Total Syntheses of 2,4-Diamino-2,4-dideoxy-L-arabinose and 2,4-Diamino-2,4-dideoxy-L-ribose

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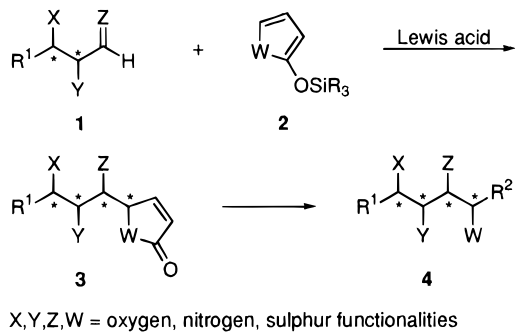
Over the past few years we have been developing methodology to access diverse collections of bioactive compounds exploiting, as a key move, the Lewis acid-assisted addition of chiral nonracemic aldehydes or imines such as **1** (Z = O, NR) to oxygen, nitrogen, and sulfur heterocyclic siloxy dienes **2** (W = O, NR, S).[2] As shown in Scheme 1, using α-hydroxy or α-amino derivatives **1** (Y = OR, NR_2) this process provides access to versatile fragments **3** related to many variants of carbohydrate and alkaloidal structures.[3] In a continuation of those studies, we were interested in the application of the strategy to the reagent couple *N*-(*tert*-butoxycarbonyl)-2-(*tert*-butyldimethylsiloxy)pyrrole (**5**) and L-serinal acetonide (**6**), which, if successful, could provide a convenient entry to multichiral sugar units of type **4** (X, Z = OH; Y, W = NH_2) equipped with alternate oxygen and nitrogen functionalities.

The synthetic utility of the process is herein demonstrated by the expeditious preparation of 2,4-diamino-2,4-dideoxy-L-arabinose (**15**) and 2,4-diamino-2,4-dideoxy-L-ribose (**16**), whose pyrrolidinose structures largely predominate.[4] Homochiral aminosugars and, in particular, those representatives carrying a nitrogen atom in the ring (azasugars) have become increasingly important as pharmacologically potent products,[5] prominent examples being densely oxygenated alkaloidal derivatives **A**−**C** (Chart 1).

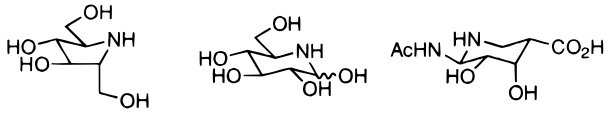
The syntheses of both **15** and **16** commenced with the coupling of siloxypyrrole **5** to enantioenriched isopropylidene-protected L-serinal **6** (93−95% ee), a quite popular three-carbon synthon and source of chirality (Scheme 2).[6,7]

Scheme 1



X,Y,Z,W = oxygen, nitrogen, sulphur functionalities

Chart 1



A (dideoxyiminomannitol) **B** (nojirimycin) **C** (siastatin B)

Remarkably, the BF_3 etherate-assisted Mukaiyama−aldol reaction (CH_2Cl_2, −80 °C) proved regioselective,[8] furnishing, after aqueous $NaHCO_3$ quenching at −80 °C, an 80% yield of two 5-*O*-silylated adducts, **7** and **8**, directly, accompained by only negligible amounts of the corresponding 5-*O*-deprotected counterparts. The asymmetric reaction showed that the 4,5-*threo* lactam **7** is favored over the 4,5-*erythro* diastereoisomer **8**, with 75:25 selectivity.[9] The two diastereomeric lactams were easily separated by flash chromatography to provide the individual precursors **7** and **8**, whose stereochemistry (tentative at this point) was ascertained at a late stage of the synthesis (*vide infra*). With L-*arabino*- and L-*ribo*-configured lactams **7** and **8** in hand, the parallel syntheses of the target sugars **15** and **16** proceeded as follows, adopting uniform reaction protocols.

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(2) Casiraghi, G.; Rassu, G. *Synthesis* **1995**, 607.

