **5**, and to probe the projected uses, (+)-**5** was converted into (+)-1-deoxynojirimycin [(+)-**1**, 3 steps, 58%] and into (−)-1,5-dideoxy-1,5-imino-L-iditol [(−)-**2**, 4 steps, 40%] adopting stereoselective routes. Similarly, (−)-1,5-dideoxy-1,5-imino-L-glucitol ((−)-**1**) and (+)-1,5-dideoxy-1,5-imino-D-iditol ((+)-**2**) were obtained with the same ease.

Keywords: Sugars with nitrogen replacing ring oxygen; 1,5-Dideoxy-1,5-iminohexitols; 1,3-Dipolar cycloaddition; Asymmetric synthesis; 1-Deoxynojirimycin; 1-Deoxy-*ido*-nojirimycin

1. Introduction

Pyranose and furanose analogues, where nitrogen replaces oxygen in the ring (iminosugars), have attracted considerable attention due to their ability to inhibit glycohydrolases [1], making these compounds potential therapeutic agents [2].

In many cases, however, several enzymes even of different classes are inhibited or insufficient activity is found. One approach to increase selectivity and, perhaps, potency is to combine the iminoglycitol monomer with the glycosyl part of the natural di- or oligosaccharide substrate. Such structures that have recently been referred to as imino-*C*-disaccharides could be iminopolyols linked to other sugar by a methylene or hydroxymethylene moiety [3].

As reported [4], we have used an aldol key step to join the iminopolyol-aldehyde to the three-position of respective hexoses for which oxa-bicycloheptenones (naked sugars) served as masked precursors. In an alternative way, latent iminopolyol aldehydes might be employed for the cross-aldolization and be trans-

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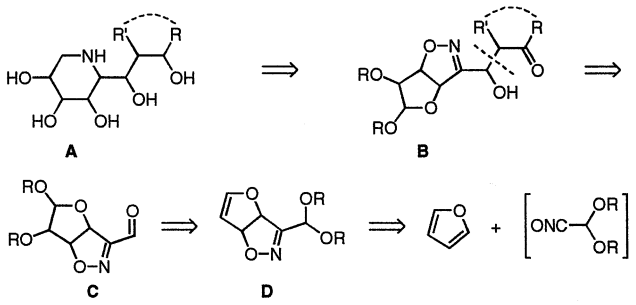
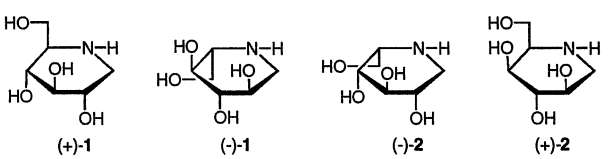


Scheme 1. Strategy to obtain imino-*C*-disaccharides from tetrahydroisoxazoline-3-carbaldehydes.

formed to the imino-glycitol at the disaccharide stage of **B**→**A** (Scheme 1). We describe here the preparation of such aldehyde building blocks, namely tetrahydrofuro-isoxazoline-3-carbaldehydes **C** in optically active forms. These aldehydes were obtained by nitrile oxide cycloaddition to furan, subsequent bis(hydroxylation) of the adduct **D**, and auxiliary-mediated separation of the racemic mixture. The disaccharide precursor **B** would have to be reduced and cyclized then, completing and extending related routes to amino-sugars, amino- and iminopolyols as proposed by Jäger et al. [5–8].

To assign the absolute configuration of the respective building blocks **C** and the derived hydroxypiperidines, **C** was converted to a series of 1,5-dideoxy-1,5-iminohexitols—deoxynojirimycin and the like—by the routes similar to those used for higher 1,5-iminopolyols [7,8]. This resulted in new and efficient syntheses of enantiomers of 1-deoxynojirimycin (**1**) (*gluco* series) and of the 5-epimers (**2**) (*ido* series) presented in this paper.



In 1967, Paulsen et al. [9] prepared the first iminosugars: (+)-1-deoxynojirimycin ((+)-**1**: 1,5-dideoxy-1,5-imino-D-glucitol) and (−)-1-deoxyidonojirimycin ((−)-**2**: 1,5-dideoxy-1,5-imino-L-iditol). Isolation of (+)-**1** from a *Morus* species was reported in 1976 [10]; it was later observed together with other iminosugars in various plants and in microorganisms [11,12].

A large number of syntheses of (+)-**1** use carbohydrates as starting materials [12,13]. Others start from *myo*-inositol [14], diethyl L-tartrate [15], or pyroglutamic acid [16]. Two asymmetric syntheses where diastereoselectivity is based on the use of a chiral auxiliary have been reported [17]. Still other syntheses rely on chemo-enzymatic processes [18,19]. Few de novo syntheses of iminosugars have been proposed thus far [6,8,12,17a,20–22]. From 1982, Jäger and Müller used cycloadditions of nitrile oxides to furan to engender isoxazolines such as (±)-**3**, that was then transformed into diol (±)-**4** and finally into several racemic 5-amino-5-deoxyfuranosides and aminopolyols [6]. In independent, related studies Vasella and Voeffray in 1982 succeeded in the synthesis of optically active nojirimycin, advancing the 1,3-dipolar cycloaddition of nitrones with an α-mannosyl auxiliary to furan. In both of these furan approaches, the enol ether double bond of the respective dihydrofuran cycloadducts was dioxygenated, with peracid/methanol [6] or with osmium tetroxide/*N*-methylmorpholine *N*-oxide [17a].

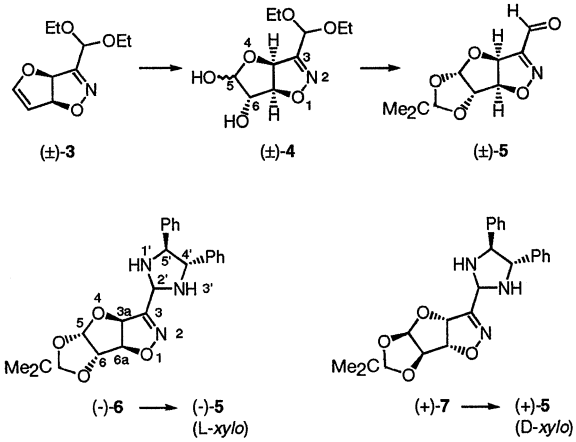
Dondoni et al. [22] have synthesized (−)-nojirimycin from L-serine. 1-Deoxy-L-idonojirimycin ((−)-**2**) has been prepared, first by Paulsen et al. [9] and then by Fowler et al. [23] and Sasinková et al. [13l]. Several syntheses of 5-amino-5-deoxy-L-idose derivatives have been published, all starting from D-glucose [24].

As we required protected forms of latent iminopolyols-aldehydes **C** as building blocks for convergent syntheses of imino-*C*-disaccharides, we looked for a method to synthesize and to separate the racemic mixture of C to obtain both enantiomerically pure aldehydes. As detailed below, this proved possible by applying the resolution technique of Alexakis and Mangeney [25]. In a complementary approach, optically active nitrileoxides have been used and the resulting mixture of diastereomers were separated later in the synthesis [7,8,26].

