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Stereoselective synthesis by double reductive amination ring closure of novel aza-heteroannulated sugars

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ABSTRACT

We present here the stereoselective synthesis of a series of 2/3-*N*-pyrrolidine derivatives of glycosides produced by diastereoselective double reductive amination ring closure of 1,4-dicarbonyl compounds. These precursors were produced by tandem ozonolysis–reduction or Wacker oxidation of known alkenes. The potential of these new compounds as glycosidase inhibitors is illustrated for compound **16**, showing selective inhibition of β-D-galactosidase.

1. Introduction

The inhibition of glycosidase enzymes by small molecules is a subject of considerable current interest inspired by potential therapeutic applications in treatment of cancer, HIV and diabetes.[1] Glycosidase inhibitors[2] (Fig. 1) fall into two categories: structures like nojirimycin **1** are amino sugars with an anomeric centre while other compounds like castanospermine **2** lack an hydroxyl group adjacent to the endocyclic heteroatom.[3] In these compounds, the presence of a nitrogen that can be protonated is apparently sufficient to give high glycosidase inhibitory activity.[2] Mannostatin A (**3**) is a potent glycosidase inhibitor where the basic nitrogen has been shown to be essential for activity,[4] indeed acetylation of this amino group destroys inhibitory activity.[5]

Our previous work has focused on the use of carbohydrates as scaffolds for the stereoselective construction of various cyclic compounds.[6] Extension of this approach to include aza-heterocycles was expected to provide a facile route to substituted pyrrolidines. Production of the desired compounds by double reductive amination of a 1,4-dicarbonyl precursor was envisaged. Several examples of highly stereoselective double reductive amination ring closures indicated the broad applicability of the intended approach.[7]

The potential to create a diverse range of derivatives by altering the substituent on the nitrogen of the resulting pyrrolidine was also attractive, as it allows for possible optimization of any observed biological activity. The stereoselective synthesis of such compounds has therefore attracted considerable interest.

In the preliminary publication on this work,[8] we demonstrated that the project was indeed viable, developing a versatile and efficient methodology for the construction of 2-*N*-substituted pyrrolidine rings on carbohydrate scaffolds. In the present work, we report in full an extended study of the methodology, including modifications on the regio- and stereochemistry of the ring junction between the sugar and pyrrolidine moieties, leading to target compounds of type **I**/**II** (Fig. 2). The potential of the resulting

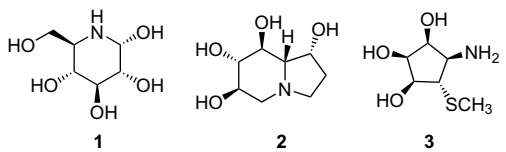

Figure 1. Selected glycosidase inhibitors nojirimycin **1**, castanospermine **2** and mannostatin A **3**.

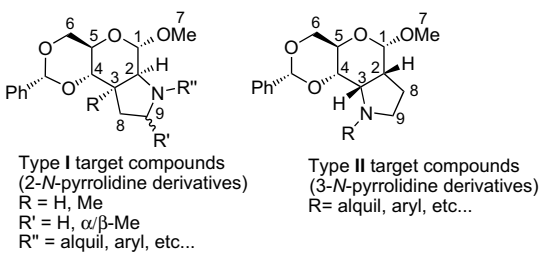

Figure 2. Type **I**/**II** target aza-heteroannulated sugars.

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modified sugars as glycosidase inhibitors is exemplified by the appreciable β-D-galactosidase inhibition activity of the deprotected sugar derivative **16**.