(3) For recent works in this area, see, for example: (a) Casiraghi, G.; Colombo, L.; Rassu, G.; Spanu, P. *J. Org. Chem.* **1991**, *56*, 2135. (b) Casiraghi, G.; Colombo, L.; Rassu, G.; Spanu, P. *J. Org. Chem.* **1991**, *56*, 6523. (c) Casiraghi, G.; Rassu, G.; Spanu, P.; Pinna, L. *J. Org. Chem.* **1992**, *57*, 3760. (d) Casiraghi, G.; Rassu, G.; Spanu, P.; Pinna, L.; Ulgheri, F. *J. Org. Chem.* **1993**, *58*, 3397. (e) Casiraghi, G.; Ulgheri, F.; Spanu, P.; Rassu, G.; Pinna, L.; Gasparri Fava, G.; Belicchi Ferrari, M.; Pelosi, G. *J. Chem. Soc., Perkin Trans. 1* **1993**, 2991. (f) Casiraghi, G.; Spanu, P.; Rassu, G.; Pinna, L.; Ulgheri, F. *J. Org. Chem.* **1994**, *59*, 2906. (g) Rassu, G.; Zanardi, F.; Cornia, M.; Casiraghi, G. *J. Chem. Soc., Perkin Trans. 1* **1994**, 2431. (h) Rassu, G.; Spanu, P.; Pinna, L.; Zanardi, F.; Casiraghi, G. *Tetrahedron Lett.* **1995**, *36*, 1941. (i) Zanardi, F.; Battistini, L.; Rassu, G.; Cornia, M.; Casiraghi, G. *J. Chem. Soc., Perkin Trans. 1* **1995**, 2471.

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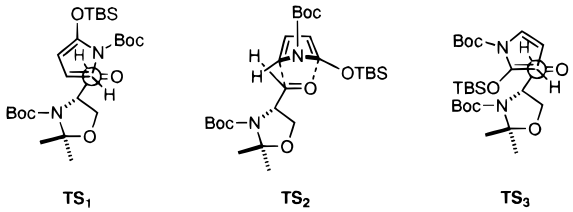
(6) (a) Garner, P.; Park, J. M. *J. Org. Chem.* **1987**, *52*, 2361. (b) Garner, P.; Park, J. M. *Org. Synth.* **1991**, *70*, 18. (c) Roush, W. R.; Hunt, J. A. *J. Org. Chem.* **1995**, *60*, 798. (d) Dondoni, A.; Perrone, D.; Merino, P. *J. Org. Chem.* **1995**, *60*, 8074.

(7) The enantiomeric purity of **6**, prepared according to ref 6c, was determined to be 93−95% by Mosher ester analysis of the corresponding carbinol derivative.

(8) A variety of Lewis acid catalysts and solvents other than BF_3 etherate in CH_2Cl_2 were employed with minor success, including $SnCl_4$ in Et_2O, $TiCl_4$ in CH_2Cl_2, and TMSOTf in 1,2-dichloroethane.

(9) The regio- and stereoselective reaction outcome might be rationalized on the basis of the following transition state models **TS$_1$**, **TS$_2$**, and **TS$_3$**.

