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Total asymmetric synthesis of 3-amino-3-deoxy-L-talose and derivatives †

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Abstract

(1*R*,2*R*,4*R*)-2-*exo*-Cyano-7-oxabicyclo[2.2.1]hept-5-en-2-yl (1*S*')-camphanate [(+)-**1**, Diels–Alder adduct of furan to 1-cyanovinyl (1*S*)-camphanate] was transformed with high stereoselectivity into (1*R*,2*R*,6*R*,7*R*)-4-phenyl-3,10-dioxa-5-azatricyclo[5.2.1.$0^{2,6}$]dec-4-en-9-one [(+)-**10**]. Bromination of the corresponding (*tert*-butyl)dimethylsilyl enol ether [(−)-**11**], followed by Baeyer–Villiger oxidation and then alkaline methanolysis provided methyl 3-amino-1,5-anhydro-2-*O*,3-*N*-benzoyl-3-deoxy-α-L-talofuranuronate [(−)-**17**], the reduction of which gave 3-amino-1,5-anhydro-2-*O*,3-*N*-benzoyl-3-deoxy-α-L-talofuranose [(−)-**19**]. Treatment with aqueous HCl furnished 3-amino-3-deoxy-L-talose hydrochloride [(−)-**2**].

1. Introduction

Carbohydrates, such as 3-amino-3-deoxyhexoses, are parts of many biologically active natural [2,3] and unnatural products [4]. Although 3-amino-3-deoxy-D-talose is a rare carbohydrate for which three syntheses starting from D-glucose have been proposed [5–7], 3-amino-3-deoxy-L-talose has never been described yet to our knowledge. A few years ago, we presented [8] an efficient total synthesis of L-talose starting with the Diels–Alder adduct (+)-**1** of furan to 1-cyanovinyl (1*S*)-camphanate (one "naked sugar" [9]). A similar approach is now reported which allows the transformation of (+)-**1** into 3-amino-3-deoxy-L-talopyranose hydrochloride [(−)-**2**] and derivatives with high stereoselectivity.

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† Enantiomerically Pure 7-Oxabicyclo[2.2.1]hept-5-en-2-yl Derivatives ("Naked Sugars") as Synthetic Intermediates. Part XXV. For Part XXIV, see ref 1.

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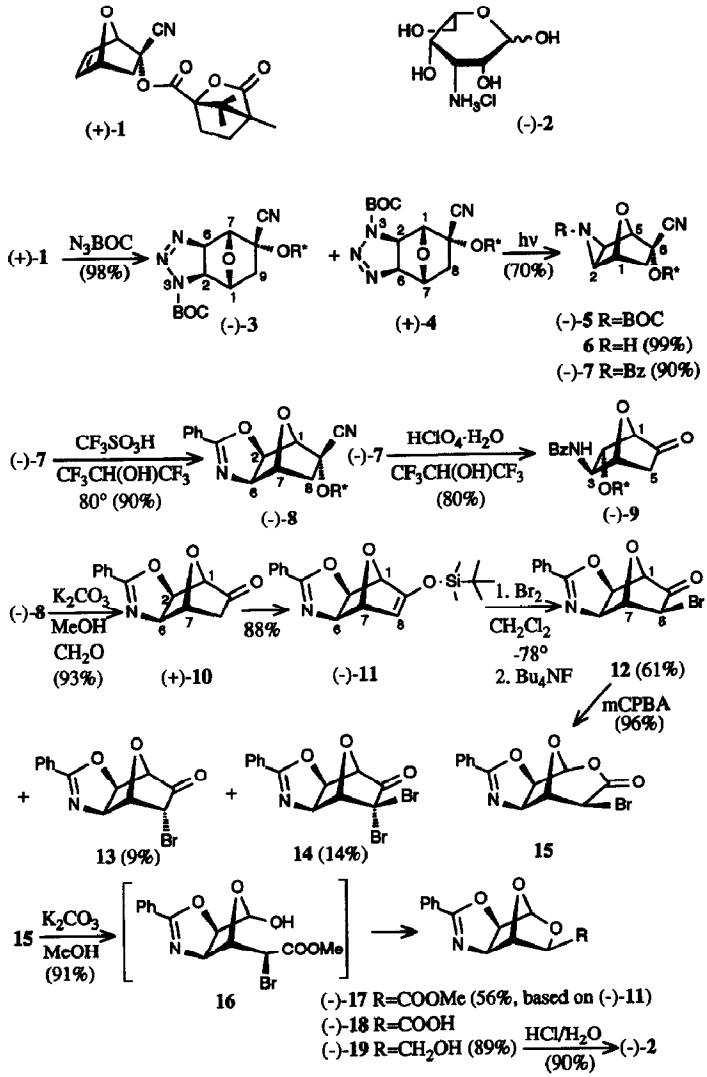
2. Results and discussion

The stereoselective aminohydroxylation of (+)-**1** followed the method recently developed by us for the racemic Diels–Alder adduct of furan and 1-cyanovinyl acetate [10]. 1,3-Dipolar cycloaddition of *tert*-butyl azidoformate to (+)-**1** gave a 2:1 mixture of the corresponding triazolines (−)-**3** and (+)-**4** (98%) (see Scheme 1), which could be separated by a combination of flash column chromatography and crystallization. Irradiation of the crude mixture of (−)-**3** and (+)-**4** in acetone (quartz vessel, high pressure Hg lamp, 0°C) afforded the protected aziridine (−)-**5**



Scheme 1.

(68%). Acidolysis (CF_3COOH) led to aziridine **6** (99%) which was benzoylated (BzCl, Et_3N) into (−)-**7** (90%). On heating (−)-**7** in anhydrous $CF_3CH(OH)CF_3$ containing 0.5 equiv of CF_3SO_3H (80°C, 1 h), oxazolidine (−)-**8** was obtained in 80% yield [10]. In the presence of H_2O and $HClO_4$, (−)-**7** was transformed into the product of *trans*-aminohydroxylation (−)-**9** (90%) [10]. Saponification of (−)-**8** with MeOH and K_2CO_3, followed by treatment with CH_2O, afforded ketone (+)-**10** (93%) and led to recovery of the chiral auxiliary, (−)-camphanic acid (87%). Treatment of (+)-**10** with *N*-[(*tert*-butyl)dimethylsilyl]-*N*-methyltrifluoroacetamide and Et_3N in DMF [11] gave the corresponding enol ether (−)-**11** (88%). Slow addition of a solution of Br_2 in CH_2Cl_2 to (−)-**11** (−78°C), followed by work-up with $Bu_4NF \cdot 3H_2O$, gave a mixture of *exo*-bromo ketone **12** (61%), *endo*-bromoketone **13** (9%), and dibromide **44** (14%), which were readily separated and purified by flash chromatography on silica gel. The major bromoketone **12** was oxidized with *m*-chloroperoxybenzoic acid (mCPBA) in the presence of $NaHCO_3$ to give the uronolactone **15** in 96% yield. In the presence of anhydrous K_2CO_3 in MeOH, **15** added 1 equiv of MeOH giving probably the methyl uronate **16** that underwent fast intramolecular bromide S_N2 displacement providing a mixture of methyl anhydrouronate **17** and of the corresponding uronic acid **18**, which was esterified with CH_2N_2 (total yield of **17**: 91%). The conversion of the silyl enol ether (−)-**11** into (−)-**17** could be carried out in one pot with an overall yield of 56% (see Experimental section). Reduction of (−)-**17** with $LiBH_4$ in THF afforded the partially protected 3-amino-1,4-anhydro-3-deoxy-β-L-talopyranose derivative (−)-**19** (89%) which, on treatment with HCl in H_2O gave crystalline 3-amino-3-deoxy-L-talose hydrochloride [(−)-**2**].

The structures of the new compounds (−)-**3**–**15**, (−)-**17**, and (−)-**19** were deduced from their mode of formation, their reactivity, their elemental analyses, and from their spectral data (see Experimental section). ^1H NMR signal attributions were confirmed by double irradiation experiments including NOE measurements. Distinction between *exo* and *endo* protons in the bicyclic systems was obvious from their coupling constants with the vicinal bridgehead protons [12].