2. Results and discussion

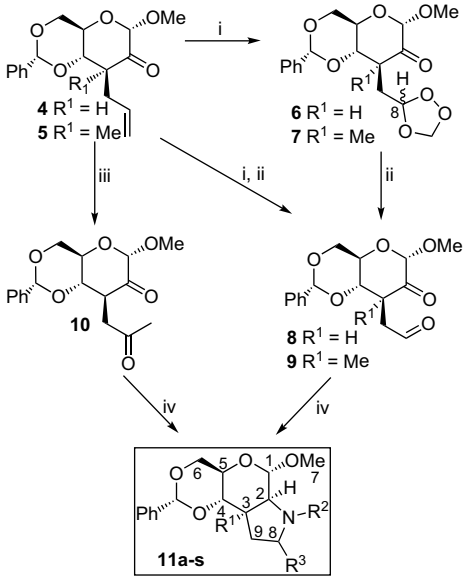
2.1. 2-*N*-Pyrrolidine derivatives

The transformation of the known alkene **4**[9] to a 1,4-dicarbonyl compound can be achieved by various methods in which oxidation of the alkene bond is a common feature (Scheme 1). The simplest route was expected to be ozonolysis of the double bond. Formation of ozonide **6** as a mixture of diastereoisomers in 85% yield was achieved by bubbling O_3 through a solution of alkene **6** in DCM at −78 °C.[10] Attempts to decompose ozonide **6** with various standard methods lead to unsatisfactory results,[9] indicating an unusually stable ozonide. Direct transformation of the alkene **6** into the dicarbonyl compound **8** was achieved by tandem ozonolysis–reduction, in a 53% overall yield, using polymer-bound PPh_3 as reducing agent.[11]

An alternative approach for the conversion of ketone **4** to a 1,4-dicarbonyl compound makes use of the Wacker oxidation. This involves the oxidation of a terminal alkene to a methyl ketone using $PdCl_2$.[12] The desired diketone **10** was produced according to the literature procedure in 85% yield.[13]

Ring closure of the dicarbonyl compound **8** was achieved by treatment with an excess of the amine hydrochloride and a catalytic amount of AcOH in THF at rt, followed by addition of $NaCNBH_3$ (Scheme 1, Table 1). Encouraged by the initial success with aliphatic amines, in which only one diastereoisomer was formed in moderate yields,[8] we decided to explore the applicability of the double reductive amination to a number of amines containing diverse functional groups, including aromatic rings, alcohols and esters (Table 1). Removal of the hydroxyl group of **11j** was achieved by hydrogenation with a catalytic amount of 5% palladium on carbon,[7b] leading to the free amine **11t** in nearly quantitative fashion. In all cases, the reaction was diastereoselective, with moderate yields after purification by flash column chromatography.

The configuration and stereochemistry of the ring junction in the series were confirmed by single-crystal X-ray crystallography of



Scheme 1. Reagents and conditions (see Table 1 for R^1, R^2 and R^3): (i) O_3, DCM, rt, 1 h; (ii) polymer-bound PPh_3, PhMe, 90 °C, 1 h; (iii) $PdCl_2$, $CuCl_2$, O_2, 1:1 DMF–H_2O, rt, 4 h; (iv) R^2NH_2 or R^2NH_2·HCl (see Experimental section for details), AcOH, THF, then $NaCNBH_3$, rt, 2 h.

Table 1
2-*N*-Pyrrolidines synthesized in the present work

Compound	R^1	R^2	R^3	Yield[a] (%)
11a	H	^{i}Pr	H	49[b]
11b	H	Et	H	41[b]
11c	H	$CH_2CH_2CH_2OH$	H	45[b]
11d	H	Ph	H	25[b]
11e	H	CH_2Ph	H	86[b]
11f	H	CH_2CH_2Ph	H	27[b]
11g	H	NHPh	H	37[b]
11h	H	CH_2CO_2Et	H	42[b]
11i	H	$CH_2(CHC_6H_4OH)CO_2Me$	H	41[b]
11j	H	OH	H	77[b]
11k	H	^{i}Pr	β-Me	29[c]
11l	H	^{i}Pr	α-Me	15[c]
11m	H	H	H	94[d]
11n	Me	Et	H	67[e]
11o	Me	Ph	H	49[e]
11p	Me	CH_2Ph	H	86[e]
11q	Me	NHPh	H	58[e]
11r	Me	OH	H	93[e]

[a] Yields after purification by flash column chromatography.
[b] Obtained by double reductive amination of **8**.
[c] Obtained by double reductive amination of **10** after separation by flash column chromatography of the 2:1 mixture of diastereomers at C8.
[d] Prepared by hydrogenation of **11j**.
[e] Obtained by double reductive amination of **9**.

compounds **11j**[8] and **11f**[14] (Fig. 3) and ^{1}H NMR NOESY experiments (as illustrated in Fig. 4 for compounds **11i/l**). For the double reductive elimination of the diketone **10** with *iso*-propylamine, this resulted in a 2:1 mixture of diastereomers at C8 in a 44% overall yield that were efficiently separated by column chromatography. The stereochemistry of **11k**/**11l** was determined by ^{1}H NMR NOESY experiments (Fig. 2), showing convincing NOE effects between $H_{9\beta}$–H_4/H_8, $H_{9\alpha}$–H_2/H_{10} for the 8-α-methyl isomer **11l**.