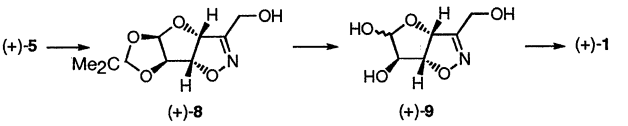
2. Results and discussion

The isoxazoline (±)-**3** was obtained from the reaction between 2-nitroethanal diethyl ac-

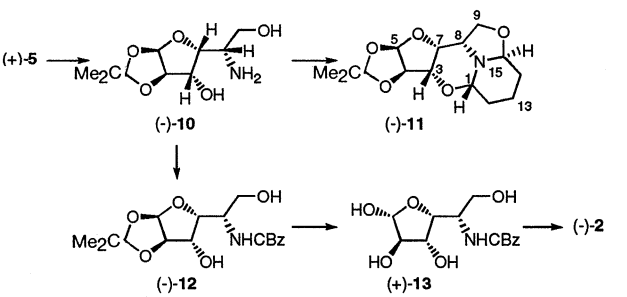
etal and furan (75%) [6,27]. Bis(hydroxylation) with *N*-methylmorpholine *N*-oxide and a catalytic amount of osmium tetroxide [7,8,17a] gave the 6-exo isomers (±)-**4** (88%) as a 3:1 mixture of anomers. Diol protection and transacetalation of (±)-**4** (with concentrated H_2SO_4 and acetone) provided the racemic aldehyde (±)-**5** (92%). Its reaction with (−)-(1*S*,2*S*)-diphenylethanediamine [25] in ether gave a mixture of diastereomeric imidazolidines (−)-**6** (40%) and (+)-**7** (45%) which were readily separated, first by crystallization to yield (+)-**7**, and then by chromatographic purification of the residue to give (−)-**6**. The diastereomeric purity of both (−)-**6** and (+)-**7** was determined by HPLC to exceed 98%. The aldehydes (−)-**5** (L-*xylo*) and (+)-**5** (D-*xylo*) were liberated by selective acidic hydrolysis (1 N H_2SO_4, Et_2O, 25 °C) with 95% yield and recovery of (−)-(1*S*,2*S*)-diphenylethanediamine (97%). Enantiomeric ratios of (−)-**5** and (+)-**5** are considered to be greater than 99:1, as determined by HPLC (Chiralcel OD–H, 1:1 *i*-PrOH/hexane). The absolute configuration of (−)-**5** (L-*xylo*) and (+)-**5** (D-*xylo*) was established by chemical correlation, i.e. by conversion of (+)-**5** into 1-deoxynojirimycin [(+)-**1**] and of (−)-**5** into (−)-**1**. (For other examples of optically pure isoxazolines, see [7,8,28]).



Reduction of the isoxazoline-3-carbaldehyde (+)-**5** with sodium borohydride in methanol afforded the alcohol (+)-**8** (90%). Deprotection (8:1 $CF_3COOH–H_2O$, 4 °C) then gave a 3.4:1 mixture of anomers (+)-**9** (100%). Hydrogenation (Pd/C, MeOH, 25 °C) provided (+)-**1** in 65% yield. The same operation starting with (−)-**5** furnished (−)-**1**. The highly stereoselective course of these C=N hydrogenations extends results obtained with higher homologues (3-substituted side-chains) [8].

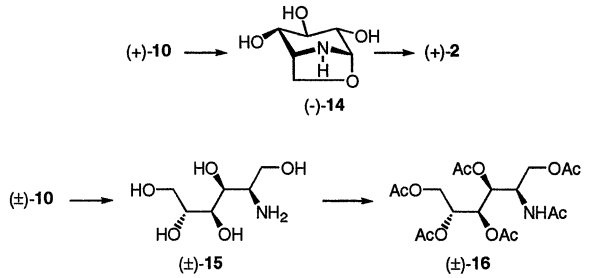


Reduction of (+)-**5** with lithium aluminium hydride [6] in ether gave the aminodiol (−)-**10** (66%). Its relative configuration was derived from ^{1}H NMR data ($J_{H,H}$, NOEs) of the pentacyclic compound (−)-**11** obtained by reaction of (−)-**10** with one equivalent of glutaraldehyde (MeOH, 25 °C). The relative configuration of (−)-**11** was given by 2D NOESY ^{1}H NMR (NOEs between signals assigned to protons 1-H, 3-H and 8-H) and by coupling constants between vicinal proton pairs. Here, the hydride delivery to the C=N bond of the isoxazoline moiety occurred from the least-hindered face of the tricyclic system as anticipated [5,6]. The opposite diastereoselectivity observed for the catalytic hydrogenation (+)-**9**→(+)-**1** suggests that the O–N bond is hydrogenolyzed first and that the 3-hydroxy group of the intermediate imine plays a lateral control on its hydrogenation.



Protection of aminodiol (−)-**10** by a modification of Oku's procedure [29], gave the carbamate (−)-**12** (81%). Deprotection (8:1 $CF_3COOH–H_2O$, 4 °C) then led to the furanose (+)-**13** (81%), the hydrogenation of which (Pd/C, MeOH, 25 °C) provided the imino-L-iditol (−)-**2** in 95% yield. The same operations carried out with (−)-**5** led to its enantiomer (+)-**2** (D-*ido*).

A more straightforward route to (+)-**2** was achieved from (+)-**10** via the formation of the 1,6-anhydro-D-*ido*-piperidinose (−)-**14** (9:1 CF_3COOH–H_2O, 25 °C; then Dowex 1 (OH^- form, 93%)) [30], the hydrogenation of which (Pd/C, H_2O, 25 °C) provided (+)-**2** in 77% yield. Treatment of the aminodiol (±)-**10** with trifluoroacetic acid (90%), followed by triethylsilane in trifluoroacetic acid provided racemic 2-amino-2-deoxy-iditol (±)-**15** [31] characterized as the hexa-acetyl derivative (±)-**16** (75%, 2 steps).



3. Conclusion

Enantiomerically pure tetrahydrofurano-isoxazoline-3-carbaldehydes (+)- and (−)-**5** are now readily available for use as building blocks with latent 1,5-iminohexitol moieties in cross-aldolizations towards imino-*C*-disaccharides. The absolute configuration of **5**, and the stereochemical course of the reductive cyclization have been established by correlation of the resulting 1,5-dideoxy-1,5-iminohexitols **1** and **2**, respectively, with natural (+)-deoxynojirimycin and the known iminoiditols. This also represents a new, stereodivergent approach to the syntheses of 1-deoxynojirimycin [(+)-**1**] and 1-deoxy-L-idonojirimycin ((−)-**2**), and of their enantiomers, (−)-**1** and (+)-**2**. Including the resolution step, (+)-**1** [and (−)-**1**] was prepared in 8 steps and 15% overall yield starting from furan and 2-nitroethanal diethylacetal taking advantage of an efficient separation of the racemic mixture of furoisoxazoline adducts after bis(hydroxylation). Iminosugar (−)-**2** [and (+)-**2**] was obtained in eight steps and 11% overall yield. As expected, this synthesis of (+)-**1** cannot compete with the most efficient one reported by Kinast and Schedel [32] which converts D-glucose into (+)-**1** in four steps with an overall yield of 60% (including an enzymatic oxidation step). However, the present work realizes the shortest synthesis of (+)-**1** starting from achiral, inexpensive starting materials; it also give the (so far) shortest approach to the synthesis of L-deoxynojirimycin (−)-**1**.