Since (1*S*,2*S*,4*S*)-2-*exo*-cyano-7-oxabicyclo[2.2.1]hept-5-en-2-yl (1*R*)-camphanate [the diastereomer of (+)-**1** derived from (1*R*)-camphanic acid [9]] is as readily available as (+)-**1**, the above approach is also applicable to the total, asymmetric synthesis of 3-amino-3-deoxy-D-talose.

3. Experimental

For general methods, see ref 13.

*(1*R*,2*S*,6*R*,7*R*,8*S*)-3-(tert-Butyloxy)carbonyl-8-*exo*-cyano-10-oxa-3,4,5-triazatricyclo[5.2.1.0^{2,6}]dec-4-en-8-*endo*-yl (1*S*)-camphanate[(−)-3] and (1*R*,2*R*,6*S*,7*R*,9*S*)-3-(tert-butyloxy)carbonyl-9-*exo*-cyano-10-oxa-3,4,5-triazatricyclo[5.2.1.0^{2,6}]dec-3-en-9-*endo*-yl (1*S*)-camphanate* [(+)-**4**].—A mixture of (1*R*,2*R*,4*R*)-2-*exo*-cyano-7-oxabicyclo[2.2.1]hept-5-en-2-*endo*-yl (1*S*)-camphanate [(+)-**1**, 2.195 g, 6.92 mmol], *tert*-butyl azidoformate (1.29 g, 8.99 mmol), and acetone (4 mL) was heated to 50°C

in the dark for 2 days. The solvent and excess of *tert*-butyl azidoformate were distilled off in vacuo and the residue separated and purified by column chromatography on silica gel (2:1 EtOAc–light petroleum 20°C), giving a first fraction ($R_f = 0.58$) yielding 1.78 g (56%) of (−)-**3** which was purified by recrystallization from CH_2Cl_2–Et_2O (4°C) giving 1.50 g (47%) of colourless crystals. A second fraction afforded 689 mg (22%) of a mixture of (−)-**3** and (+)-**4** and the third fraction ($R_f = 0.46$) gave 651 mg (20%) of (+)-**4** as an oil. Total yield of (−)-**3** and (+)-**4**: 98%.

Characteristic of (−)-**3**: mp 182–183.5°C (dec); $[\alpha]_{589}^{25}$ −171°, $[\alpha]_{578}^{25}$ −177°, $[\alpha]_{546}^{25}$ −206°, $[\alpha]_{436}^{25}$ −389°, $[\alpha]_{365}^{25}$ −730° (*c* 1, CH_2Cl_2); λ_{max} (CH_3CN) 241 nm (ϵ 7200); ν_{max}^{KBr} 2980, 2940, 2250, 1790, 1765, 1740, 1525, 1450, 1360, 1320, 1260, 1200, 1150, 1105, 1070, 1045, 990, 960, 835, 795, and 745 cm^{-1}. NMR data ($CDCl_3$): ^1H (250 MHz), δ 5.37 (br s, 1 H, $J_{7,2} = J_{9exo,7} = J_{7,1} < 1$ Hz, H-7), 5.22 (d, 1 H, $J_{6,2}$ 8.5 Hz, H-6), 4.92 (br d, 1 H, $J_{1,9exo}$ 6.0 Hz, H-1), 4.09 (br d, 1 H, H-2), 2.86 (dd, 1 H, J_{gem} 14.5 Hz, H-9*exo*), 2.52–2.41 (m, 1 H, H-6′), 2.13–1.93 (m, 2 H, H-5′, H-6′), 2.02 (d, 1 H, J_{gem} 14.5 Hz, H-9*endo*), 1.80–1.69 (m 1 H, H-5′), 1.59 (s, 9 H, *t*-Bu), 1.16, 1.12, 1.06 (3 s, each 3 H, 3 Me), a weak NOC between *t*-Bu and H-1 (doublet) signals was observed; ^{13}C (90.55 MHz), δ 177.2, 166.1 (2 s, COO, C-3′), 149.4 (s, NCO), 116.6 (CN), 89.9 (s, C-1′), 84.4 (s, quat. C of *t*-Bu), 83.6 (d, $^1J_{C,H}$ 160 Hz, C-1), 81.9 (d, $^1J_{C,H}$ 150 Hz, C-7), 80.5 (d, $^1J_{C,H}$ 170 Hz, C-6), 73.3 (s, C-8), 57.4 (d, $^1J_{C,H}$ 160 Hz, C-2), 55.1, 54.8 (2 s, C-4′, C-7′) 40.8 (t, $^1J_{C,H}$ 140 Hz, C-9), 30.8 (t, $^1J_{C,H}$ 135 Hz, C-5′ or C-6′), 28.6 (t, $^1J_{C,H}$ 140 Hz, C-6′ or C-5′), 28.1 (q, $^1J_{C,H}$ 127 Hz, Me of *t*-Bu), 16.7, 16.5, 9.6 (3 q, $^1J_{C,H}$ 126 Hz, 3 Me). CIMS (NH_3): *m/z* 478 (7%, $[M + NH_4]^+$), 461 (5, $[M + H]^+$), 417 (11), 394 (15), 334 (21), 333 (100, $[M - t\text{-BuOCO} - N_2 + H]^+$), 216 (27), 166 (27), 164 (27), 154 (31), 137 (21), 125 (27), 109 (54), 105 (46), 97 (36), 96 (23), 91 (59), 83 (98). Anal. Calcd for $C_{22}H_{28}N_4O_7$ (460.49): C, 57.38; H, 6.13; N, 12.19. Found: C, 57.27; H, 6.08; N, 12.03.

Characteristics of (+)-**4**: $[\alpha]_{589}^{25}$ + 21°, $[\alpha]_{578}^{25}$ + 23°, $[\alpha]_{546}^{25}$ + 27°, $[\alpha]_{436}^{25}$ + 59°, $[\alpha]_{365}^{25}$ + 143° (*c* 1, CH_2Cl_2); λ_{max} (CH_3CN) 240 nm (ϵ 6050); $\nu_{max}^{CH_2Cl_2}$ 3050, 2980, 2310, 1795, 1755, 1720, 1390, 1370, 1315, 1145, 1095, 1045, 990, 945, and 835 cm^{-1}. NMR data ($CDCl_3$): ^1H (250 MHz), δ 5.19 (br s, 1 H, $J_{1,7} = J_{1,8exo} < 1$ Hz, H-1), 5.08 (br d, 1 H, $J_{7,8exo}$ 6.0, $J_{7,2} < 1$ Hz, H-7), 4.96 (d, 1 H, $J_{2,6}$ 8.5 Hz, H-6), 4.35 (d, 1 H, H-2), 2.92 (dd, 1 H, J_{gem} 14.5 Hz, H-8*exo*), 2.52–2.41 (m, 1 H, H-6′), 2.12 (d, 1 H, H-8*endo*), 2.12–1.93 (m, 2 H, H-5′, H-6′), 1.79–1.64 (m, 1 H, H-5′), 1.59 (s, 9 H, *t*-Bu), 1.15, 1.12, 1.05 (3 s, each 3 H, 3 Me); a weak NOE between *t*-Bu and H-1 (singlet) signals was observed; ^{13}C (90.55 MHz), δ 177.3 (s, COO), 165.9 (C-3′), 148.9 (s, NCO), 116.6 (s, CN), 89.9 (s, C-1′), 86.3 (d, $^1J_{C,H}$ 155 Hz, C-1), 84.5 (s, C quat. of *t*-Bu), 83.7, 80.1 (2 d, $^1J_{C,H}$ 165 Hz, C-7, C-6), 73.5 (s, C-9), 55.0, 54.8 (2 s, C-4′, C-7′), 53.8 (d, $^1J_{C,H}$ 160 Hz, C-2), 41.4 (t, $^1J_{C,H}$ 140 Hz, C-8), 30.8 (t, $^1J_{C,H}$ 135 Hz, C-5′ or C-6′), 28.6 (t, $^1J_{C,H}$ 140 Hz, C-6′ or C-5′), 28.1 (q, $^1J_{C,H}$ 127 Hz, Me of *t*-Bu), 16.6, 16.5, 9.6 (3 q, $^1J_{C,H}$ 126 Hz, 3 Me). CIMS (NH_3): *m/z* 479 (28%), 478 (80, $[M + NH_4]^+$), 461 (3, $[M + H]^+$), 394 (43), 377 (36), 350 (24), 333 (76, $[M - t\text{-BuOCO} - N_2 + H]^+$), 172 (28), 153 (20), 137 (27), 135 (27), 126 (21), 109 (73), 107 (25), 106 (46), 105 (39), 91 (48), 97 (36), 96 (23), 95 (27), 91 (48), 83 (100).