The stereochemistry at the C-2 ring junction is thought to arise due to an initial reductive amination at the less hindered (and more reactive) aldehyde group at C-8, followed by ring closure. Reduction of the imine formed could then be from the α- or β-face. Although the preference for attack of the hydride from the face opposite from the anomeric OMe group may still be a factor, reductive amination at C-2 of analogous compounds was found to give the opposite stereochemistry (i.e., α-amines),[15] the greater thermodynamic stability of a cis ring junction for the fused five-membered rings compared to their trans counterparts is expected to be more significant in determining the orientation of reduction.[16]

The initial reductive amination reactions attempted were found to vary significantly in yields. In order to improve the average yield of these reactions, it was proposed that analogous pyrrolidines should be synthesized that contain a quaternary centre at C-3. The Thorpe–Ingold effect[17] informs that the placement of a quaternary carbon at the centre of a chain can substantially enhance the rate of ring formation. This is due to a reduction in the C–C–C bond angle and restriction of the degrees of freedom of the chain, and an increase in the entropy of the open chain starting material, which makes it easier for the ring to form.

Ozonolysis of the C-3 methylated alkene **5**[6a] proceeded as for compound **4**, again with the production of an unusually stable ozonide (**9**) in 70% yield that could not be reduced using DMS or thiourea. Reduction of **7** using polymer-bound PPh_3 allowed the isolation of the dicarbonyl compound **9** in a 70% yield after column chromatography (Scheme 1).

The double reductive amination procedure was applied to **9** using a range of primary amines (Scheme 1 and Table 1). As expected, the inclusion of the methyl group at C-3 increased the yields to 49–93% for **11n–r**, compared to 25–86% for **11a–l**. The replacement of the H-3 proton with a methyl greatly simplified

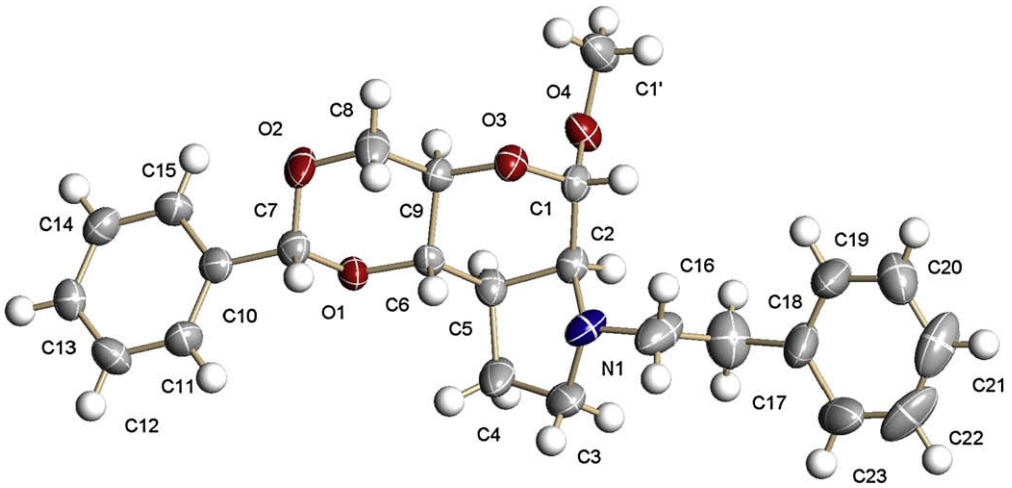


Figure 3. ORTEP plot (ellipsoids, 50% probability) of the solid state structure of **11f**[14] with arbitrary numbering scheme.

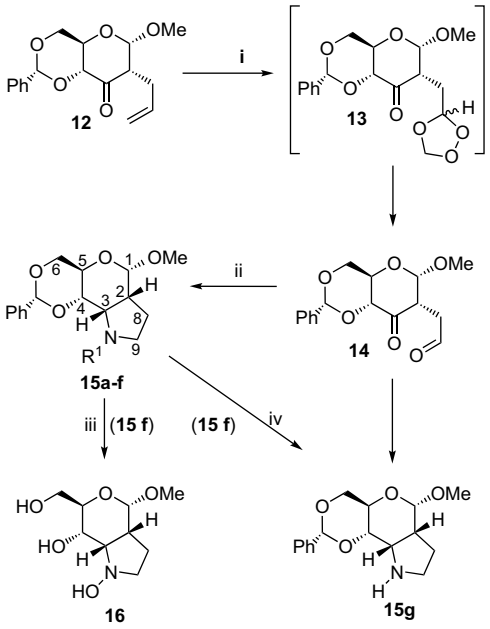
the ^{1}H NMR spectra of **11a–l**, allowing confirmation of the stereochemistry by measuring the appropriate coupling constants. The increased yields in this step were not deemed to be sufficiently high to make the route more efficient than the previously described for the non-methylated 2-*N*-pyrrolidines, due to loss of material during the methylation step.