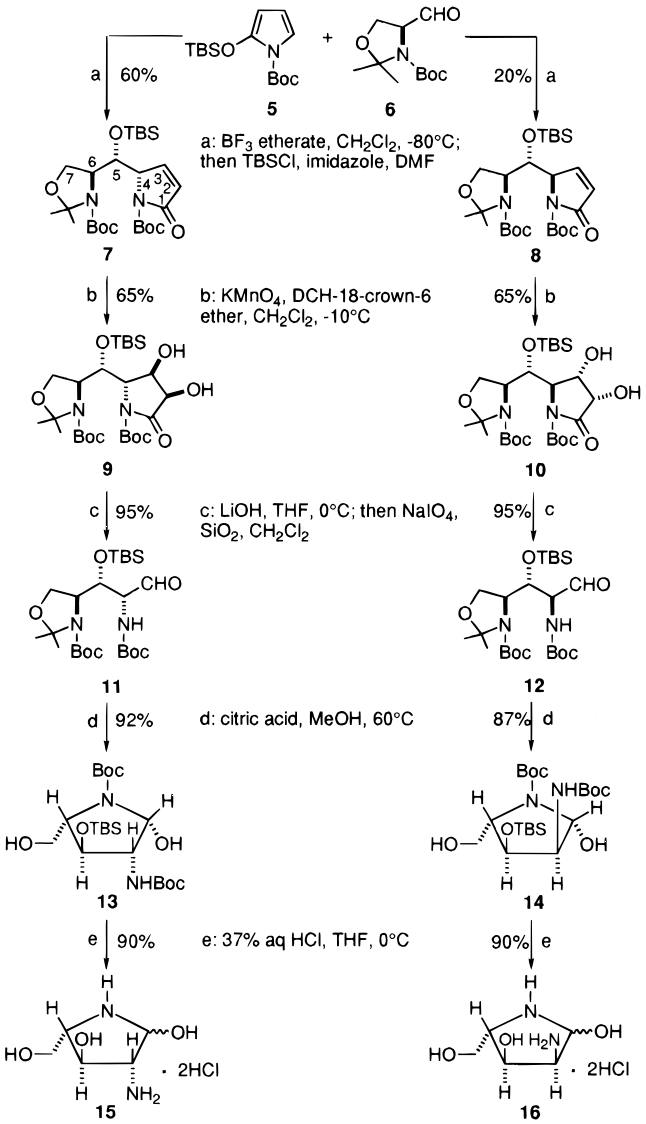


TS$_1$ **TS$_2$** **TS$_3$**

Transition structures **TS$_1$** and **TS$_2$** correspond to nonchelation-type approaches of the prochiral diene γ-carbon (*Re* face) to the prochiral aldehyde carbonyl (*Re* face), both predicting regioselective formation of the 4,5-*syn*-5,6-*anti*-configured stereoisomer **7**. Structure **TS$_3$** illustrates a low-energy model for the alternative α-attack (not observed) along the *Si*−*Re* trajectory. Likely, *endo* Diels−Alder-like model **TS$_2$** seems preferred over its counterparts **TS$_1$** and **TS$_3$**, owing to favorable overlapping of the siloxy diene moiety with the incoming aldehyde π-system. For a detailed discussion on this subject matter, see also ref 2.

S0022-3263(96)00246-0 CCC: $12.00

Scheme 2



At first, the formyl function of the five-carbon sugars was installed by oxidative sacrifice of the C-1 and C-2 atoms within the seven-carbon matrices **7** and **8**. Thus, selective dihydroxylation of the lone carbon−carbon double bond ($KMnO_4$, *cis*-dicyclohexano-18-crown-6 ether) furnished the free diols **9** and **10** (65% each), which were then sequentially subjected to hydrolytic ring opening (LiOH, THF) and diol fission ($NaIO_4$, SiO_2, CH_2Cl_2, H_2O). There were obtained protected diamino aldoses **11** and **12** almost quantitatively, which were used as such during the next stages of the syntheses. The crucial annulation reactions to **13** and **14** were cleanly performed through selective deacetonidation of **11** and **12** by the mild reagent system citric acid/methanol at 60 °C, which also ensured concomitant regio- and stereoselective five-membered ring formation. Pyrrolidines **13** and **14** were obtained as the sole reaction products in 92% and 87% yields, respectively. ^{1}H NMR analyses, including ^{1}H-^{1}H COSY and NOESY experiments, confirmed **13** and **14** as being single β-anomeric L-*arabino*- and L-*ribo*-configured pyrrolidinoses, as shown.[10] Thus, for **13**, mutual NOE contacts between H-1, H-2, and H-4 confirmed their *cis*-location; analogously, for **14**, mutual NOE contacts between H-2, H-3, and H_2-5 indicated that they are in a *cis*-relationship.[11] The final unmasking of the NBoc and OTBS protective groups within **13** and **14** was effected by 3 N HCl in THF at ambient temperature and quantitatively afforded the bis-hydrochloride salts **15** and **16**, which were isolated as inseparable mixtures of α and β anomers.