Anal. Calcd for $C_{22}H_{28}N_4O_7$ (460.49): C, 57.38; H, 6.13; N, 12.19. Found: C, 57.31; H, 6.25; N, 12.25.

*(1R,2S,4R,5R,6S)-[*tert*-Butyl-6-*endo*-(1S)-camphanoyloxy-6-*exo*-cyano-8-oxa-3-azatricyclo[3.2.1.0^{2,4}]octane-3-carboxylate]* [(−)-**5**].—A mixture of (+)-**1** (15 g, 47.3 mmol), *tert*-butyl azidoformate (8.8 g, 61.5 mmol), and acetone (25 mL) was heated to 50°C in the dark for 2 days. The solvent and excess of *tert*-butyl azidoformate were distilled off in vacuo. The solid residue was dissolved in acetone (150 mL) and irradiated in a quartz vessel (Philips HPK 125, high pressure Hg lamp) at 0°C for 2 h. The solvent was evaporated and the residue crystallized from CH_2Cl_2–Et_2O (4°C), giving 13.86 g (68%) of colourless crystals; mp 172–177°C (dec); $[\alpha]_{589}^{25}$ −30°, $[\alpha]_{578}^{25}$ −33°, $[\alpha]_{546}^{25}$ −34°, $[\alpha]_{435}^{25}$ −44°, $[\alpha]_{405}^{25}$ −54° (*c* 1, CH_2Cl_2); ν_{max}^{KBr} 2970, 2940, 2880, 2110, 1795, 1760, 1725, 1480, 1450, 1380, 1330, 1295, 1260, 1165, 1110, 1065, 1050, 995, 895, and 810 cm^{-1}. NMR data ($CDCl_3$): ^{1}H (250 MHz), δ 5.10 (s, 1 H, H-5), 4.79 (d, 1 H, $J_{1,7exo}$ 5.2 Hz, H-1), 2.88 (dd, 1 H, J_{gem} 14.0 H-7*exo*), 2.88 (d, 1 H, $J_{2,4}$ 3.5 Hz, H-4), 2.80 (d, 1 H, H-2), 2.49–2.38 (m, 1 H, H-6′), 2.12–1.92 (m, 2 H, H-6′, H-5′), 2.05 (d, 1 H, H-7*endo*), 1.77–1.66 (m, 1 H, H-5′), 1.45 (s, 9 H, *t*-Bu), 1.39, 1.11, 1.03 (3 s, each 3 H, 3 Me); ^{13}C (90.55 MHz), δ 177.3 (s, COO), 166.4 (s, C-3′), 158.6 (s, NCO), 117.1 (s, CN), 90.0 (s, C-1′), 81.7 (s, C quat. of *t*-Bu), 79.2 (d, $^1J_{C,H}$ 175 Hz, C-5), 76.3 (s, C-6), 75.1 (d, $^1J_{C,H}$ 170 Hz, C-1), 54.9, 54.8 (2 s, C-4′, C-7′), 42.1 (t, $^1J_{C,H}$ 140 Hz, C-7), 35.5, 32.4 (2 d, $^1J_{C,H}$ 195 Hz, C-2, C-4), 30.8 (t, $^1J_{C,H}$ 135 Hz, C-5′ or C-6′), 28.7 (t, $^1J_{C,H}$ 140 Hz, C-6′ or C-5′), 27.9 (q, $^1J_{C,H}$ 127 Hz, Me_3C), 16.7, 16.6, 9.6 (3q, $^1J_{C,H}$ 126 Hz, 3 Me). CIMS (NH_3): *m/z* 433 (0.03%, $[M + H]^+$), 333 (4, $[M + H - t\text{-BuOCO}]^+$), 139 (6), 109 (7), 97 (6), 91 (5), 84 (5), 83 (100). Anal. Calcd for $C_{22}H_{28}N_2O_7$ (432.48): C, 61.10; H, 6.56; N, 6.48. Found: C, 61.15; H 6.57; N, 6.46.

*(1R,2S,4R,5R,6S)-[3-Benzoyl-6-*exo*-cyano-8-oxa-3-azatricyclo[3.2.1.0^{2,4}] oct-6-*endo*-yl (1S)-camphanate]* [(−)-**7**].—Crystalline (−)-**5** (1.15 g, 2.66 mmol) was dissolved in anhyd CH_2Cl_2 (11 mL) at 20°C and the solution cooled to 0°C under N_2, CF_3COOH (3 mL, freshly distilled from P_4O_{10}) was added dropwise under stirring. The mixture was stirred for 15 h after having removed the cooling bath. The mixture was poured at once into satd aq $NaHCO_3$ cooled to 0°C under vigorous stirring, and the mixture was extracted with CH_2Cl_2 (4 × 20 mL). The combined extracts were dried ($MgSO_4$) and the solvent evaporated in vacuo, yielding 882 mg (99%) of a colourless oil that crystallized slowly (aziridine **6**). The residue was dissolved in anhyd CH_2Cl_2 (10 mL) and the solution cooled to 0°C. Et_3N (1.11 mL, 7.99 mmol) and BzCl (0.62 mL, 5.32 mmol) were added slowly under stirring. The mixture was stirred for 15 h after having removed the cooling bath. The mixture was poured into vigorously stirred 1 N HCl cooled to 0°C and extracted with CH_2Cl_2 (4 × 20 mL). The combined extracts were dried ($MgSO_4$) and the solvent evaporated in vacuo. The residue was purified by column chromatography on silica gel (1 : 1 CH_2Cl_2–Et_2O, 20°C) giving (R_f 0.49) 1.15 mg (99%) of (−)-**7** pure enough for the next synthetic step. Recrystallization from CH_2Cl_2–Et_2O (4°C) gave 1.05 g (90%) of colourless crystals; mp 220–221°C; $[\alpha]_{589}^{25}$ −50°, $[\alpha]_{577}^{25}$ −54°, $[\alpha]_{546}^{25}$ −56°, $[\alpha]_{435}^{25}$ −84°, $[\alpha]_{405}^{25}$ −101° (*c* 1, CH_2Cl_2); λ_{max} (CH_3CN) 203 nm (ε 12950), 234 nm (ε 13250), 268 nm (ε 1260); ν_{max}^{KBr} 3060, 2960, 2220, 1790,