2.2. 3-*N*-Pyrrolidine derivatives

An isomeric set of aza-heteroannulated sugars of type **II** (3-*N*-pyrrolidine derivatives) were prepared starting from the known ketone **12**.[6a] Ozonolysis of **12** proceeded in the usual way, with the production of the ozonide intermediate **13** as a mixture of diastereoisomers in 86% yield (Scheme 2).[18] This time, in situ reduction of the ozonide using thiourea afforded dicarbonyl **14** as a colourless syrup in 70% yield.[19]

Ring closure of dicarbonyl **14** by reductive amination was expected to give only the products with α-cis ring junctions (Scheme 2). The arm attached at C-2 is α-equatorial in the starting material, so the preference for cis ring junctions in fused five-membered rings would favour the α-amino product as for the 2-*N*-pyrrolidine series. The reductive amination ring-closing reaction was applied to the dicarbonyl compound **14** with a variety of amines including alkyl and aryl amines, phenylhydrazine and hydroxylamine (Scheme 2, Table 2). The resulting type **II** target compounds **15a–f** were obtained in 37–72% yields as colourless syrups after flash chromatography. Furthermore, the free amine derivative **15g** was obtained in good yield removing the hydroxyl group of **15f** by reaction with $Mo(CO)_6$ (Table 2). Removal of the benzylidene group of **15g** using aqueous acetic acid lead to the deprotected derivative **16** in good yield (Scheme 2).

The products (**15a–g**) were identified by ^{1}H and ^{13}C NMR spectroscopy and MS and HRMS (FAB). The ^{1}H NMR spectra of all



Scheme 2. Reagents and conditions: (i) (a) O_3, DCM, rt, 1 h, 86%; (b) thiourea, rt, 1 h, 70%; (ii) R^1NH_2 or $R^1NH_2{\cdot}HCl$ (see Experimental section for details), AcOH, THF, then $NaCNBH_3$, rt, 2 h (Table 2); (iii) 80% aq AcOH, reflux, 4 h, 44%; (iv) $Mo(CO)_6$, MeOH/CH_3CN, reflux, 12 h, 85%.

the 3-*N*-pyrrolidines showed similar distribution of signals for protons on the five-membered ring. The signals for H-3 appeared as doublet of doublets or triplet (except where obscured) between δ 3.27 and δ 4.02 ppm with an axial–equatorial coupling to H-4 and a di-equatorial coupling to H-2 of approximately 5 Hz each. The

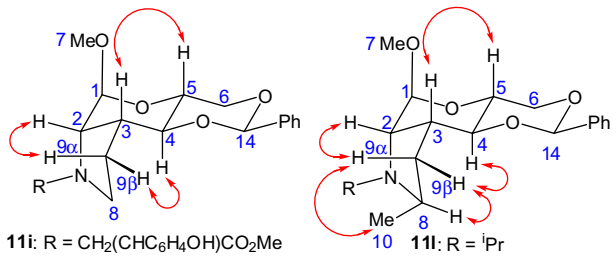


Figure 4. Selected NOE effects observed for compounds **11i** and **11l**.

Table 2
3-*N*-Pyrrolidines synthesized in the present work

Compound	R^1	Yield[a] (%)
15a	Et	37
15b	Ph	36
15c	CH_2Ph	62
15d	CH_2CH_2Ph	62
15e	NHPh	72
15f	OH	44
15g	H	85[b]

[a] Yields after purification by flash column chromatography.
[b] Prepared by reaction of **15f** with $Mo(CO)_6$.

signal for H-4 appeared as doublet of doublets in all the products, which also showed that H-3 was equatorial as expected. This suggests that the cis geometry of the ring junction is present in all of the products. The large number of overlapping signals in these products made ^{1}H NMR NOE experiments of limited use.

2.3. Biological activity

In the previous communication on this work,[8] we showed that removal of the benzylidene group in 2-*N*-pyrrolidine derivatives **11a**,**c**,**h**,**j**,**k**,**l** leading to compounds **17a**–**f** (Fig. 5) could be achieved by acidic hydrolysis. Measurement of the inhibitory activities of the corresponding deprotected derivatives against a range of glycosidases indicated that **17a**–**e** were not significant inhibitors of those. The exception to this trend was compound **17f** that was found to be a weak, but specific, inhibitor of β-D-galactosidase with an IC_{50}=0.77 mM.