In conclusion, this methodology exploiting the use of readily available pyrrole-based reagent *N*-(*tert*-butoxycarbonyl)-2-(*tert*-butyldimethylsiloxy)pyrrole (**5**) and enantioenriched (93−95% ee) L-serinal **6** can easily lead to densely functionalized pyrrolidines, **15** and **16**, representatives of a scantly investigated subclass of five-membered ring azasugars.[12] When the lactam intermediates **7** and **8** are used as starting materials, both syntheses proceeded through a uniform protocol of only four reactions (51% and 48% overall yields), comprising shortening of the seven-carbon backbone by two atoms (**7**/**8** → **11**/**12**) and remarkably selective intramolecular aldehyde amination (**11**/**12** → **13**/**14**).

Experimental Section

General. ^{1}H NMR spectra were obtained at 300 MHz with a Varian XL-300 instrument. Chemical shifts are reported in ppm units, by reference to Me_4Si. When necessary, unambiguous assignments were made by decoupling experiments. ^{13}C NMR spectra were recorded with the same instrument at 75.4 MHz. $[\alpha]_D$ values were measured with a Perkin-Elmer 241 polarimeter at 20 ± 1 °C using a 1 cm cell. Microanalyses were performed by the Microanalytical Laboratory of the University of Sassari. Chromatographic separations were performed on silica gel (230−400 mesh, Merck). TLC was done on precoated silica gel plates (Merck 60 F_{254}) with detection by a solution of cerium(III) sulfate (1.0 g), ammonium molybdate (21 g), 96% sulfuric acid (31 mL), and distilled water (500 mL). All solvents were purified by standard procedures, and manipulations involving air/moisture-sensitive substances were carried out under an argon atmosphere using vacuum line, syringe/septum techniques. The preparation of *N*-(*tert*-butoxycarbonyl)-2-(*tert*-butyldimethylsiloxy)pyrrole (TBSOP) (**5**) was carried out by the method in a precedent paper.[3c] *N*-*t*-Boc-2,3-*N*,*O*-isopropylidene-L-serinal (**6**) was prepared from commercial L-serine (Aldrich) according to the protocol of Dondoni[6c] and used immediately.

5-*O*-(*tert*-Butyldimethylsilyl)-4,6-bis((*tert*-butoxycarbonyl)amino)-6,7-*N*,*O*-isopropylidene-2,3,4,6-tetradeoxy-L-*arabino*-hept-2-enonic Acid 1,4-Lactam (7) and 5-*O*-(*tert*-Butyldimethylsilyl)-4,6-bis((*tert*-butoxycarbonyl)amino)-6,7-*N*,*O*-isopropylidene-2,3,4,6-tetradeoxy-L-*ribo*-hept-2-enonic Acid 1,4-Lactam (8). *N*-(*tert*-Butoxycarbonyl)-2-(*tert*-butyldimethylsiloxy)pyrrole (**5**) (4.0 g, 13.4 mmol) and serinal **6** (2.6 g, 11.3 mmol) were dissolved in anhydrous CH_2Cl_2 (60 mL) under argon, and the mixture was cooled to −80 °C with stirring. Freshly distilled BF_3 etherate (1.6 g, 11.3 mmol), cooled to the same temperature, was added via cannula over 10 min, and the solution was stirred for 8 h at −80 °C. The reaction was then quenched by addition of an excess of a saturated aqueous $NaHCO_3$ solution, and the mixture was extracted with brine, dried ($MgSO_4$), and concentrated in vacuo. The residue was chromatographed on silica gel (70:30 CH_2Cl_2/diethyl ether) to afford 4.76 g (80%) of a 75:25 mixture of compounds **7** and **8**, which were isolated as individual components by a further chromatographic treatment (80:20 hexanes/ethyl acetate).

(10) A plausible rationale accounting for this β-selective annulation behavior is hard to construct on the sole basis of the reaction data in our hand and simple molecular modeling, and a detailed study addressing this issue should be necessary.

(11) Additional diagnostic contacts include the following: for **13**, H-3 *vs* NH-2; for **14**, H-1 *vs* NH-2.