1760, 1660, 1450, 1380, 1320, 1260, 1210, 1100, 1050, 930, 840, 790, and 710 cm^{-1}. NMR data ($CDCl_3$): ^1H (250 MHz), δ 7.95–7.91 (m, 2 H, arom), 7.61–7.44 (m, 3 H, arom), 4.88 (s, 1 H, H-5), 4.65 (d, 1 H, $J_{1,7exo}$ 5.0 Hz, H-1), 3.30, 3.15 (2 d, 1 H, $J_{2,4}$ 3.5 Hz, H-2, H-4), 2.83 (dd, 1 H, J_{gem} 14.0 Hz, H-7*exo*), 2.50–2.38 (m, 1 H, H-6′), 2.13–1.93 (m, 2 H, H-5′, H-6′), 2.04 (d, 1 H, H-7*endo*), 1.79–1.68 (m, 1 H, H-5′), 1.15, 1.11, 1.03 (3 s, each 3 H, 3 Me); ^{13}C (90.55 MHz), δ 177.3 (s, COO), 166.4 (s, C-3′), 175.7 (s, NCO), 132.9 (s, C arom), 132.7, 128.6, 128.0 (3 d $^1J_{C,H}$ 160 Hz, HC arom), 116.8 (s, CN), 90.0 (s, C-1′), 78.9 (d, $^1J_{C,H}$ 175 Hz, H-5), 76.1 (s, C-6), 74.8 (d, $^1J_{C,H}$ 170 Hz, C-1), 55.0, 54.9 (2 s, C-4′, C-7′), 41.7 (t, $^1J_{C,H}$ 140 Hz, C-7), 36.8, 34.0 (2 d, $^1J_{C,H}$ 195 Hz, C-2, C-4), 30.8, 28.7 (2 t, $^1J_{C,H}$ 135 Hz, C-5′, C-6′), 16.7, 16.6, 9.6 (3 q, $^1J_{C,H}$ 126 Hz, 3 Me). CIMS (NH_3): *m/z* 437 (3%, $[M+H]^+$), 187 (11), 166 (6), 106 (13), 105 (100), 91 (8), 77 (15). Anal. Calcd for $C_{24}H_{24}N_2O_6$ (436.47): C, 66.05, H, 5.54; N, 6.42. Found: C, 66.04; H, 5.56; N, 6.35.

*(1*R,*2*S,*4*R,*5*R,*6*S*)-[6*-exo-*Cyano-8-oxa-3-azatricyclo[3.2.1.0[2,4]oct-6*-endo-*yl(1*S*)-camphanate]* (**6**).—Prepared from (−)-**5** as described above. NMR data ($CDCl_3$): ^1H (250 MHz), δ 4.93 (s, 1 H, H-5), 4.54 (d, 1 H, $J_{1,7exo}$ 5.0 Hz, H-1), 2.83 (dd, 1 H, J_{gem} 13.5 Hz, H-7*exo*), 2.49–2.38 (m, 1 H, H-6′), 2.34 (d, 1 H, $J_{2,4}$ 3.8 Hz, H-4), 2.29 (d, 1 H, H-2), 2.18–1.92 (m, 2 H, H-5′, H-6′), 2.01 (d, 1 H, H-7*endo*), 1.90–1.62 (m, 1 H, H-5′), 1.14, 1.11, 1.03 (3 s, each 3 H, 3 Me).

*(1*R,*2*R,*6*R,*7*R,*9*S*)-[9*-exo-*Cyano-4-phenyl-3,10-dioxa-5-azatricyclo[5.2.1.0^{2,6}]-dec-4-en-2*-endo-*yl(1*S*)-camphanate]* [(−)-**8**].—A mixture of (−)-**7** (0.5 g, 1.15 mmol), anhyd $CF_3CH(OH)CF_3$ (5 mL), and CF_3SO_3H (50 μL, 0.593 mmol) was heated to 80°C for 1 h. The mixture was cooled to 20°C and poured into vigorously stirred satd aq $NaHCO_3$ (25 mL) cooled to 0°C. The mixture was extracted with CH_2Cl_2 (4 × 25 mL). The combined extracts were dried ($MgSO_4$) and the solvent evaporated in vacuo. The residue was purified by column chromatography on silica gel (1:1 CH_2Cl_2–Et_2O) giving a first fraction (R_f 0.48) yielding 144 mg of (−)-**7**, and a second fraction (R_f 0.23) yielding 321 mg (90%, including the recovered starting material) of (−)-**8**. Crystallization from CH_2Cl_2–Et_2O (4°C) furnished 285 mg (80%) of colourless crystals; mp 227.5–228.5°C; $[\alpha]_{589}^{25}$ −145°, $[\alpha]_{577}^{25}$ −153°, $[\alpha]_{546}^{25}$ −172°, $[\alpha]_{435}^{25}$ −314°, $[\alpha]_{405}^{25}$ −398° (*c* 1, CH_2Cl_2); λ_{max} (CH_3CN) 204 nm (ϵ 13200), 241 nm (ϵ 11000); ν_{max}^{KBr} 2985, 1790, 1760, 1645, 1450, 1355, 1260, 1170, 1100, 1065, 995, 965, 935, 870, 780, and 695 cm^{-1}. NMR data ($CDCl_3$): ^1H (250 MHz), δ 7.92–7.88 (m, 2 H, H arom), 7.54–7.39 (m, 3 H, H arom), 5.19 (br s, 1 H, $J_{1,8exo} = J_{1,7} < 1$ Hz, H-1), 5.13 (d, 1 H, $J_{2,6}$ 7.0 Hz, H-2), 4.77 (d, 1 H, $J_{7,8exo}$ 6.0 Hz, H-7), 4.56 (d, 1 H H-6), 2.89 (dd, 1 H, J_{gem} 14.5 Hz, H-8*exo*), 2.53–2.41 (m, 1 H, H-6′), 2.15–1.93 (m, 2 H, H-5′, H-6′), 2.05 (d, 1 H H-8*endo*), 1.80–1.69 (m, 1 H, H-5′), 1.16, 1.13, 1.07 (3 s, each 3 H, 3 Me); ^{13}C (90.55 MHz), δ 177.3 (s, COO), 166.2 (s, C-3′), 166.2 (s, C-4), 132.0, 128.5, 128.4 (3 d, $^1J_{C,H}$ 160 Hz, HC arom), 127.1 (s, C quat. arom), 117.0 (s, CN), 90.0 (s, C-1′), 84.5, 80.9 (2 d, $^1J_{C,H}$ 170 Hz, C-1, C-7), 79.5 (d, $^1J_{C,H}$ 165 Hz, C-2), 75.0 (d, $^1J_{C,H}$ 155 Hz, C-6), 73.6 (s, C-9), 55.0, 54.9, (2 s, C-4′, C-7′), 41.4 (t, $^1J_{C,H}$ 140 Hz, C-8), 30.8, 28.7 (2 t, $^1J_{C,H}$ 135 Hz, C-5′, C-6′), 16.7, 16.6, 9.6 (3 q, $^1J_{C,H}$ 126 Hz, 3 Me). CIMS (NH_3): *m/z* 437 (20%, $[M+H]^+$), 436 (7, $[M]^+$), 240 (10), 239 (23), 230 (13), 158 (27), 146 (44), 145 (65),

117 (14), 109 (19), 105 (100), 103 (11), 97 (13), 90 (19), 77 (29). Anal. Calcd for $C_{24}H_{24}N_2O_6$ (436.47): C, 66.05; H, 5.54; N, 6.42. Found: C, 65.99; H, 5.56; N, 6.38.