In order to prove the potential of compound **16** as glycosidase inhibitor compared with its counterpart **17f**, this compound was tested for inhibitory activity against a range of glycosidase processing enzymes. As **17f**, compound **16** showed weak, but specific activity as β-D-galactosidase inhibitor with an IC_{50}=0.81 mM. It is worthy to mention that inhibition of β-galactosidases is significant because these enzymes are overexpressed in senescent cells.[20]

In conclusion, we have developed a methodology for the stereoselective synthesis of a wide range of 2/3-*N*-pyrrolidine derivatives by double reductive amination ring closure of 1,4-dicarbonyl derivatives of glycosides. Work is in progress for the optimization of the observed biological activities of these new series of carbohydrate derivatives.

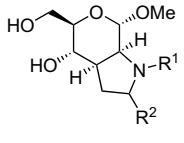
3. Experimental

3.1. General

Flash column chromatography was performed on Sorbil C-60 silica gel (Crossfield Chemicals) 40–60 nm. Thin layer chromatography analysis was conducted on pre-coated aluminium-backed sheets (60–254) with a 0.2 mm thickness manufactured by Merck and Co. Melting points were measured on a Köfler block and are uncorrected. NMR spectra were recorded on BrukerARX250, AM300 or DRX400 spectrometer. Chemical shifts are given in parts per million and coupling constants *J* are given in hertz (Hz). Mass spectra were recorded on a Kratos Concept 1H spectrometer. X-ray diffraction data were collected using a Bruker APEX 2000 diffractometer.

3.2. Crystal structure of compound 11f[14]

A single crystal of **11f** was obtained by recrystallization from dichloromethane–methanol, mounted on inert oil and transferred to the cold gas stream of the diffractometer. Crystal data: $C_{24}H_{29}NO_4$, M=395.48, monoclinic, a=8.949(1), b=11.187(3), c=10.867(3) Å, U=1034.4(4) Å^3, T=200(2) K, space group $P21$, Z=2, absorption coefficient=0.086 mm^{-1}, 2223 reflections measured, 2087 unique (R_{int}=0.0207). The final $wR(F^2)$ was 0.0911 for all data.



17a: R^1 = Pr^i, R^2 = H
17b: R^1 = Pr^i, R^2 = β-Me
17c: R^1 = Pr^i, R^2 = α-Me
17d: R^1 = $CH_2CH_2CH_2OH$, R^2 = H
17e: R^1 = CH_2CO_2Et, R^2 = H
17f: R^1 = OH, R^2 = H

Figure 5. Previously reported deprotected 2-*N*-pyrrolidine derivatives.[8]

3.3. β-D-Galactosidase inhibition tests

β-Galactosidase enzyme (bovine liver) and PNP-β-D-galactopyranoside were purchased from Sigma. Enzyme and substrate (PNP-β-D-galactopyranoside) solutions were made using 0.2 M sodium phosphate buffers at suitable pH and protein concentrations (pH 7.3 and 2.0 U mL^{-1}). PNP-β-D-galactopyranoside was used as substrate at a concentration of 5 mM.

Compounds tested for enzyme inhibition were dissolved in distilled water at a concentration of 1 mg mL^{-1}. Where required, compounds were dissolved in methanol (ca. 20 μL) before dilution using distilled water. Inhibitor solutions were stored at −20 °C. All assays were carried out in triplicate using water as a blank in place of the inhibitor. Reaction time was determined based on the length of time needed to give a final absorbance of 0.3–1.5 units.

Linearity of the reaction time course was checked using a series of incubation times. Rate of colour development after the addition of Trinder glucose reagent was determined using a linear time course.

Enzyme solution (10 μL), inhibitor solution (10 μL) and substrate solution (50 μL) were combined in the well of a flat bottomed 96-well (300 μL) microtitre plate. The reaction mixture was incubated at 25 °C for 5–20 min and was stopped using glycine solution (70 μL, 0.4 M, adjusted to pH 10.4 using NaOH). Absorbance at 405 nm was measured immediately in a microtitre plate reader (Molecular Devices VersaMax microplate reader). Percentage activity was calculated by reference to the control reaction for each assay and percentage inhibition determined by subtraction from 100%.

For IC_{50} determinations, the inhibitors were serially diluted, starting with a tenfold series (0.1–0.0001 mg mL^{-1}) to establish the approximate range, and then diluted within a selected range. IC_{50} values were taken from the resulting curve of percentage absorbance (relative to an uninhibited control) versus concentration.