4. Experimental

General methods.—See Ref. [33].

*(±)-(3a*RS,*6*RS,*6a*SR*)-3-(Diethoxymethyl)-3a,5,6,6a-tetrahydrofuro[2,3-*d*]isoxazole-5,6-diol [(±)-**4**].*—*N*-methylmorpholine *N*-oxide (6.35 g, 47 mmol) and a 0.1 M solution of OsO_4 (1 mL) were added successively to a stirred solution of (±)-3-(diethoxymethyl)-3a,6a-dihydrofuro[2,3-*d*]isoxazole ((±)-**3** [6a], 5.0 g 23.44 mmol) in 4:1 acetone–water (75 mL). After stirring at 60 °C for 3 h, the solvent was evaporated under reduced pressure and the residue extracted with EtOAc (80 mL, three times). The combined extracts were washed with 1 N HCl saturated with NaCl (60 mL, twice), then with a saturated solution of $NaHCO_3$/NaCl (60 mL). After drying ($MgSO_4$), the solvent was evaporated under reduced pressure and the residue recrystallized from 1:1 ether–light petroleum to give 5.10 g (88%) of (±)-**4** as a 3:1 mixture of anomers, colorless crystals, mp 68–69 °C. UV (MeCN): λ 210 nm ($\varepsilon = 3900$); IR (KBr): ν 3390, 2975, 2900, 1620, 1480, 1450, 1340, 1215, 1180, 1065, 950, 860, 795 cm^{-1}. ^1H NMR (CD_3OD, 400 MHz) of the major anomer: δ 5.65 (d, ^3J 7.5 Hz, 3a-H), 5.40 (s, C*H*$(OEt)_2$), 5.36 (s, 5-H), 4.88 (s, 2 OH), 4.84 (d, ^3J 7.5 Hz, 6a-H), 4.27 (s, H-6), 3.86–3.60 (m, 4 H, 2 OCH_2Me), 1.30–1.24 (m, 6 H, 2 Me); ^{13}C NMR (CD_3OD, 100.61 MHz) of the major anomer: δ 158.4 (s, C-3), 105.1 (d, ^1J(C,H) 172 Hz, C-5), 97.9 (d, ^1J(C,H) 163 Hz, *C*H$(OEt)_2$), 90.2 (d, ^1J(C,H) 163 Hz, C-6a), 88.3 (d, ^1J(C,H) 168 Hz, C-3a), 81.0 (d, ^1J(C,H) 154 Hz, C-6), 64.0 and 63.2 (2 t, ^1J(C,H) 143 Hz, 2 O*C*H_2Me), 15.3 (q, ^1J(C,H) 126 Hz, 2 Me). CIMS (NH_3): m/z 265 ($[M + NH_4]^+$, 3), 248 ($[M + H]^+$, 7), 202 (100), 173 (61), 156 (4), 126 (24), 97 (18), 75 (5). Anal. Calcd for $C_{10}H_{17}NO_6$ (247.24): C, 48.58; H, 6.93; N, 5.67. Found: C, 48.73; H, 6.82; N, 5.59.

*(±) - (3a*RS,*5*RS,*6*RS,*6a*SR*) - 3a,5,6,6a-Tetrahydro-5,6-isopropylidenedioxyfuro[2,3-*d*]-isoxazole-3-carbaldehyde [(±)-**5**].*—A mixture of (±)-**4** (5.15 g, 20.83 mmol), concentrated H_2SO_4 (5.9 mL), and Sikkon (55 g, Fluka) in anhyd acetone (180 mL) was stirred at 25 °C for 3 h. After neutralization through portionwise addition of Na_2CO_3 (50 g), the solution was filtered and the solvent evaporated under reduced pressure. Purification by column chromatography on silica gel (400 g, 5:1 light petroleum–EtOAc) and then distillation under reduced pressure (0.1 kPa, 140 °C) afforded 4.08 g (92%) of (±)-**5** as a colorless oil. UV (MeCN): λ 243 nm (ε = 7800); IR (film): ν 2990, 2940, 2860, 1695, 1575, 1375, 1215, 1160, 1080, 1030, 760 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 9.95 (s, CHO), 5.85 (d, ^3J 3.5 Hz, H-5), 5.80 (d, ^3J 6.4 Hz, H-3a), 5.17 (d, ^3J 6.4 Hz, H-6a), 4.90 (d, ^3J 3.5 Hz, H-6), 1.52 and 1.38 (2 s, Me_2C); ^{13}C NMR ($CDCl_3$, 100.61 MHz): δ 183.9 (d, ^1J(C,H) 190 Hz, CHO), 158.6 (s, C-3), 114.2 (s, CMe_2), 106.2 (d, ^1J(C,H) 185 Hz, C-5), 90.6 (d, ^1J(C,H) 165 Hz, C-6), 83.8 (d, ^1J(C,H) 162 Hz, C-6a), 82.5 (d, ^1J(C,H) 166 Hz, C-3a), 27.7 and 26.9 (2 q, ^1J(C,H) 127 Hz, Me_2C); CIMS (NH_3): *m/z* 231 ($[M + NH_4]^+$, 100), 198 (87), 100 (4), 85 (20). Anal. Calcd for $C_9H_{11}NO_5$ (213.19): C, 50.71; H, 5.20; N, 6.57. Found: C, 50.71; H, 5.11; N, 6.43.

*Mixture of (−)-(3a*S,*4′*S,*5*S,*5′*S,*6*S,*6a*R*)-3-(4′,5′ - diphenylimidazolid - 2′ - yl) - 3a,5,6,6a-tetrahydro-5,6-isopropylidenedioxyfuro[2,3-*d*]-isoxazole [(−) - **6**] and (+) - (3a*R,*4′*S,*5*R,*5′*S,*6*R,*6a*S*) - 3 - (4′,5′ - diphenylimidazolid - 2′ - yl) - 3a,5,6,6a - tetrahydro - 5,6 - isopropylidenedioxyfuro[2,3-*d*]isoxazole [(+)-**7**].*—A mixture of aldehyde (±)-**5** (1.78 g, 8.35 mmol) and 1*S*,2*S*-(−)-diphenylethanediamine (1.78 g, 8.38 mmol) in Et_2O (30 mL) was stirred at 25 °C for 10 h under Ar in the presence of 4 Å molecular sieves (2 g). The solution was filtered through Celite, evaporated to dryness, and the residue crystallized in Et_2O (200 mL). Filtration gave (+)-**7** (1.01 g, 30%). The mother liquor was concentrated and purified by column chromatography on silica gel (1:3 AcOEt–light petroleum, 1% NEt_3) to yield (−)-**6** (1.35 g, 40%) and additional (+)-**7** (0.50 g, total 45%).