(1R,2S,3R,4R)-[3-exo-Benzamido-6-oxo-7-oxabicyclo[2.2.1]hept-2-endo-yl (1S)-camphanate] [(−)-**9**].—A mixture of (−)-**7** (120 mg, 0.28 mmol), $CF_3CH(OH)CF_3$ (24 mL), and aq 70% $HClO_4$ (24 μL) was stirred at 20°C for 5 h. After the addition of more aq 70% $HClO_4$ (48 μL), the mixture was stirred for an additional 2 h and then poured into vigorously stirred satd aq $NaHCO_3$ cooled to 0°C, and extracted with CH_2Cl_2 (4 × 50 mL). The combined extracts were dried ($MgSO_4$) and the solvent evaporated in vacuo. The residue was purified by column chromatography on silica gel (1:1 CH_2Cl_2–Et_2O, 20°C) giving (R_f 0.47) 106 mg (90%) of (−)-**9** which was recrystallized form CH_2Cl_2–Et_2O (4°C) yielding 103 mg (87%) of colourless crystals; mp 218–221.5°C; $[\alpha]_{589}^{25}$ −90°, $[\alpha]_{577}^{25}$ −94°, $[\alpha]_{546}^{25}$ −103°, $[\alpha]_{435}^{25}$ −167°, $[\alpha]_{405}^{25}$ −204° (*c* 1, CH_2Cl_2); λ_{max} (CH_3CN) 201 nm (ε 11600), 226 nm (ε 12250); ν_{max}^{KBr} 3420, 2970, 2930, 1780, 1765, 1745, 1650, 1575, 1510, 1480, 1400, 1350, 1330, 1300, 1255, 1225, 1150, 1065, 1015, 930, 830, 780, and 715 cm^{-1}. NMR data ($CDCl_3$): ^1H (250 MHz), δ 7.84–7.79 (m, 2 H, H arom), 7.59–7.43 (m, 3 H, H arom), 6.71 (d, 1 H, $J_{3,NH}$ 7.5 Hz, NH), 5.10 (ddd, 1 H, $J_{1,2}$ 5.5, $J_{2,3}$ 2.0, $J_{2,4}$ < 1 Hz, H-2), 4.87 (dd, 1 H, $J_{4,5exo}$ 6.5 Hz, H-4), 4.69 (dd, 1 H, $J_{1,5exo}$ 1.0 Hz, H-1), 4.56 (dd, 1 H, H-3), 2.67 (ddd, 1 H, J_{gem} 18.0 Hz, H-5*exo*), 2.45–2.34 (m, 1 H, H-6′), 2.38 (d, 1 H, H-5*endo*), 2.18–1.63 (m, 3 H, 2 H-5′, H-6′), 1.11, 1.04, 1.01 (3 s, each 3 H, 3 Me); ^{13}C (90.55 MHz), δ 205.3 (s, C-6), 177.7 (s, COO), 167.3 (s, C-3′), 166.8 (s, NCO), 133.2 (s, C quat. arom), 131.2, 128.8, 127.1 (3 d, $^1J_{C,H}$ 160 Hz, HC arom), 90.5 (s, C-1′), 81.7 (d, $^1J_{C,H}$ 165 Hz), 79.5 (d, $^1J_{C,H}$ 175 Hz), 78.4 (d, $^1J_{C,H}$ 165 Hz), 58.4 (d, $^1J_{C,H}$ 150 Hz), 54.9, 54.4 (2 s, C-4′, C-7′), 40.6 (t, $^1J_{C,H}$ 135 Hz, C-5), 30.9, 28.8 (2 t, $^1J_{C,H}$ 135 Hz, C-5′, C-6′), 16.5, 16.4, 9.6 (3 q, $^1J_{C,H}$ 126 Hz, 3 Me). CIMS (NH_3): *m/z* 429 (3%), 428 (10, $[M+H]^+$), 427 (6, $[M]^{+\cdot}$), 370 (4), 166 (62), 106 (62), 105 (100), 91 (79). Anal. Calcd for $C_{23}H_{25}NO_7$ (427.46): C, 64.63; H, 5.90; N, 3.28. Found: C, 64.52; H, 5.91; N, 3.33.

(1R,2R,6R,7R)-4-Phenyl-3,10-dioxa-5-azatricyclo[5.2.1.0^{2,6}]dec-4-en-9-one [(+)-**10**].—A mixture of (−)-**8** (100 mg, 0.23 mmol), MeOH (5 mL), K_2CO_3 (50 mg), and formaline (aq 37% CH_2O, 0.1 mL) was stirred at 20°C for 3 h (control by TLC on silica gel, 2:1 EtOAc–light petroleum, R_f [(−)-**8**] 0.38, R_f [(+)-**9**] 0.25, R_f [(1*S*)-camphanic acid] 0.64 (revel.: Pancaldi). The mixture was poured into brine (20 mL), cooled to 0°C and extracted with CH_2Cl_2 (4 × 20 mL). The combined extracts were dried ($MgSO_4$) and the solvent was evaporated in vacuo. The residue was purified by column chromatography on silica gel (2:1 EtOAc–light petroleum) yielding (R_f 0.64) 39 mg (87%) of (1*S*)-camphanic acid and (R_f 0.25) 49 mg (93%) of (+)-**10** which was recrystallized from CH_2Cl_2–Et_2O (20°C); colourless crystals; mp 195–198°C; $[\alpha]_{589}^{25}$ +61°, $[\alpha]_{577}^{25}$ +65°, $[\alpha]_{546}^{25}$ +83°, $[\alpha]_{435}^{25}$ +225°, $[\alpha]_{405}^{25}$ +338° (*c* 1, CH_2Cl_2). Other spectral data were identical to those reported for (±)-**10** [10a].

(1R,2R,6R,7R)-9-{[(tert-butyl)dimethylsilyl]oxy}-4-phenyl-3,10-dioxa-5-azatricyclo[5.2.1.0^{2,6}]deca-4,8-diene [(−)-**11**].—*N*-[(*tert*-butyl)dimethylsilyl]-*N*-methyltrifluoroacetamide (209 μL, 0.91 mmol) was added slowly to a stirred solution of (+)-**10** (160 mg, 0.70 mmol) and Et_3N (448 μL, 3.5 mmol) in anhyd DMF (5 mL).

After stirring at 60°C for 5 h, *N*-[(*tert*-butyl)dimethylsilyl]-*N*-methyltrifluoroacetamide (48 μL, 0.21 mmol) was added and the mixture stirred at 60°C for an additional 2 h. After cooling to 20°C, the solvent was distilled off under high vacuum. The residue was purified by column chromatography on silica gel (3:2 Et_2O–light petroleum) yielding 210 mg (88%) of colourless crystals; mp 99–101°C; $[\alpha]_{589}^{25}$ −146°, $[\alpha]_{577}^{25}$ −154°, $[\alpha]_{546}^{25}$ −175°, $[\alpha]_{435}^{25}$ −333°, $[\alpha]_{405}^{25}$ −432° (*c* 1, CH_2Cl_2); λ_{max} (CH_3CN) 208 nm (ε 12100), 242 nm (ε 10300); ν_{max}^{KBr} 2960, 2850, 1645, 1625, 1470, 1450, 1350, 1320, 1300, 1260, 1210, 1180, 1085, 1065, 1025, 985, 900, 840, 785, and 710 cm^{-1}. NMR data ($CDCl_3$): ^1H (250 MHz), δ 7.93–7.89 (m, 2 H, H arom), 7.47–7.36 (m, 3 H, H arom), 5.03 (d, 1 H, $J_{7,8}$ 1.9 Hz, H-8), 4.97 (d, 1 H, $J_{2,6}$ 6.3 Hz, H-2), 4.93 (br s, 1 H, H-7), 4.61 (br s, 1 H, H-1), 4.59 (d, 1 H, H-6), 0.94 (s, 9 H, *t*-BuSi), 0.21, 0.18 (2 s, each 3 H, Me_2Si); ^{13}C (90.55 MHz), δ 166.4, 160.0 (2 s, C-4, C-9), 131.4, 128.5, 128.3 (3 d, $^1J_{C,H}$ 160 Hz, HC arom), 127.6 (s, C arom), 104.9 (d, $^1J_{C,H}$ 175 Hz, C-8), 83.2, 83.15 (2 d, $^1J_{C,H}$ 170 Hz, C-1, C-7), 81.6 (d, $^1J_{C,H}$ 165 Hz, C-2), 75.9 (d, $^1J_{C,H}$ 160 Hz, C-6), 25.5 (q, $^1J_{C,H}$ 130 Hz, Me of *t*-Bu), 18.0 (s, C quat. of *t*-Bu), −4.9, −5.1 (2 q, $^1J_{C,H}$ 120 Hz, Me_2Si). CIMS (NH_3): *m/z* 344 (6%, $[M + H]^+$), 198 (71), 142 (59), 141 (81), 75 (51), 74 (100), 73 (76). Anal. Calcd for $C_{19}H_{25}NO_3Si$ (343.50): C, 66.44; H, 7.34; N, 4.08. Found: C, 66.51; H 7.26; N, 4.09.