3.4. Chemistry

*3.4.1. Synthesis of 1,4-dicarbonyl derivatives **8**, **9**, **10** and **14***

*3.4.1.1. Methyl-α-D-(R)-4,6-O-benzylidene-3-deoxy-3-C-(2-oxo-ethyl)-glucopyranosid-2-ulose (**6**).* Previously reported.[8]

*3.4.1.2. Methyl-α-D-(R)-4,6-O-benzylidene-3-deoxy-3-(S)-methyl-3-C-(3-(S)-methyl[1,2,4]trioxolane)-glucopyranosid-2-ulose and methyl-α-D-(R)-4,6-O-benzylidene-3-deoxy-3-(S)-methyl-3-C-(3-(R)-methyl-[1,2,4]trioxolane)-glucopyranosid-2-ulose (**7**).* Nitrogen gas was bubbled through a solution of the known olefin **5** (500 mg, 1.64 mmol) in dry CH_2Cl_2 (30 mL) for 2–3 min. The solution was cooled to −78 °C. Ozone was bubbled through the solvent until TLC showed no starting material. Thiourea (130 mg, 1.70 mmol) was added in portions and the solution warmed to 0 °C and stirred for 1 h, then allowed to stir at rt overnight. The reaction was filtered, washed with satd NaCl solution (2×25 mL) and extracted into CH_2Cl_2 (2×5 mL), dried and concentrated to leave a colourless oil. Chromatography on silica gel with 3:1 petrol–ether as the eluent yielded 341 mg (70% yield) of the mixture of diastereoisomers **7** as a colourless syrup. R_f (3:1 petrol–Et_2O)=0.40. ^{1}H NMR (250 MHz, $CDCl_3$, major diastereoisomer) δ_H 1.40 (3H, s, H_3-11), 2.05/2.11 (1H, 2×dd, $^2J_{8a,8b}$=14.8, $J_{8a,9}$=6.3/5.0, H-8), 2.25/2.40 (1H, 2×dd, $^2J_{8a,8b}$=14.8, $J_{8b,9}$=4.7/3.8, H-8), 3.45 (3H, s, H_3-7), 3.88/3.91 (1H, 2×d, $J_{4,5}$=9.1, H-4), 3.76/3.78 (1H, 2×t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=9.9, H-6ax), 4.30 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.8, J=4.9, H-5), 4.42 (1H, dd, $^2J_{6ax,6eq}$=10.1, $J_{5,6eq}$=5.0, H-6eq), 4.61 (1H, s, H-1), 5.04–5.12 (2H, m, H_2-10), 5.30–5.35 (2H, m, 9-H), 5.50/7.58 (1H, s, H-12), 7.32–7.52 (5H, Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, major diastereoisomer) δ_C 18.9/19.1 (CH_3, C-11), 36.1 (CH_2, C-8), 49.7/49.8 (C, C-3), 56.7 (CH_3, C-7), 60.1

(CH, C-5), 69.7 (CH_2, C-6), 80.6/80.9 (CH, C-4), 94.0/94.4 (CH_2, C-10), 101.6 (CH, C-9), 101.8 (CH, C-12), 126.6 (2×CH, *o*-Ph), 128.7 (2×CH, *m*-Ph), 129.5 (CH, *p*-Ph), 137.7 (C, Ph), 203.0/203.1 (C, C2) ppm. MS (FAB^+) *m*/*z* 367 $[MH]^+$. FAB HRMS for $C_{18}H_{23}O_8$ $[MH]^+$ requires *m*/*z* 367.1393; found *m*/*z* 367.1393.

*3.4.1.3. Methyl-α-D-(R)-4,6-O-benzylidene-3-deoxy-3-C-(2-oxo-ethyl)-glucopyranosid-2-ulose (**8**).* Previously reported.[8]