*Data for (−)-**6**.*—Colorless oil, $[\alpha]^{25}_{589}$ −106°, $[\alpha]^{25}_{577}$ −112°, $[\alpha]^{25}_{546}$ −127°, $[\alpha]^{25}_{435}$ −221°, $[\alpha]^{25}_{405}$ −269° (*c* 1.0, $CHCl_3$); UV (MeCN): λ 205 nm (ε = 20000); IR (film): ν 3355, 3030, 2990, 2935, 1495, 1455, 1420, 1385, 1375, 1225, 1165, 1085 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 7.32–7.22 (m, 10 H Ar), 5.95 (d, ^3J 6.5 Hz, H-3a), 5.91 (d, ^3J 3.6 Hz, H-5), 5.41 (s, H-2′), 5.08 (d, ^3J 6.5 Hz, H-6a), 4.87 (d, ^3J 3.6 Hz, H-6), 4.23 (s, H-4′, H-5′), 2.90–2.60 (br. s, 2 NH), 1.56 and 1.40 (2 s, Me_2C); ^{13}C NMR ($CDCl_3$, 100.61 MHz): δ 159.4 (s, C-3), 140.0, 139.8, 128.6, 128.4, 127.7, 127.5, 127.2, 127.0 (12 C Ar), 113.8 (s, CMe_2), 106.3 (d, ^1J(C,H) 184 Hz, C-5), 87.3 (d, ^1J(C,H) 163 Hz, C-6), 86.7 (d, ^1J(C,H) 164 Hz, C-3a), 84.8 (d, ^1J(C,H) 161 Hz, C-6a), 70.4 (d, ^1J(C,H) 149 Hz, C-4′ or C-5′), 69.0 (d, ^1J(C,H) 153 Hz, C-2′), 68.5 (d, ^1J(C,H) 141 Hz, C-5′ or C-4′), 27.8 and 26.9 (2 q, ^1J(C,H) 128 Hz, Me_2C). CIMS (NH_3): *m/z* 408 ($[M + H]^+$, 1), 377 (1), 302 (9), 283 (2), 244 (31), 215 (4), 165 (7), 106 (51), 83 (100). Anal. Calcd for $C_{23}H_{25}N_3O_4$ (407.47): C, 67.80; H, 6.18; N, 10.31. Found: C, 67.74; H, 6.25; N, 10.35.

*Data for (+)-**7**.*—Colorless solid, mp 141–142 °C. $[\alpha]^{25}_{589}$ +48°, $[\alpha]^{25}_{577}$ +49°, $[\alpha]^{25}_{546}$ +56°, $[\alpha]^{25}_{435}$ +92°, $[\alpha]^{25}_{405}$ +108° (*c* 1.0, $CHCl_3$); UV (MeCN): λ 206 nm (ε = 21000); IR (KBr): ν 3345, 3030, 2990, 2940, 1495, 1455, 1385, 1375, 1225, 1160, 1080, 995 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 7.31–7.25 (m, 10 H Ar), 5.93 (d, ^3J 3.5 Hz, H-5), 5.90 (d, ^3J 6.5 Hz, H-3a), 5.42 (s, H-2′), 5.06 (d, ^3J 6.5, H-6a), 4.86 (d, ^3J 3.5, H-6), 4.23 (s, H-4′, H-5′), 2.90–2.60 (br. s, 2 NH), 1.56 and 1.41 (2 s, Me_2C); ^{13}C NMR ($CDCl_3$, 100.61 MHz): δ 159.2 (s, C-3), 140.1, 139.4, 128.5, 128.4, 127.6, 127.0, 126.9 (12 C Ar), 113.8 (s, CMe_2), 106.3 (d, ^1J(C,H) 184 Hz, C-5), 87.2 and 87.1 (2 d, ^1J(C,H) 163 Hz, C-3a, C-6a), 84.8 (d, ^1J(C,H) 161 Hz, C-6), 70.6 and 69.1 (2 d, ^1J(C,H) 149 Hz, C-4′, C-5′), 69.6 (d, ^1J(C,H) 153 Hz, C-2′), 27.8 and 26.9 (2 q, ^1J(C,H) 127 Hz, Me_2C); CIMS (NH_3): *m/z* 408 ($[M + H]^+$, 2), 407 ($M^{+\bullet}$, 2), 302 (8), 259 (11), 219 (20), 153 (8), 106 (45), 83 (100). Anal. Calcd for $C_{23}H_{25}N_3O_4$ (407.47): C, 67.80; H, 6.18; N, 10.31. Found: C, 67.89; H, 6.14; N, 10.38.

*(−) - (3a*S*,5*S*,6*S*,6a*R*) - 3a,5,6,6a - Tetrahydro - 5,6 - isopropylidenedioxyfuro[2,3 - d]isoxazole-3-carbaldehyde [(−)-**5**].*—A mixture of (−)-**6** (1.0 g, 2.45 mmol), Et_2O (60 mL) and 1 N H_2SO_4 (25 mL) was stirred vigorously at 25 °C for 30 min. The aqueous phase was extracted with Et_2O (20 mL, twice). The combined organic phases were dried ($MgSO_4$) and the solvent was evaporated under reduced pressure. The residue was distilled (0.1 kPa, bp 140 °C) giving 496 mg (95%) of (−)-**5** as a colorless oil that solidified at −20 °C. The aqueous phase was made basic with 1 N NaOH and extracted with CH_2Cl_2 (20 mL, five times). The combined organic extracts were dried ($MgSO_4$) and the solvent was evaporated under reduced pressure giving 505 mg (97%) of (−)-(1*S*,2*S*)-1,2-diphenylethanediamine. (−)-**5**: $[\alpha]_{589}^{25}$ −208°, $[\alpha]_{577}^{25}$ −217°, $[\alpha]_{546}^{25}$ −269°, $[\alpha]_{435}^{25}$ −440°, $[\alpha]_{405}^{25}$ −480° (*c* 1.0, $CHCl_3$).

*(+) - (3a*R*,5*R*,6*R*,6a*S*) - 3a,5,6,6a - Tetrahydro - 5,6 - isopropylidenedioxyfuro[2,3 - d]isoxazole-3-carbaldehyde [(+)-**5**].*—Same procedure as for the preparation of (−)-**5**, starting with (+)-**7**. $[\alpha]_{589}^{25}$ +205°, $[\alpha]_{577}^{25}$ +214°, $[\alpha]_{546}^{25}$ +246°, $[\alpha]_{435}^{25}$ +435°, $[\alpha]_{405}^{25}$ +477° (*c* 1.0, $CHCl_3$). Other spectral data were identical to those of (±)-**5**.