(12) 2,4-Diamino-2,4-dideoxy-α,β-L-arabinopyranose is the sugar component of the naturally occurring antifungal antibiotic prumycin: (a) Hata, T.; Ōmura, S.; Katagiri, M.; Atsumi, K.; Awaya, J.; Higashikawa, S.; Yasui, K.; Terada, H.; Kuyama, S. *J. Antibiot.* **1971**, *24*, 900. (b) Ōmura, S.; Katagiri, M.; Atsumi, K.; Hata, T.; Jakubowski, A. A.; Bleecker Springs, E.; Tishler, M. *J. Chem. Soc., Perkin Trans. 1* **1974**, 1627.

Compound 7: 3.57 g (60%), an oil; $R_f = 0.44$; $[\alpha]^{20}_D = -105.1$ (*c* 2.0, $CHCl_3$); ^1H NMR (300 MHz, DMSO, 80 °C) δ 7.41 (dd, 1H, $J = 5.7$, 1.5 Hz), 6.15 (dd, 1H, $J = 5.7$, 1.5 Hz), 5.05 (d, 1H, $J = 5.1$ Hz), 4.64 (dt, 1H, $J = 5.1$, 1.5 Hz), 3.84 (dd, 1H, $J = 8.1$, 3.9 Hz), 3.63 (t, 1H, $J = 8.1$ Hz), 3.54 (dd, 1H, $J = 8.1$, 3.9 Hz), 1.57 (s, 9H), 1.50 (s, 3H), 1.46 (s, 9H) 1.44 (s, 3H), 0.97 (s, 9H), 0.20 and 0.12 (2s, each 3H); ^{13}C NMR (75.4 MHz, DMSO) δ 167.7, 151.7, 148.0, 147.8, 126.8, 92.4, 81.8, 78.6, 68.9, 64.5, 61.6, 56.2, 27.4, 27.3, 26.1, 25.3, 23.7, 17.1, −4.9, −5.5. Anal. Calcd for $C_{26}H_{46}N_2O_7Si$: C, 59.29; H, 8.80; N, 5.32. Found: C, 59.24; H, 8.50; N, 5.52.

Compound 8: 1.19 g (20%), white solid; mp 120−122 °C; $R_f = 0.57$; $[\alpha]^{20}_D = +86.6$ (*c* 0.15, $CHCl_3$); ^1H NMR (300 MHz, DMSO, 80 °C) δ 7.46 (dd, 1H, $J = 6.3$, 1.5 Hz), 6.08 (dd, 1H, $J = 6.3$, 1.5 Hz), 4.76 (bs, 1H), 4.46 (d, 1H, $J = 7.2$ Hz), 4.04 (t, 1H, $J = 7.2$ Hz), 3.90−3.98 (m, 2H), 1.58 (s, 3H), 1.51 (s, 9H), 1.46 (s, 9H), 1.44 (s, 3H), 0.87 (s, 9H), 0.03 and 0.02 (2s, each 3H); ^{13}C NMR (75.4 MHz, DMSO) δ 167.9, 152.1, 149.0, 148.5, 126.3, 93.4, 81.5, 79.7, 70.9, 64.4, 63.2, 58.8, 27.5, 27.4, 26.6, 23.5, 17.3, −5.0, −5.5. Anal. Calcd for $C_{26}H_{46}N_2O_7Si$: C, 59.29; H, 8.80; N, 5.32. Found: C, 59.32; H, 8.65; N, 5.45.