*3.4.1.4. Methyl-α-D-(R)-4,6-O-benzylidene-3-deoxy-3-(S)-methyl-3-C-(2-oxo-ethyl)-glucopyranosid-2-ulose (**9**).* The triphenyl phosphine polymer was washed with CH_2Cl_2 (10 mL), acetone (10 mL), and MeOH (10 mL), and then dried at 60 °C under vacuum for 24 h. The polymer beads (133 mg, 0.40 mmol) were allowed to swell in *n*-heptane for 0.5 h, without stirring, before the start of the reaction and a Teflon blade was positioned above the beads. Ozonide **7** (100 mg, 0.27 mmol) was added. The reaction mixture was heated to reflux for 1 h and then filtered through a fritted funnel and washed with *n*-heptane (2×25 mL). The solvent was removed by vacuum to give a colourless oil. Flash column chromatography with 2:1 petrol–Et_2O as eluent yielded 79 mg of **9** (79 mg, 62%). R_f (1:1 petrol–Et_2O)=0.33. ^1H NMR (250 MHz, $CDCl_3$) δ_H 1.22 (3H, s, H_3-10), 2.80 (1H, d, $^2J_{8a,8b}$=18.6, H-8a), 3.02 (1H, d, $^2J_{8a,8b}$=18.6, H-8b), 3.41 (3H, s, H_3-7), 3.67 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=9.9, H-6ax), 3.91 (1H, d, $J_{4,5}$=9.4, H-4), 4.19 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.4, $J_{5,6eq}$=4.7, H-5), 4.31 (1H, dd, $^2J_{6ax,6eq}$=10.3, $J_{5,6eq}$=5.7, H-6eq), 4.60 (1H, s, H-1), 5.41 (1H, s, H-10), 7.35–7.50 (5H, m, Ph), 9.73 (1H, br s, H-9). ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 18.8 (CH_3, C-10), 48.3 (CH_2, C-8), 49.6 (C, C-3), 56.7 (CH_3, C-7), 60.2 (CH, C-5), 69.7 (CH_2, C-6), 80.5 (CH, C-4), 100.1 (CH, C-1), 101.8 (CH, C-11), 126.7 (2×CH, *o*-Ph), 128.8 (2×CH, *m*-Ph), 129.7 (Ch, *p*-Ph), 137.8 (C, Ph), 200.3 (C=O, C-2) 201.6 (HC=O, C-9). $C_{17}H_{20}O_5$ $[MH]^+$ requires *m*/*z* 321.1338; HR-FABMS found *m*/*z* 321.1338.

*3.4.1.5. Methyl-α-D-(R)-4,6-O-benzylidene-3-deoxy-3-C-(2-oxo-propyl)-glucopyranoside-2-ulose (**10**).* Previously reported.[13]

*3.4.1.6. Methyl-α-D-(R)-4,6-O-benzylidene-2-deoxy-2-C-(2-oxo-ethyl)-glucopyranosid-3-ulose (**14**).* Previously reported.[19]

*3.4.2. General procedure for the double reductive amination using amines: synthesis of compounds **11a**,**c**,**k**,**l***

The corresponding dicarbonyl compound **8** or **10** was dissolved in dry THF, and an equivalent weight of dry, cooled 4 Å molecular sieves added. AcOH (1 equiv) was added, followed by 8 equiv of the appropriate amine. The flask was flushed with N_2 and the solution stirred at rt for 1 h. $NaCNBH_3$ (3 equiv) was then added and the mixture stirred for a further 2 h at rt. Saturated aqueous NH_4Cl solution was added followed by Et_2O. The organic layer was collected and washed with H_2O. The solvent was removed in vacuo and the resulting yellow syrup was purified by flash chromatography.

*3.4.2.1. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-2-N-iso-propyl-mannopyranoside (**11a**).* Previously reported.[8]