*(+) - (3a*R*,5*R*,6*R*,6a*S*) - 3a,5,6,6a - Tetrahydro - 5,6 - isopropylidenedioxyfuro[2,3 - d]isoxazole-3-methanol [(+)-**8**].*—$NaBH_4$ (38 mg, 1 mmol) was added portionwise to a stirred solution of (+)-**5** (102 mg, 0.48 mmol) in MeOH (1.5 mL) cooled to 5 °C. After the addition of H_2O (1.0 mL), the mixture was extracted with CH_2Cl_2 (3 × 3 mL). The combined organic extracts were dried ($MgSO_4$) and the solvent was evaporated under reduced pressure. The residue was recrystallized from 1:3 EtOAc–light petroleum, giving 93 mg (90%) of (+)-**8** as white crystals, mp 94–96 °C. $[\alpha]_{589}^{25}$ +104°, $[\alpha]_{577}^{25}$ +109°, $[\alpha]_{546}^{25}$ +123°, $[\alpha]_{435}^{25}$ +208°, $[\alpha]_{405}^{25}$ +250° (*c* 1.0, $CHCl_3$); UV (MeCN): λ 209 nm ($\varepsilon = 3200$); IR (KBr): *v* 3465, 2990, 1460, 1385, 1230, 1165, 1115, 1080, 1040, 985 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 5.85 (d, ^3J 3.5 Hz, H-4a), 5.68 (d, ^3J 6.5 Hz, H-3a), 5.00 (d, ^3J 6.5 Hz, H-6a), 4.81 (d, ^3J 3.5 Hz, H-6), 4.55 (m, 2 H, CH_2OH), 2.04 (t, ^3J 6.1 Hz, OH), 1.53 and 1.39 (2 s, Me_2C); ^{13}C NMR ($CDCl_3$, 100.61 MHz): δ 157.9 (s, C-3), 114.0 (s, CMe_2), 106.1 (d, ^1J(C,H) 184 Hz, C-5), 86.9 and 86.5 (2 d, ^1J(C,H) 163 Hz, C-3a, C-6a), 84.8 (d, ^1J(C,H) 168 Hz, C-6), 56.7 (t, ^1J(C,H) 146 Hz, CH_2-C(3)), 27.8 and 26.9 (2 q, ^1J(C,H) 127 Hz, Me_2C); CIMS (NH_3): *m/z* 216 ($[M+H]^+$, 31), 200 (83), 170 (9), 158 (66), 128 (14), 112 (35), 100 (100), 85 (93). Anal. Calcd for $C_9H_{13}NO_5$ (215.2): C, 50.23; H, 6.09; N, 6.51. Found: C, 50.25; H, 6.00; N, 6.56.

*(−) - (3a*S*,5*S*,6*S*,6a*R*) - 3a,5,6,6a - Tetrahydro - 5,6 - isopropylidenedioxyfuro[2,3 - d]isoxazole-3-methanol [(−)-**8**].*—Same procedure as for the preparation of (+)-**8**, starting from (−)-**5**. $[\alpha]_{589}^{25}$ −104°, $[\alpha]_{577}^{25}$ −109°, $[\alpha]_{546}^{25}$ −124°, $[\alpha]_{435}^{25}$ −209°, $[\alpha]_{405}^{25}$ −251° (*c* 1.0, $CHCl_3$). Anal. Calcd. for $C_9H_{13}NO_5$ (215.2): C, 50.23; H, 6.09; N, 6.51. Found: C, 50.30; H, 6.07; N, 6.59.

*(+)-(3a*R*,5*R*&5*S*,6*R*,6a*S*)-3a,5,6,6a-Tetrahydro - 5,6 - dihydroxyfuro[2,3 - d]isoxazole - 3-methanol [(+)-**9**].*—A solution of (+)-**8** (175 mg, 0.813 mmol) in 8:1 CF_3COOH–H_2O (10 mL) was stirred at 4 °C for 15 h. The solvent was evaporated under reduced pressure and the residue purified by column chromatography on silica gel (15 g, EtOAc) to give 142 mg (100%) of (+)-**9** as a 3.4:1 mixture of anomers, colorless oil. $[\alpha]_{589}^{25}$ +43°, $[\alpha]_{577}^{25}$ +46°, $[\alpha]_{546}^{25}$ +51°, $[\alpha]_{435}^{25}$ +80°, $[\alpha]_{405}^{25}$ +91° (*c* 1.0, MeOH); UV (MeCN): λ 212 nm ($\varepsilon =$ 1800); IR (film): *v* 3350, 2930, 1420, 1035, 945 cm^{-1}; ^1H NMR (CD_3OD, 400 MHz) of the major anomer: δ 5.70 (d, ^3J 7.7 Hz, H-3a), 5.32 (s, H-5), 4.79 (d, ^3J 7.7 Hz, H-6a), 4.44 (s, 2 H, CH_2OH), 4.21 (s, H-6). ^{13}C NMR (CD_3OD, 100.61 MHz): δ 160.5 (s, C-3), 105.1 (d, ^1J(C,H) 173 Hz, C-5), 89.5 (d, ^1J(C,H) 163 Hz, C-6a), 88.4 (d, ^1J(C,H) 163 Hz, C-3a), 81.4 (d, ^1J(C,H) 154 Hz, C-6), 56.4 (t, ^1J(C,H) 145 Hz, CH_2–O); CIMS (NH_3): *m/z* 178 ($[M+3]^+$, 100), 165 (23), 152 (10), 129 (5), 95 (23). Anal. Calcd for $C_6H_9NO_5$ (175.14): C, 41.15; H, 5.18; N, 8.00. Found: C, 41.14; H, 5.24; N, 7.96.

*(−)-(3a*S*,5*S*&5*R*,6*S*,6a*R*)-3a,5,6,6a-Tetrahydro - 5,6 - dihydroxyfuro[2,3 - d]isoxazole - 3-methanol [(−)-**9**].*—Same procedure as for the preparation of (+)-**9**, starting from (−)-**8**. $[\alpha]_{589}^{25}$ −45°, $[\alpha]_{577}^{25}$ −46°, $[\alpha]_{546}^{25}$ −51°, $[\alpha]_{435}^{25}$ −79°, $[\alpha]_{405}^{25}$ −90° (*c* 0.5, MeOH).

*(+)-1-Deoxynojirimycin [1,5-dideoxy-1,5-imino-D-glucitol; (+)-**1**].*—A mixture of (+)-**9** (150 mg, 0.86 mmol), MeOH (5 mL) and 10% Pd/C (10 mg) was degassed, pressurized with H_2 (0.1 MPa), and shaken at 25 °C for 15 h. After filtration (Celite) the solvent was evaporated under reduced pressure. The residue was purified by column chromatography on Dowex 1 (10 g, OH^- form, eluent H_2O) yielding 91 mg (65%) of (+)-**1** as a colorless solid, mp 194–195 °C. $[\alpha]_{589}^{25}$ +44°, $[\alpha]_{577}^{25}$ +50°, $[\alpha]_{546}^{25}$ +55°, $[\alpha]_{435}^{25}$ +90°, $[\alpha]_{405}^{25}$ +107° (*c* 0.2, H_2O). Anal. Calcd for $C_6H_{13}NO_4$ (163.17): C, 44.17; H, 8.03; N, 8,58. Found: C, 44.40; H, 7.99. (Lit. [10b] mp 196 °C, $[\alpha]_{589}^{25}$ +47°; H_2O).

*(−)-1,5-Dideoxy-1,5-imino-L-glucitol [(−)-**1**].*—This compound was prepared from (−)-**9** following the procedure used for the preparation of (+)-**1**. Yield: 65% mp 193–195 °C. $[\alpha]_{589}^{25}$ −46°, $[\alpha]_{577}^{25}$ −44°, $[\alpha]_{546}^{25}$ −40°, $[\alpha]_{435}^{25}$ −81°, $[\alpha]_{405}^{25}$ −96° (*c* 0.3, H_2O). Anal. Calcd for $C_6H_{13}NO_4$ (163.17): C, 44.17; H, 8.03; N, 8.58. Found: C, 44.26; H, 8.04; N, 8.52.