*(1*RS,*2*RS,*6*RS,*7*RS*)-9-{[(*tert*-Butyl)dimethylsilyl]oxy}-4-phenyl-3,10-dioxa-5-azatricyclo[5.2.1.0^{2,6}]deca-4,8-diene* [(±)-**11**].—Prepared from (±)-**10**[10a], as described above, (±)-**11** had mp 74–75°C.

*(1*RS,*2*RS,*6*SR,*7*SR,*8*SR*)-8-*exo-*Bromo-4-phenyl-3,10-dioxa-5-azatricyclo-[5.2.1.0^{2,6}]dec-4-en-9-one* [(±)-**12**], *(1*RS,*2*RS,*6*SR,*7*SR,*8*RS*)-8-*endo-*bromo-4-phenyl-3,10-dioxa-5-azatricyclo[5.2.1.0^{2,6}]dec-4-en-9-one* [(±)-**13**], *and (1*RS,*2*RS,*6*SR,*7*SR*)-8,8-dibromo-4-phenyl-3,10-dioxa-5-azatricyclo[5.2.1.0^{2,6}]dec-4-en-9-one* [(±)-**14**]—A solution of Br_2 (79 μL, 1.05 equiv) in anhyd CH_2Cl_2 (10 mL) was added dropwise during 1 h to a stirred solution of (±)-**11** (0.5 g, 1.46 mmol) in anhyd CH_2Cl_2 (30 mL) cooled to −78°C under N_2. The addition was stopped when the yellow colour persisted. The temperature was allowed to reach 0°C (ice bath). The solution was washed with satd aq $NaHCO_3$ (100 mL) containing $Bu_4NF \cdot 3H_2O$ (100 mg) at 0°C, and then with brine (100 mL) at 0°C. The combined aq phases were extracted with CH_2Cl_2 (4 × 100 mL). The combined organic phases were dried ($MgSO_4$) and the solvent was evaporated in vacuo. The residue was purified by column chromatography on silica gel (25 g, 3:2 Et_2O–light petroleum, 20°C). A first fraction (R_f 0.49) gave 80 mg (14%) of (±)-**14**. A second fraction (R_f 0.40) afforded 41 mg (9%) of (±)-**13**, and a third fraction (R_f = 0.12) furnished 272 mg (61%) of (±)-**12**.

Characteristics of (±)-**12**: colourless crystals; mp 205–206.5°C; λ_{max} (CH_3CN) 206 nm (ε 11700), 240 nm (ε 10900); ν_{max}^{KBr} 2980, 1775, 1645, 1450, 1355, 1285, 1195, 1060, 1025, 990, 925, 900, 780, 710, and 695 cm^{-1}. NMR data ($CDCl_3$): ^1H (250 MHz), δ 7.95–7.92 (m, 2 H, arom), 7.57–7.40 (m, 3 H, arom), 4.96 (d, 1 H, $J_{2,6}$ 7.0 Hz, H-2), 4.91 (d, 1 H, $J_{1,7}$ 1.0 Hz, H-7), 4.72 (d, 1 H, H-6), 4.71 (br s, 1 H, $J_{7,8}$ < 1.0 Hz, H-1), 4.00 (br s, 1 H, $J_{8,1}$ < 1.0 Hz, H-8); ^{13}C (90.55 MHz), δ 206.6 (s, C-9), 166.4 (s, C-4), 132.1, 128.6, 128.5 (3 d, $^1J_{C,H}$ 160 Hz, HC arom), 126.2 (s, C quat. arom), 87.1 (d, $^1J_{C,H}$ 170 Hz), 84.3 (d, $^1J_{C,H}$ 175 Hz), 79.0 (d, $^1J_{C,H}$ 165 Hz),

74.2 (d, $^1J_{C,H}$ 155 Hz, C-1, C-2, C-6, C-7), 42.4 (d, $^1J_{C,H}$ 160 Hz, C-8). CIMS (NH_3): *m/z* 230 (16%), 229 (46), 228 (32, [M − Br^+]), 200 (12), 185 (17), 172 (10), 158 (21), 145 (17), 125 (23), 117 (32), 105 (100), 104 (32), 97 (65), 90 (51), 89 (33), 84 (26), 82 (20), 77 (84). Anal. Calcd for $C_{13}H_{10}BrNO_3$ (308.14): C, 50.67; H, 3.27; N, 4.55. Found: C, 50.65; H, 3.26; N, 4.41.

Characteristics of (±)-**13**: colourless crystals; mp 155–161°C; λ_{max} (CH_3CN) 207 nm (ε 10600), 240 nm (ε 11000); ν_{max}^{KBr} 2960, 1765, 1645, 1490, 1450, 1365, 1245, 1210, 1125, 1065, 1025, 1000, 920, 780, 695, and 625 cm^{-1}. NMR data ($CDCl_3$): ^1H (250 MHz), δ 7.97–7.92 (m, 2 H, arom), 7.57–7.41 (m, 3 H, arom), 5.28 (d, 1 H, $J_{2,6}$ 7.0 Hz, H-2), 4.99 (d, 1 H, $J_{7,8}$ 6.0, $J_{1,7}$ 1.0 Hz, H-7), 4.94 (d, 1 H, H-6), 4.73 (br s, 1 H, $J_{1,8}$ 1.5 Hz, H-1), 4.65 (dd, 1 H, H-8); ^{13}C (90.55 MHz), δ 202.3 (s, C-9), 165.6 (s, C-4), 132.4, 128.6, 128.6 (3 d, $^1J_{C,H}$ 160 Hz, HC arom), 126.0 (s, C quat. arom), 103.9 (d, $^1J_{C,H}$ 190 Hz), 84.5 (d, $^1J_{C,H}$ 165 Hz), 84.2 (d, $^1J_{C,H}$ 170 Hz), 70.9 (d, $^1J_{C,H}$ 155 Hz, C-1, C-2, C-6, C-7), 41.8 (d, $^1J_{C,H}$ 155 Hz, C-8). CIMS (NH_3), *m/z* 310 (1%, $[M^{81}Br + H]^+$), 308 (s, $[M^{79}Br + H]^+$), 230 (7), 229 (25), 228 (57, $[M - Br]^+$), 158 (14), 145 (13), 125 (44), 116 (17), 105 (100), 104 (24), 97 (84), 90 (30), 89 (31), 77 (80), 76 (14). Anal. Calcd for $C_{13}H_{10}BrNO_3$ (308.14): C, 50.67; H, 3.27; N, 4.55; Br, 25.94. Found: C, 50.61; H, 3.44; N, 4.61; Br, 25.79.

Characteristics of (±)-**14**: colourless crystals, mp 174.5–177°C; λ_{max} (CH_3CN): 202 nm (ε 9500), 240 nm (ε 7000); ν_{max}^{KBr} 1785, 1645, 1450, 1350, 1315, 1285, 1240, 1120, 1060, 1020, 1000, 900, 855, 795, 775, 690, and 630 cm^{-1}. NMR data ($CDCl_3$): ^1H (250 MHz), δ 7.97–7.91 (m, 2 H, arom), 7.58–7.41 (m, 3 H, arom), 5.38 (d, 1 H, $J_{2,6}$ 6.5 Hz, H-2), 5.09 (d, 1 H, $J_{1,7}$ 1.0 Hz, H-7), 4.98 (d, 1 H H-6), 4.83 (br s, 1 H H-1); CIMS (NH_3): *m/z* 308 (11%, $[M - {}^{81}Br]^+$), 306 (9, $[M - {}^{79}Br]^+$), 229 (27), 228 (41, $[M - 2Br]^+$), 145 (23), 125 (21), 117 (40), 116 (28), 105 (75), 104 (33), 103 (28), 97 (45), 90 (71), 89 (48), 82 (26), 77 (100), 76 (25). Anal. Calcd for $C_{13}H_9Br_2NO_3$ (387.04): C, 40.34; H, 2.34; N, 3.62; Br, 41.29. Found: C, 40.36; H, 2.19; N, 3.75; Br, 41.22.