5-*O*-(*tert*-Butyldimethylsilyl)-4,6-bis((*tert*-butoxycarbonyl)amino)-6,7-*N*,*O*-isopropylidene-4,6-dideoxy-L-*glycero*-L-*talo*-heptonic Acid 1,4-Lactam (9). To a stirred solution of lactam **7** (3.40 g, 6.45 mmol) in anhydrous CH_2Cl_2 (40 mL) were added *cis*-dicyclohexano-18-crown-6 ether (0.48 g, 1.29 mmol) and powdered $KMnO_4$ (0.61 g, 3.85 mmol) under argon at −10 °C. The reaction was stirred at this temperature for 5 h; then a saturated aqueous Na_2SO_3 solution and a 5% citric acid solution were added. The mixture was extracted with CH_2Cl_2 (3 × 40 mL), and the combined extracts were dried ($MgSO_4$) and concentrated in vacuo. Flash chromatography over silica gel (50:50 hexanes/ethyl acetate) afforded 2.35 g of **9** (65%) as an oil: $[\alpha]^{20}_D = -30.7$ (*c* 1.7, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 4.48 (bd, 1H, $J = 7.5$ Hz), 4.42 (bd, 1H, $J = 4.8$ Hz), 4.30 (bs, 1H), 4.25 (bd, 1H, $J = 4.8$ Hz), 4.07 (d, 1H, $J = 7.5$ Hz), 3.86−3.94 (m, 2H), 3.31 (bs, 1H), 2.87 (bs, 1H), 1.56 and 1.46 (2s, each 9H), 1.40 and 1.25 (2s, each 3H), 0.92 (s, 9H), 0.09 and 0.07 (2s, each 3H); ^{13}C NMR (75.4 MHz, $CDCl_3$) δ 173.6, 153.3, 149.8, 93.9, 84.1, 80.5, 71.1, 67.9, 66.9, 65.3, 61.8, 58.8, 28.3, 28.0, 26.8, 26.0, 23.8, 17.8, −3.9, −5.0. Anal. Calcd for $C_{26}H_{48}N_2O_9Si$: C, 55.69; H, 8.63; N, 5.00. Found: C, 55.75; H, 8.70; N, 5.07.

5-*O*-(*tert*-Butyldimethylsilyl)-4,6-bis((*tert*-butoxycarbonyl)amino)-6,7-*N*,*O*-isopropylidene-4,6-dideoxy-L-*glycero*-L-*allo*-heptonic Acid 1,4-Lactam (10). The title compound was prepared from lactam **8** (1.1 g, 2.08 mmol) following the procedure described for compound **9**: yield 0.76 g (65%); white solid; mp 194−195 °C; $[\alpha]^{20}_D = -1.0$ (*c* 2.0, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 4.60 (dd, 1H, $J = 6.3$, 2.4 Hz), 4.32 (dd, 1H, $J = 8.7$, 6.3 Hz), 4.08−4.11 (m, 2H), 4.01 (d, 1H, $J = 9.0$ Hz), 3.83−3.89 (m, 3H), 3.01 (d, 1H, $J = 9.0$ Hz), 1.64 (s, 3H), 1.55 (s, 12H), 1.50 (s, 9H), 0.86 (s, 9H), 0.09 and 0.01 (2s, each 3H); ^{13}C NMR (75.4 MHz, $CDCl_3$) δ 172.8, 153.7, 151.1, 94.4, 83.4, 81.8, 71.4, 70.5, 66.5, 64.9, 64.5, 59.1, 28.4, 28.0, 27.4, 25.9, 24.3, 18.1, −3.6, −5.7. Anal. Calcd for $C_{26}H_{48}N_2O_9Si$: C, 55.69; H, 8.63; N, 5.00. Found: C, 55.59; H, 8.59; N, 5.03.

3-*O*-(*tert*-Butyldimethylsilyl)-2,4-bis((*tert*-butoxycarbonyl)amino)-4,5-*N*,*O*-isopropylidene-2,4-dideoxy-L-arabinose (11). Lactam **9** (2.2 g, 3.92 mmol) was dissolved in THF (50 mL), and a 1 M LiOH solution (20 mL) was added under stirring at 0 °C. After 30 min, the solvent was removed, the residue was dissolved in CH_2Cl_2 (60 mL), silica gel (230−400 mesh, 20 g) was added, and the resulting slurry was treated with 0.65 M $NaIO_4$ (35 mL) at room temperature under vigorous stirring. After 30 min, the slurry was filtered under suction over a Celite pad and thoroughly washed with CH_2Cl_2. The filtrates were evaporated to leave crude aldehyde **11** (1.87 g, 95%) as an oil: $[\alpha]^{20}_D = -48.3$ (*c* 2.9, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 9.73 (s, 1H), 5.41 (bs, 1H), 4.67 (dd, 1H, $J = 4.3$, 2.1 Hz), 4.20 (bs, 1H), 4.05 (dd, 1H, $J = 8.7$, 3.0 Hz), 3.96−4.10 (m, 1H), 3.83 (dd, 1H, $J = 8.7$, 6.6 Hz), 1.49 and 1.46 (2s, each 12H), 0.89 (s, 9H), 0.12 and 0.06 (2s, each 3H); ^{13}C NMR (75.4 MHz, DMSO) δ 199.8, 154.4, 151.1, 84.0, 79.5, 79.1, 69.7, 62.7, 62.0, 58.8, 27.6, 26.0, 25.4, 23.4, 17.1, −5.1. Anal. Calcd for $C_{24}H_{46}N_2O_7Si$: C, 57.34; H, 9.22; N, 5.57. Found: C, 57.41; H, 9.19; N, 5.52.