*(−)-5-Amino-5-deoxy-1,2-O-isopropylidene β-L-idofuranose [(−)-**10**].*—$LiAlH_4$ (150 mg, 3.9 mmol) was added portionwise to a stirred solution of (+)-**5** (277 mg, 1.3 mmol) in anhydrous Et_2O (5 mL). After stirring at 25 °C for 4 days, H_2O (0.15 mL), 20% aq NaOH (0.10 mL) and then H_2O (0.3 mL) were added. After stirring at 25 °C for 2 h, $MgSO_4$ (1.5 g) was added and the mixture was stirred at 25 °C for another 2 h. Filtration (Celite) and solvent evaporation under reduced pressure yielded 188 mg (66%) of (−)-**10** as a colorless solid, mp 178–179 °C. $[\alpha]_{589}^{25}$ −4°, $[\alpha]_{577}^{25}$ −5°, $[\alpha]_{546}^{25}$ −6°, $[\alpha]_{435}^{25}$ −12°, $[\alpha]_{405}^{25}$ −15° (*c* 1.1, MeOH); UV (MeCN): λ 200 nm ($\varepsilon = 500$); IR (KBr): ν 3360, 2985, 2935, 1375, 1215, 1165, 1070, 1015 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 5.97 (d, ^3J 3.6 Hz, H-1), 4.49 (dd, ^3J 3.6, 0.5 Hz, H-2), 4.32 (dd, ^3J 2.9, 0.5 Hz, H-3), 4.18 (dd, ^3J 2.9, 1.7 Hz, H-4), 3.74 (dd, ^2J 11.0, ^3J 5.3 Hz, H-6), 3.66 (dd, ^2J 11.0, ^3J 5.3 Hz, H′-6), 3.28 (ddd, ^3J 5.3, 5.3, 1.7 Hz, H-5), 1.49 and 1.32 (2 s, Me_2C); ^{13}C NMR ($CDCl_3$, 100.61 MHz): δ 111.5 (s, CMe_2), 105.1 (d, ^1J(C,H) 183 Hz, C-1), 85.4 (d, ^1J(C,H) 161 Hz, C-2), 78.2 (d, ^1J(C,H) 154 Hz, C-4), 77.5 (d, ^1J(C,H) 157 Hz, C-3), 66.5 (t, ^1J(C,H) 142 Hz, C-6), 52.5 (d, ^1J(C,H) 134 Hz, C-5), 26.7 and 26.0 (2 q, ^1J(C,H) 126 Hz, Me_2C); CIMS (NH_4): *m/z* 220 ($[M+H]^+$, 20), 202 (7), 188 (50), 162 (7), 129 (33), 113 (36), 100 (100), 85 (87). Anal. Calcd for $C_9H_{17}NO_5$ (219.2): C, 49.31; H, 7.82; N, 6.39. Found: C, 49.38; H, 7.80; N, 6.47. (Lit. [29] mp 183–185 °C, $[\alpha]_{589}^{25}$ −3.3° (*c* 1, MeOH)).

*(+)-5-Amino-5-deoxy-1,2-O-isopropylidene β-D-idofuranose [(+)-**10**].*—Prepared as (−)-**10**, starting from (−)-**5**. $[\alpha]_{589}^{25}$ +4°, $[\alpha]_{577}^{25}$ +5°, $[\alpha]_{546}^{25}$ +6°, $[\alpha]_{435}^{25}$ +12°, $[\alpha]_{405}^{25}$ +15° (*c* 0.9, MeOH). Anal. Calcd. for $C_9H_{17}NO_5$ (219.2): C, 49.31; H, 7.82; N, 6.39. Found: C, 49.29; H, 7.68; N, 6.33.

*(−)-(1S,3S,4R,5R,7R,8S,11S)-4,5-Isopropylidenedioxy-2,6,10-trioxa-15-azatetracyclo[9.3.1.0^{3,7}.0^{8,15}]pentadecane [(−)-**11**].*—A mixture of (−)-**10** (30 mg, 0.137 mmol), MeOH (0.3 mL) and glutaraldehyde (24 μL, 0.137 mmol) was stirred at 25 °C for 12 h. The solvent was evaporated under reduced pressure and the residue purified by column chromatography on silica gel (4 g, 2:1 CH_2Cl_2–EtOAc) giving 26.4 mg (68%) of (−)-**11** as a colorless oil. $[\alpha]_{589}^{25}$ −0.8°, $[\alpha]_{577}^{25}$ 0°, $[\alpha]_{546}^{25}$ +0.2°, $[\alpha]_{435}^{25}$ −1.3°, $[\alpha]_{405}^{25}$ −1.7° (*c* 0.25, $CHCl_3$). IR (film): ν 2935, 1460, 1375, 1295, 1265, 1200, 1165, 1075, 1015, 965 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 5.93 (d, ^3J 3.8 Hz, H-5), 4.72 (dd, ^3J 3.3, 2.0 Hz, H-11), 4.57 (d, ^3J 3.8 Hz, H-4), 4.54 (dd, ^3J 10.3, 2.7 Hz, H-8), 4.26 (dd, ^2J 8.0, ^3J 2.7 Hz, H-9), 4.17 (d, ^3J 2.0 Hz, H-3), 4.09 (dd, ^2J 8.0, ^3J 8.0 Hz, H′-9), 3.98 (dd, ^3J 4.0, 2.0 Hz, H-1), 3.81–3.77 (m, H-8), 2.00–1.97 (m, 1 H), 1.82–1.68 (m, 3 H), 1.64–1.54 (m, 1 H), 1.30–1.21 (m, 1 H, H-12, H-13, H-14), 1.48 and 1.32 (2 s, Me_2C) (assignments confirmed by a NOESY spectrum). ^{13}C NMR ($CDCl_3$, 100.61 MHz): δ 111.5 (s, Me_2C), 104.1 (d, ^1J(C,H) 183 Hz, C-5), 86.0, 84.0 and 83.9 (3d, ^1J(C,H) 160 Hz, C-1, C-7, C-11), 79.8 (d, ^1J(C,H) 152 Hz, C-4), 72.2 (d, ^1J(C,H) 148 Hz, C-8), 65.5 (t, ^1J(C,H) 150 Hz, C-9), 54.1 (d, ^1J(C,H) 141 Hz, C-8), 29.8 (t, ^1J(C,H) 131 Hz, C-12 or C-14), 29.0 (t, ^1J(C,H) 127 Hz, C-13), 26.4 and 26.0 (2 q, ^1J(C,H) 127 Hz, Me_2C), 18.5 (t, ^1J(C,H) 130 Hz, C-14 or C-12). CIMS (NH_3): *m/z* 285 ($[M+2]^+$, 46), 284 ($[M+H]^+$, 100), 282 (11), 268 (9), 225 (6), 154 (2), 113 (8).

Product decomposes at room temperature and no elemental analysis could be made.