*3-Amino-2-O,3-N-benzoyl-5-bromo-3,5-dideoxy-β-*DL*-allofuranurono-6,1-lactone* [(±)-**15**].—A mixture of (±)-**12** (294 mg, 0.95 mmol), mCPBA 200 mg, 1.2 equiv), and $NaHCO_3$ (200 mg) in CH_2Cl_2 (50 mL) was stirred at 20°C for 12 h (control by TLC on silica gel, 1:2 EtOAc–Et_2O, UV). Commercial mCPBA (Fluka, contains 45% H_2O) was dissolved in aq 5% NaCl and extracted with CH_2Cl_2. The organic extract of mCPBA was dried ($MgSO_4$) and the solvent evaporated in vacuo to 50 mL of CH_2Cl_2. The mixture was washed with H_2O (20 mL), then with satd aq $NaHCO_3$ (20 mL) at 0°C. The aq phases were combined and extracted with CH_2Cl_2 (4 × 20 mL). The organic phases were combined and dried ($MgSO_4$) and the solvent was evaporated in vacuo giving 298 mg (96%) of (±)-**15** pure enough for the next step. An analytical sample was obtained by recrystallization from CH_2Cl_2–Et_2O (20°C); colourless crystals; mp 236–238°C (dec); λ_{max} (CH_3CN) 207 nm (ε 11900), 237 nm (ε 11800); ν_{max}^{KBr} 2955, 1750, 1645, 1580, 1495, 1450, 1335, 1250, 1220, 1200, 1065, 1030, 990, 845, 805, 730, and 690 cm^{-1}. NMR data ($CDCl_3$: ^1H (250 MHz), δ 7.93–7.90 (m, 2 H, arom), 7.59–7.41 (m, 3 H, arom), 6.04 (s, 1 H, H-1), 5.28 (d, 1 H, $J_{2,3}$ 7.0 Hz, H-2), 4.89 (br s, 1 H, $J_{4,5}$ 1.0 Hz, H-4), 4.87 (d, 1 H, H-3), 4.47 (br s, 1 H, H-5); ^{13}C (90.55 MHz), δ 161.9 (s, C-6), 166.3 (s, C-4), 132.5,

128.6, 128.6 (3 d, $^1J_{C,H}$ 160 Hz, HC arom), 126.3 (s, C quat. arom), 103.4 (d, $^1J_{C,H}$ 185 Hz, C-1), 86.2 (d, $^1J_{C,H}$ 165 Hz), 84.3 (d, $^1J_{C,H}$ 165 Hz), 76.7 (d, $^1J_{C,H}$ 155 Hz, C-2, C-3, C-4), 40.0 (d, $^1J_{C,H}$ 155 Hz, C-5). CIMS (NH_3): *m/z* 326 (6%, $[M^{81}Br + H]^+$), 324 (5, $[M^{79}Br + H]^+$), 246 (6), 245 (9), 244 (30, $[M - Br]^+$), 147 (10), 146 (100), 145 (15), 117 (20), 105 (49), 104 (19), 103 (15), 99 (43), 91 (30), 90 (44), 89 (33), 86 (10), 84 (11), 77 (59), 71 (65). Anal. Calcd for $C_{13}H_{10}BrNO_4$ (324.14): C, 48.17; H, 3.11; N, 4.32. Found: C, 47.12; H, 3.13; N, 4.40.

*Methyl 3-amino-1,5-anhydro-2-*O*,3-*N*-benzoyl-3-deoxy-α-*DL*-talofuranuronate* [(±)-**17**].—A solution of (±)-**15** (200 mg, 0.62 mmol), in anhyd MeOH (12 mL) satd with anhyd K_2CO_3 was stirred at 20°C for 1 h. The mixture was acidified with 1 N HCl until pH 2–3 and a solution of CH_2N_2 in Et_2O was added until persistance of the yellow colour, under stirring and at 0°C. The mixture was poured into brine (20 mL) and extracted with CH_2Cl_2 (4 × 20 mL). The combined organic extracts were dried ($MgSO_4$) and the solvent was evaporated in vacuo giving 154 mg (91%) of colourless crystals; mp 150–152°C (dec); λ_{max} (CH_3CN) 207 nm (ε 9200), 244 nm (ε 9200); ν_{max}^{KBr} 2960, 1760, 1735, 1645, 1580, 1500, 1450, 1440, 1355, 1290, 1270, 1250, 1210, 1080, 1060, 1030, 1000, 920, 825, 710, and 690 cm^{-1}. NMR data ($CDCl_3$): ^1H (250 MHz), δ 7.91–7.87 (m, 2 H, arom), 7.53–7.37 (m, 3 H, arom), 5.87 (s, 1 H, H-1), 5.09 (s, 1 H, H-4), 4.84 (d, 1 H, $J_{2,3}$ 6.5 Hz, H-2), 4.61 (d, 1 H, H-3), 4.20 (s, 1 H, H-5), 3.80 (s, 3 H, Me); ^{13}C (62.88 MHz), δ 169.2 (s, C-6), 166.3 (s, C-4), 131.9, 128.5, 128.4 (3 d, $^1J_{C,H}$ 160 Hz, HC arom), 126.5 (s, C quat. arom), 101.2 (d, $^1J_{C,H}$ 185 Hz, C-1), 82.4 (d, $^1J_{C,H}$ 170 Hz), 81.7 (d, $^1J_{C,H}$ 165 Hz), 74.0 (d, $^1J_{C,H}$ 155 Hz), 72.5 (d, $^1J_{C,H}$ 155 Hz, C-2, C-3, C-4, C-5), 52.7 (q, $^1J_{C,H}$ 145 Hz, Me). CIMS (NH_3): *m/z* 277 (3%), 276 (20, $[M]^{+\cdot}$), 229 (41), 158 (29), 145 (20), 127 (8), 118 (9), 117 (11), 105 (100), 104 (31), 103 (18), 99 (11), 98 (13), 91 (16), 90 (38), 89 (15), 77 (47), 76 (15), 71 (57). Anal. Calcd for $C_{14}H_{13}NO_5$ (275.26): C, 61.09; H 4.76; N, 5.09. Found: C, 61.10; H, 4.87; N, 5.00.

*3-Amino-1,5-anhydro-2-*O*,3-*N*-benzoyl-3-deoxy-α-*DL*-talofuranuronic acid* [(±)-**18**].—Prepared by the above procedure from (±)-**15**. If the treatment with 1 N HCl and with CH_2N_2 was omitted, the alkaline aq phase contained the potassium salt of (±)-**18**. Acidification with 1 N HCl and extraction with CH_2Cl_2 (4 × 10 mL), drying ($MgSO_4$) and solvent evaporation afforded 46 mg (29%) of colourless crystals; mp 210°C (dec); λ_{max} (CH_3CN) 207 nm (ε 9900), 240 nm (ε 9600); ν_{max}^{KBr} 3480, 3030, 1730, 1635, 1575, 1450, 1360, 1240, 1090, 1065, 1030, 1010, 915, 825, 790, and 700 cm^{-1}. NMR data (CD_3OD): ^1H (250 MHz), δ 7.96–7.92 (m, 2 H, arom), 7.63–7.46 (m, 3 H, arom), 5.90 (s, 1 H, H-1), 5.03 (s, 1 H, H-4), 4.98 (d, 1 H, $J_{2,3}$ 6.5 Hz, H-2), 4.77 (d, 1 H, H-3), 4.39 (s, 1 H, H-5); ^{13}C (CD_3OD, 90.55 MHz), δ 172.8 (s, C-6), 168.3 (s, C-4), 133.4, 129.7, 129.5 (3 d, $^1J_{C,H}$ 160 Hz, HC arom.), 127.6 (s, C quat. arom), 102.5 (d, $^1J_{C,H}$ 190 Hz, C-1), 83.9 (d, $^1J_{C,H}$ 170 Hz), 83.6 (d, $^1J_{C,H}$ 170 Hz), 74.9 (d, $^1J_{C,H}$ 155 Hz), 73.0 (d, $^1J_{C,H}$ 160 Hz, C-2, C-3, C-4, C-5). CIMS (NH_3): *m/z* 263 (11%), 262 (65, $[M]^{+\cdot}$), 261 (4), 215 (35), 105 (100), 104 (37), 90 (25), 89 (25), 84 (22), 77 (60), 71 (30). Anal. Calcd for $C_{13}H_{11}NO_5$ (261.24): C, 59.77; H, 4.24; N, 5.36. Found: C, 59.67; H, 4.29; N, 5.41.