3-*O*-(*tert*-Butyldimethylsilyl)-2,4-bis((*tert*-butoxycarbonyl)amino)-4,5-*N*,*O*-isopropylidene-2,4-dideoxy-L-ribose (12). The title compound was prepared from lactam **10** (0.7 g, 1.24 mmol) following the procedure described for compound **11**: yield 0.59 g (95%); an oil; $[\alpha]^{20}_D = +4.6$ (*c* 3.0, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 9.55 (s, 1H), 6.29 (d, 1H, $J = 8.4$ Hz), 4.42 (dd, 1H, $J = 8.4$, 1.8 Hz), 4.12 (dd, 1H, $J = 9.6$, 1.8 Hz), 3.91−3.96 (m, 2H), 3.77 (dd, 1H, $J = 9.6$, 5.1 Hz), 1.42 (s, 3H), 1.40 (s, 9H), 1.38 (s, 12H), 0.79 (s, 9H), 0.09 and 0.05 (2s, each 3H); ^{13}C NMR (75.4 MHz, $CDCl_3$) δ 200.2, 155.7, 153.5, 94.4, 81.2, 79.3, 71.6, 64.9, 62.8, 58.4, 28.3, 28.2, 27.0, 25.7, 24.4, 17.9, −4.2, −5.2. Anal. Calcd for $C_{24}H_{46}N_2O_7Si$: C, 57.34; H, 9.22; N, 5.57. Found: C, 57.29; H, 9.16; N, 5.60.

3-*O*-(*tert*-Butyldimethylsilyl)-2,4-bis((*tert*-butoxycarbonyl)amino)-2,4-di-deoxy-β-L-arabinofuranose (13). The protected aldehyde **11** (1.7 g, 3.38 mmol) was dissolved in MeOH (35 mL) and treated with 50 mL of a 5% aqueous citric acid solution. The mixture was allowed to react at 60 °C. After the solution was stirred for 2 h, the solvent was removed under vacuum and the oily residue was purified by flash chromatography on silica gel eluting with 80:20 hexanes/ethyl acetate to give 1.44 g of pyrrolidine **13** (92%) as a white solid: mp 110−112 °C; $[\alpha]^{20}_D = +20.0$ (*c* 1.0, $CHCl_3$); ^1H NMR (300 MHz, DMSO) δ 6.80 (bd, 1H, $J = 6.0$ Hz, NH), 4.82 (d, 1H, $J = 4.5$ Hz, H-1), 4.67 (t, 1H, $J = 5.4$ Hz, OH), 4.18 (m, 1H, H-3), 3.74 (m, 1H, H-4), 3.50 (m, 2H, H_2-5), 3.33 (m, 1H, H-2), 2.82 (bs, 1H, OH), 1.42, 1.37, and 0.81 (3s, each 9H, 3 × Bu^t), 0.06 and 0.05 (2s, each 3H, 2 × Me); ^{13}C NMR (75.4 MHz, DMSO) δ 155.3, 86.0, 79.6, 77.8, 75.2, 64.1, 60.3, 54.9, 28.2, 27.9, 25.7, 17.5, −4.6, -4.8. Anal. Calcd for $C_{21}H_{42}N_2O_7Si$: C, 54.52; H, 9.15; N, 6.05. Found: C, 54.47; H, 9.20; N, 6.10.