*(−)-5-Benzyloxycarbonylamino-5-deoxy-1,2-*O*-isopropylidene-β-*L*-idofuranose [(−)-**12**].*—To a solution of aminodiol (−)-**10** (60 mg, 0.274 mmol) in aq. EtOH 50% (4.5 mL) was added $NaHCO_3$ (41 mg, 0.49 mmol, 1.8 equiv) and CbzCl (45 μL, 0.328 mmol, 1.2 equiv) and the reaction mixture was stirred at 25 °C for 1 h 30 min. After addition of AcOEt (10 mL) the reaction mixture was extracted twice with $NaHCO_3$ (4 mL). The organic phase was dried over $MgSO_4$, and the product purified by column chromatography on silica gel (2:1 AcOEt–light petroleum), yielding 78.4 mg (81%) of colorless crystals (mp 138–139 °C). $[\alpha]_{589}^{25}$ −24°, $[\alpha]_{577}^{25}$ −25°, $[\alpha]_{546}^{25}$ −29°, $[\alpha]_{435}^{25}$ −50°, $[\alpha]_{405}^{25}$ −59° (*c* 0.45, MeOH); UV (MeCN): λ 257 nm (ε = 585), 251 (545), 207 (7900); IR (film): *ν* 3355, 3065, 2990, 1700, 1530, 1455, 1375, 1215, 1165, 1075, 1015, 860, 740 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 7.39–7.30 (m, 5 H Ar), 5.93 (d, ^3J 3.7 Hz, H-1), 5.44 (d, ^3J 7.5 Hz, H–N), 5.12 (AB, J_{AB} 12.2 Hz, 1 H, $-OCH_2-$), 5.07 (AB, J_{AB} 12.2 Hz, 1 H, $-OCH_2-$), 4.53 (d, ^3J 3.7 Hz, H-2), 4.26 (d, ^3J 2.5 Hz, H-3), 4.19 (dd, ^3J 6.7, 2.5 Hz, H-4), 4.09–4.04 (m, H-5), 3.86 (dd, ^2J 11.1, ^3J 3.9, H-6a), 3.68 (dd, ^2J 11.1, ^3J 5.9, H-6b), 2.97 (br. s, 2-OH), 1.49 and 1.31 (2 s, Me_2C); ^{13}C NMR ($CDCl_3$, 100.61 MHz): δ 157.1 (s, CO), 136.0 (s, C Ar), 128.5, 128.2 and 128.0 (3 d, ^1J(C,H) 160, 160, 158 Hz, 5 C Ar), 111.6 (s, CMe_2), 104.4 (d, ^1J(C,H) 184 Hz, C-1), 85.2 (d, ^1J(C,H) 162 Hz, C-2), 80.1 (d, ^1J(C,H) 147 Hz, C-4), 74.8 (d, ^1J(C,H) 151 Hz, C-3), 67.2 (t, ^1J(C,H) 147 Hz, $-OCH_2Ph$), 62.6 (t, ^1J(C,H) 147 Hz, C-6), 52.1 (d, ^1J(C,H) 141 Hz, C-5), 26.7 and 26.0 (2 q, ^1J(C,H) 130, 126 Hz, Me_2C); CIMS (NH_4): *m*/*z* 355 ($[M+2]^+$, 14), 354 ($[M+H]^+$, 56), 310 (16), 278 (7), 246 (3), 220 (12), 150 (5), 91 (100). Anal. Calcd for $C_{17}H_{23}NO_7$ (353.37): C, 57.78; H, 6.56; N, 3.96. Found: C, 57.84; H, 6.46; N, 3.98. (Lit. [29] mp 140–141 °C, $[\alpha]_{589}^{25}$ −24.5 (*c* 0.5, $CHCl_3$)).

*(+)-5-Benzyloxycarbonylamino-5-deoxy-1,2-*O*-isopropylidene-β-*D*-idofuranose [(+)-**12**].*—This compound was prepared from (+)-**10** following the procedure used for the preparation of (−)-**12**. $[\alpha]_{589}^{25}$ +24°, $[\alpha]_{577}^{25}$ +25°, $[\alpha]_{546}^{25}$ +28°, $[\alpha]_{435}^{25}$ +47°, $[\alpha]_{405}^{25}$ +56° (*c* 0.36, MeOH); Anal. Calcd for $C_{17}H_{23}NO_7$ (353.37): C, 57.78; H, 6.56; N, 3.96. Found: C, 57.79; H, 6.66; N, 3.88.

*(+)-5-Benzyloxycarbonylamino-5-deoxy-L-idofuranose [(+)-**13**].*—A solution of carbamate (−)-**12** (68 mg, 0.192 mmol) in 8:1 $CF_3COOH–H_2O$ (6 mL) was stirred at 4 °C for 15 h. The solvents were removed by evaporation and the product was purified by column chromatography on silica gel (AcOEt), yielding 49 mg (81%) of (+)-**13** as colorless oil. $[\alpha]_{589}^{25}$ +37°, $[\alpha]_{577}^{25}$ +41°, $[\alpha]_{546}^{25}$ +46°, $[\alpha]_{435}^{25}$ +76°, $[\alpha]_{405}^{25}$ +90° (*c* 0.12, MeOH); UV (MeCN): λ 267 nm (ε = 360), 261 (425), 257 (470), 251 (430), 208 (6500); IR (film): *ν* 3390, 3030, 2970, 1710, 1455, 1410, 1310, 1275, 1110, 1070, 700 cm^{-1}; ^1H NMR (CD_3OD, 400 MHz): δ 7.38–7.33 (m, 5 H Ar), 5.42 (d, ^3J 1.7 Hz, H-1), 5.18 (s, 2 H, $-OCH_2Ph$), 4.37 (dd, ^3J 4.4, 4.4 Hz, H-5), 4.03 (d, ^3J 8.0 Hz, H-6a), 3.66–3.62 (m, H-4, H-6b), 3.48 (dd, ^3J 8.1, 8.0 Hz, H-3), 3.40 (dd, ^3J 8.0, 1.75 Hz, H-2); ^{13}C NMR (CD_3OD, 100.61 MHz): δ 155.1 (s, CO), 137.4 (s, C Ar), 129.6, 129.4 and 129.1 (3 d, ^3J(C,H) 165, 160, 160 Hz, 5 C Ar), 88.3 (d, ^1J(C,H) 168 Hz, C-1), 77.0 (d, ^1J(C,H) 145, C-3), 76.7 (d, ^1J(C,H) 144, C-2), 73.2 (d, ^1J(C,H) 150 Hz, C-4), 68.9 (t, *J* 147 Hz, $-OCH_2Ph$), 66.8 (t, ^1J(C,H) 150 Hz, C-6), 58.4 (d, ^1J(C,H) 152, C-5); CIMS (NH_4): *m*/*z* 313 (M^+, 14), 296 (37), 252 (21), 162 (17), 91 (100). Anal. Calcd for $C_{14}H_{19}NO_7$ (313.31). C, 53.67; H, 6.11; N, 4.47. Found: C, 53.73; H, 5.96; N, 4.45.