*Methyl 3-amino-1,5-anhydro-2-*O*,3-*N*-benzoyl-3-deoxy-α-*L*-talofuranuronate* [(−)-**17**].—A solution of Br_2 (132 μL) in anhyd CH_2Cl_2 (17 mL) was added dropwise

(90 min) to a stirred solution of (−)-**11** (840 mg, 2.45 mmol) in anhyd CH_2Cl_2 (50 mL), cooled to −78°C under N_2. The temperature was allowed to rise to 0°C and the mixture was poured into ice-cold satd aq $NaHCO_3$ containing $Bu_4NF \cdot 3H_2O$ (170 mg). The organic phase was washed with brine at 0°C (100 mL) and the aq phases were extracted with CH_2Cl_2 (4 × 150 mL). The combined organic extracts were dried ($MgSO_4$) and the solvent was evaporated giving 1144 mg of an oil. mCPBA (920 mg, 55%, Fluka) was dissolved in brine (10 mL) and extracted with CH_2Cl_2 (130 mL). The extract was dried ($MgSO_4$) and added to the oil obtained above. After the addition of $NaHCO_3$ (514 mg, 6.12 mmol), an orange colour appeared. After stirring at 20°C for 24 h, the mixture was poured into ice-cold water (100 mL). The organic phase was collected and washed with satd aq $NaHCO_3$ cooled to 0°C. The combined aq phases were extracted with CH_2Cl_2 (4 × 100 mL). The combined organic extracts were dried ($MgSO_4$) and the solvent was evaporated yielding 1019 g of an oily residue that was dried under high vacuum (10^{-3} torr, 20°C, 24 h). Anhydrous MeOH (50 mL) saturated with anhyd K_2CO_3 was added and the mixture stirred at 20°C for 1 h. Brine (50 mL) and CH_2Cl_2 (100 mL) were added under stirring. After acidifying to pH 3 with 1 N HCl, the mixture was extracted with CH_2Cl_2 (4 × 100 mL). The combined extracts were dried ($MgSO_4$), the solvent was evaporated in vacuo, and the residue dissolved in MeOH (50 mL). A solution of CH_2N_2 in Et_2O was added until persistance of the yellow colour. After the addition of a few drops of AcOH the solvent was evaporated in vacuo and the residue purified by column chromatography on silica gel (3:5 EtOAc–light petroleum, R_f 0.24) yielding 380 mg (56%) of colourless crystals; mp 94–97°C; $[\alpha]_{589}^{25}$ −19°, $[\alpha]_{577}^{25}$ −19°, $[\alpha]_{546}^{25}$ −19°, $[\alpha]_{435}^{25}$ −34°, $[\alpha]_{405}^{25}$ −42° (*c*1, CH_2Cl_2). Other spectral data were identical to those of (±)-**17**.

*3-Amino-1,5-anhydro-2-*O*,3-*N*-benzoyl-3-deoxy-α-*L*-talofuranose* [(−)-**19**].—A solution of (−)-**17** (50 mg, 0.182 mmol) in anhyd THF (2 mL) was cooled to 0°C and added dropwise to a stirred solution of $LiBH_4$ (4.4 mg, 0.199 mmol) in anhyd THF (1 mL) cooled to 0°C under Ar. The temperature was allowed to rise to 20°C and the mixture was stirred at 20°C for 15 h. Saturated aq NH_4Cl (4 mL) was added and the mixture stirred for 30 min. The mixture was poured into satd aq NH_4Cl (10 mL) cooled to 0°C and was extracted with CH_2Cl_2 (4 × 10 mL). The combined extracts were dried ($MgSO_4$) and the solvent was evaporated in vacuo, yielding 40 mg (89%) of colourless crystals; mp 151–153°C (dec); $[\alpha]_{589}^{25}$ −71°, $[\alpha]_{577}^{25}$ −75°, $[\alpha]_{546}^{25}$ −84°, $[\alpha]_{435}^{25}$ −158°, $[\alpha]_{405}^{25}$ −208° (*c* 1, CH_2Cl_2); λ_{max} (CH_3CN) 208 nm (ε 13700), 241 nm (ε 9300); ν_{max}^{KBr} 3410, 3170, 3020, 2940, 2920, 2850, 1635, 1580, 1495, 1450, 1360, 1320, 1250, 1090, 1050, 1025, 980, 930, 815, 780, 700, and 685 cm^{-1}. NMR data ($CDCl_3$): ^1H (250 MHz), δ 7.92–7.88 (m, 2 H, arom), 7.50–7.38 (m, 3 H, arom), 5.67 (s, 1 H, H-1), 4.80 (d, 1 H, $J_{2,3}$ 6.5 Hz, H-2), 4.75 (s, 1 H, H-4), 4.53 (d, H-3), 3.80 (t, 1 H, $J_{5,6}$ 6.0 Hz, H-5), 3.56 (d, 2 H, H-6), 2.43 (br s, 1 H, OH); ^{13}C (90.55 MHz), δ 166.1 (s, C-4), 131.8, 128.5, 128.4 (3 d, $^1J_{C,H}$ 160 Hz, HC arom), 126.9 (s, C quat. arom), 100.6 (d, $^1J_{C,H}$ 185 Hz, C-1), 82.2 (d, $^1J_{C,H}$ 165 Hz), 80.4 (d, $^1J_{C,H}$ 165 Hz), 72.9 (d, $^1J_{C,H}$ 165 Hz), 72.7 (d, $^1J_{C,H}$ 155 Hz, C-2, C-3, C-4, C-5), 63.3 (t, $^1J_{C,H}$ 145 Hz, C-6). CIMS (NH_3): *m/z* 249 (2%), 248 (14), 247 (2, $[M]^{+\cdot}$), 201

(11), 158 (18), 146 (13), 145 (17), 117 (18), 105 (100), 104 (39), 103 (11), 99 (11), 98 (13), 91 (9), 90 (23), 89 (11), 86 (14), 77 (48), 71 (27). Anal. Calc. for $C_{13}H_{13}NO_4$ (247.25): C, 63.15; H, 5.30; N, 5.67. Found: C, 62.87; H, 5.48; N, 5.68.

*3-Amino-1,5-anhydro-2-O,3-N-benzoyl-3-deoxy-α-*DL*-talofuranuronic acid* [(±)-**18**].—Prepared by the above procedure from (±)-**17**, (±)-**18** had mp 119–121°C (dec).

*3-Amino-3-deoxy-*L*-talose hydrochloride* [(−)-**2**].—A solution of (−)-**19** (200 mg, 0.809 mmol) in 2.5 N HCl (20 mL) was heated under reflux for 90 min. Benzoic acid was extracted with CH_2Cl_2 [yield: 85 mg (86%), after drying and solvent evaporation]. The aq phase was decolourized with a minimum amount of active charcoal. After filtration through Celite, the solvent was evaporated yielding 157 mg (90%) of a colourless, strongly hygroscopic solid; mp 90–92°C; $[\alpha]_{589}^{25}$ −18°, $[\alpha]_{577}^{25}$ −20°, $[\alpha]_{546}^{25}$ −18°, $[\alpha]_{435}^{25}$ −20°, $[\alpha]_{405}^{25}$ −26° (*c* 1, H_2O). Lit. [5] for 3-amino-3-deoxy-D-talose hydrochloride; $[\alpha]_{589}^{25}$ +23.7° (*c* 1, H_2O) and mp 158-160°C.

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