3-*O*-(*tert*-Butyldimethylsilyl)-2,4-bis((*tert*-butoxycarbonyl)amino)-2,4-dideoxy-β-L-ribofuranose (14). The title compound was prepared from protected aldehyde **12** (0.5 g, 0.99 mmol) following the procedure described for compound **13**: yield 0.4 g (87%); an oil; $[\alpha]^{20}_D = -21.4$ (*c* 0.7, $CHCl_3$); ^1H NMR (300 MHz, DMSO, 80 °C) δ 6.15 (bd, 1H, $J = 8.1$ Hz, NH), 4.93 (d, 1H, $J = 3.3$ Hz, H-1), 4.34 (dd, 1H, $J = 5.4$, 3.9 Hz, H-3), 3.88 (ddd, 1H, $J = 8.1$, 5.4, 3.3 Hz, H-2), 3.71 (ddd, 1H, $J = 8.1$, 3.9, 3.9 Hz, H-4), 3.64−3.54 (m, 2H, H_2-5), 3.20 (bs, 2H, OH), 1.43, 1.41, and 0.89 (3s, each 9H, 3 × Bu^t), 0.07 (s, 6H, 2 × Me); ^{13}C NMR (75.4 MHz, DMSO) δ 155.2, 91.8, 79.9, 71.0, 66.4, 60.0, 55.9, 28.2, 28.0, 25.6, 17.7, −5.1. Anal. Calcd for $C_{21}H_{42}N_2O_7Si$: C, 54.52; H, 9.15; N, 6.05. Found: C, 54.55; H, 9.22; N, 6.08.

2,4-Diamino-2,4-dideoxy-α,β-L-arabinofuranose Dihydrochloride (15). To a stirred solution of **13** (1.4 g, 3.0 mmol) in THF (40 mL) was added a 37% aqueous HCl solution (20 mL) at 0 °C. After the solution was stirred for 30 min, the solvent was evaporated under vacuo to afford 0.6 g of hydrochloride salt **15** (90%) as a colorless glass: $[\alpha]^{20}_D = +14.0$ (*c* 0.5, MeOH); ^1H NMR (300 MHz, D_2O) δ 5.41 (d, 0.6H, $J = 3.6$ Hz, H-1_α), 4.82 (dd, 0.4H, $J = 9.6$, 0.9 Hz, H-1_β), 4.32 (dd, 0.6H, $J = 10.8$, 5.1 Hz, H-3_α), 4.23 (d, 0.6H, $J = 13.8$ Hz, H-$5a_\alpha$), 4.20 (ddd, 0.4H, $J = 9.6$, 4.8, 0.9 Hz, H-3_β), 4.06 (d, 0.4H, $J = 14.1$ Hz, H-$5a_\beta$), 3.85 (d, 0.4H, $J = 14.1$ Hz, H-$5b_\beta$), 3.75 (d, 0.6H, $J = 13.8$ Hz, H-$5b_\alpha$), 3.66 (bs, 1H, H-4_α and H-4_β), 3.38 (dd, 0.6H, $J = 10.8$, 3.6 Hz, H-2_α), 3.10 (t, 0.4H, $J = 9.6$ Hz, H-2_β); ^{13}C NMR (75.4 MHz, D_2O) δ 102.2, 97.8, 74.2, 71.1, 70.9, 66.0, 62.5, 60.0, 59.6, 59.3. Anal. Calcd for $C_5H_{14}N_2O_3Cl_2$: C, 27.16; H, 6.38; N, 12.67. Found: C, 27.20; H, 6.35; N, 12.72.

2,4-Diamino-2,4-dideoxy-α,β-L-ribofuranose Dihydrochloride (16). The title compound was prepared from **14** (0.35 g, 0.75 mmol) following the procedure described for compound **15**: yield 0.15 g (90%); colorless glass; $[\alpha]^{20}_D = +11.3$ (*c* 0.3, MeOH); ^1H NMR (300 MHz, D_2O, major anomer) δ 5.0 (d, 1H, $J = 9.0$ Hz), 4.31−4.38 (m, 1H), 3.52−4.02 (m, 3H), 3.21 (dd, 1H, $J = 9.0$, 2.7 Hz); ^{13}C NMR (75.4 MHz, D_2O, major anomer) δ 96.1, 69.4, 65.6, 59.1, 53.4. Anal. Calcd for $C_5H_{14}N_2O_3Cl_2$: C, 27.16; H, 6.38; N, 12.67. Found: C, 27.22; H, 6.41; N, 12.61.

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