*(−)-5-Benzyloxycarbonylamino-5-deoxy-D-idofuranose [(−)-**13**].*—Prepared from (+)-**12** following the procedure used for the preparation of (+)-**13**. $[\alpha]_{589}^{25}$ −38°, $[\alpha]_{577}^{25}$ −38°, $[\alpha]_{546}^{25}$ −45°, $[\alpha]_{435}^{25}$ −76°, $[\alpha]_{405}^{25}$ −88° (*c* 0.12, MeOH).

*(−)-1,6-Anhydro-*D*-ido-piperidinose [(−)-**14**].*—A solution of aminodiol ((+)-**10** (54 mg, 0.246 mmol) in 9:1 $CF_3COOH–H_2O$ was stirred at 25 °C for 90 min. The solvents were removed by evaporation to dryness, the residue was dissolved in water (2 mL) and passed through a column of Dowex 1 (OH^- form) and eluted with water. The resulting solution was lyophilized to give (−)-**14** (33 mg, 83%) as white solid (135 °C, dec). $[\alpha]_{589}^{25}$

$-109°$, $[\alpha]_{577}^{25}$ $-112°$, $[\alpha]_{546}^{25}$ $-128°$, $[\alpha]_{435}^{25}$ $-220°$, $[\alpha]_{405}^{25}$ $-264°$ (*c* 0.7, H_2O). Anal. Calcd for $C_6H_{11}NO_4$ (161.2): C 44.72; H 6.88; N 8.69. Found: C, 44.60; H, 6.93; N, 8.63. (Lit. [30] L-isomer: mp 140 °C (dec), $[\alpha]_{589}^{25}$ $+114.5$ (*c* 1, H_2O)).

(+)-1-Deoxy-D-ido-*nojirimycin [(+)-**2**].*—(a) From tetrol (−)-**13**: a mixture of tetrol (−)-**13** (40 mg, 0.128 mmol) in MeOH (5 mL) and Pd/C 10% (10 mg) was degassed, pressurized with H_2 (0.1 MPa) and shaken at 25 °C for 15 h. After filtration (Celite), the solvent was evaporated under reduced pressure. The residue was purified by column chromatography on Dowex 1 (OH^- form, eluent H_2O) yielding 20 mg (95%) of (+)-**2**. (b) From (−)-anhydrosugar (−)-**14**: a mixture of anhydrosugar (−)-**14** (28 mg, 0.174 mmol) in H_2O (4 mL) and Pd/C 10% (10 mg) was degassed, pressurized with H_2 (0.1 MPa) and shaken at 25 °C for 15 h. After filtration (Celite), the solvent was evaporated under reduced pressure. The residue was purified by column chromatography on Dowex 1 (OH^- form, eluent H_2O) yielding 22 mg (77%) of (+)-**2** as white crystals ($MeOH–Et_2O$) mp 137–139 °C. $[\alpha]_{589}^{25}$ $+28°$, $[\alpha]_{577}^{25}$ $+31°$, $[\alpha]_{546}^{25}$ $+33°$, $[\alpha]_{435}^{25}$ $+54°$, $[\alpha]_{405}^{25}$ $+65°$ (*c* 0.5, H_2O). Anal. Calcd for $C_6H_{13}NO_4$ (163.2): C, 44.17; H, 8.03; N, 8.58. Found: C, 44.01; H, 7.89; N, 8.50.

(−)-1-Deoxy-L-ido-*nojirimycin [(−)-**2**].*—Prepared from (+)-**13** following the procedure used for the preparation of (+)-**2**. $[\alpha]_{589}^{25}$ $-27°$, $[\alpha]_{577}^{25}$ $-28°$, $[\alpha]_{546}^{25}$ $-32°$, $[\alpha]_{435}^{25}$ $-52°$, $[\alpha]_{405}^{25}$ $-62°$ (*c* 0.33, H_2O); Anal. Calcd for $C_6H_{13}NO_4$ (163.2): C, 44.17; H, 8.03; N, 8.38. Found: C, 44.18; H, 7.88; N, 8.41. (Lit. [9] mp 139–141 °C, $[\alpha]_{589}^{25}$ $-31°$, (*c* 1, H_2O)).

(±)-2-Amino-2-deoxy-DL-*iditol [(±)-**15**] and (±)-1,2,3,4,6,-penta*-O-*acetyl-2-deoxy*-DL-*iditol [(±)-**16**].*—A solution of amino diol ((±)-**10** (12 mg, 0.055 mmol) in 9:1 $CF_3COOH–H_2O$ was stirred at 25 °C for 90 min. The solvent was removed by evaporation to dryness, the residue was dissolved in CF_3COOH (1 mL) and Et_3SiH (36 μL, 0.22 mmol, 4 equiv) and stirred for 15 h at 25 °C. Evaporation of the solvent followed by filtration through Dowex 1 (OH^- form) gave 2-amino-2-deoxy-DL-iditol ((±)-**15**) which was poured into Ac_2O (0.6 mL), pyridine (1 mL) and DMAP (5 mg) and stirred for 15 h at 25 °C. The solvents were removed by evaporation and the residue purified by column chromatography on silica gel (6:1 AcOEt–light petroleum) to give 17.9 mg of polyacetate (±)-**16** (75%, two steps) as colorless oil. UV (MeCN): λ 194 ($\varepsilon = 5000$); IR (film): ν 3360, 3060, 2960, 1745, 1675, 1540, 1435, 1370, 1220, 1050, 735 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 5.76 (d, ^3J 9.5 Hz, H–N), 5.42 (ddd, ^3J 6.4, 4.7, 3.6 Hz, H-5), 5.28–5.22 (m, $H_3 + H_4$), 4.60 (dddd, ^3J 9.5, 6.0, 5.7, 3.4 Hz, H-2), 4.23 (dd, ^2J 11.9 Hz, ^3J 4.7, H-6a), 4.09 (dd, ^2J 11.5 Hz, ^3J 5.7 Hz, H-1a), 4.05 (dd, ^2J 11.9 Hz, ^3J 6.4 Hz, H-6b), 3.99 (dd, ^2J 11.5 Hz, ^3J 6.0 Hz, H-1b), 2.13 (s, NH*Ac*), 2.10, 2.07, 2.05, 2.04 (4 s, 5 OAc). ^{13}C NMR ($CDCl_3$, 100.61 MHz): δ 170.6, 170.3, 170.0, 169.9, 169.8 (5 s, 5 Ac), 69.5 and 69.2 (2 d, ^1J(C,H) 150, 149 Hz, $C_3 + C_4$), 68.9 (d, ^1J(C,H) 149 Hz, C-5), 62.7 (t, ^1J(C,H) 150 Hz, C-1), 61.8 (t, ^1J(C,H) 150 Hz, C-6), 47.7 (d, ^1J(C,H) 140 Hz, C-2), 23.1, 20.7, 20.6, 20.5 (4 q, ^1J(C,H) 130 Hz, 6-CH_3); CIMS (NH_3): 434 ($[M+1]^+$, 0.5), 374 (8), 318 (6), 259 (12), 219 (12), 144 (13), 71 (100). Anal. Calcd for $C_{18}H_{27}NO_{11}$ (433.40): C, 49.88; H, 6.28; N, 3.23. Found: C, 49.84; H, 6.25; N, 3.19.

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