*3.4.2.2. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-2-N-(3-hydroxy-propyl)-mannopyranoside (**11c**).* Compound **8** as starting material. Purification by flash column chromatography using an eluant solvent gradient of 1:1 petrol–Et_2O to Et_2O. Yield 45%, colourless syrup. ^1H NMR (400 MHz, $CDCl_3$) δ_H 1.58 (1H, dquint, $^2J_{11a,11b}$=14.6, $J_{(10a,b),11a}$=$J_{(12a,b),11a}$=3.4, H-11a), 1.89 (1H, obs ddt, $^2J_{9\alpha,9\beta}$=13.5, $J_{8\alpha,9\beta}$=11.0, $J_{3,9\beta}$=$J_{8\alpha,9\beta}$=6.7, H-9β), 1.97 (3H, ov m, H-11b, H-9α, OH-19), 2.42 (1H, td, $^2J_{8\alpha,8\beta}$=$J_{8\alpha,9\beta}$=10.6, $J_{8\alpha,9\alpha}$=4.8, H-8α), 2.49 (1H, dt, $J_{3,4}$=10.3, $J_{2,3}$=$J_{3,9\beta}$=6.1, H-3), 2.60 (1H, dt, $^2J_{10a,10b}$=$J_{10a,(11a,b)}$=3.5, H-10a), 2.64 (1H, d, $J_{2,3}$=5.5, H-2), 3.02 (1H, td, $^2J_{10a,10b}$=$J_{10b,11b}$=12.3, $J_{10b,11a}$=3.6 H-10b), 3.44 (3H, s, H_3-7), 3.54 (2H, ov m, H-4, H-8β), 3.75 (1H, t, $J_{5,6ax}$=$^2J_{6ax,6eq}$=10.2, H-6ax), 3.83 (3H, ov m, H-5, H-12a, H-12b), 4.27 (1H, dd, $^2J_{6ax,6eq}$=14.3, $J_{5,6eq}$=4.6, H-6eq), 4.78 (1H, s, H-1), 5.55 (1H, s, H-13), 7.33–7.41 (3H, ov m, *m*-Ph, *p*-Ph), 7.47–7.52 (2H, m, *o*-Ph) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$) δ_C 24.9 (CH_2, C-9), 29.2 (CH_2, C-11), 39.3 (CH, C-3), 52.2 (CH_2, C-8), 54.9 (CH_3, C-7), 55.7 (CH_2, C-10), 62.8 (CH, C-5), 64.5 (CH_2, C-12), 67.9 (CH, C-2), 69.3 (CH_2, C-6), 78.5 (CH, C-4), 97.8 (CH, C-1), 102.1 (CH, C-13), 126.2 (2×CH, *o*-Ph), 128.3 (2×CH, *m*-Ph), 129.0 (CH, *p*-Ph), 137.7 (C, Ph) ppm. MS (FAB^+) *m*/*z* 350 $[MH]^+$. FAB HRMS for $C_{19}H_{27}O_4N$ $[MH]^+$ requires *m*/*z* 350.1967; found *m*/*z* 350.1968.

*3.4.2.3. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-((2S)-2-propane-2,3-diyl)-2-N-iso-propyl-mannopyranoside (**11k**) and methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-((2R)-2-propane-2,3-diyl)-2-N-iso-propyl-mannopyranoside (**11l**).* Compound **10** as starting material. Purification by flash column chromatography and separation by FC in 5:1 petrol–Et_2O afforded crude samples of diastereotopic amines **11k** and **11l** that were further purified by chromatotron in 7:1 petrol–Et_2O and 15:1 petrol–Et_2O, respectively, yielding 29% yield of amine **11k** and 15% of amine **11l**.

*Compound **11k**.* Colourless syrup. ^1H NMR δ_H (300 MHz, $CDCl_3$) 1.03 (3H, d, $J_{11,12a}$=6.6, H_3-12a), 1.10 (3H, d, $J_{11,12b}$=6.8, H_3-12b), 1.20 (3H, d, $J_{8,10}$=6.4, H_3-10(β)), 1.68 (1H, dd, $^2J_{9\alpha,9\beta}$=13.3, $J_{8(\alpha),9\alpha}$=2.7, H-9α), 2.20 (1H, ddd, $^2J_{9\alpha,9\beta}$=13.4, $J_{8(\alpha),9\beta}$=10.2, $J_{3,9\beta}$=7.5, H-9β), 2.37 (1H, dt, $J_{3,4}$=9.9, $J_{2,3}$=$J_{3,9\beta}$=6.6, H-3), 3.05 (1H, sept, $J_{11,12a}$=$J_{11,12b}$=6.8, H-11), 3.10 (2H, ov d, $J_{2,3}$=6.2, H-2, and m, H-8α), 3.40 (3H, s, H_3-7), 3.75 (1H, obs td, $J_{4,5}$=$J_{5,6ax}$=9.8, $J_{5,6eq}$=4.1, H-5), 3.80 (2H, 2×t, $J_{3,4}$=$J_{4,5}$=9.3, $J_{5,6ax}$=$^2J_{6ax,6eq}$=10.0, H-4, H-6ax), 4.29 (1H, dd, $^2J_{6ax,6eq}$=9.7, $J_{5,6eq}$=4.2, H-6eq), 4.71 (1H, s, H-1), 5.58 (1H, s, H-13), 7.25–7.50 (5H, m, Ph) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$) δ_C 16.6 (CH_3, C-12a), 22.1 (CH_3, C-12b), 26.6 (CH_3, C-10), 34.6 (CH_2, C-9), 39.5 (CH, C-3), 49.5 (CH, C-11), 52.9 (CH, C-8), 55.3 (CH_3, C-7), 63.1 (CH, C-2), 65.4 (CH, C-5), 69.8 (CH_2, C-6), 79.8 (CH, C-4), 99.8 (CH, C-1), 102.4 (CH, C-13), 126.6 (2×CH, *o*-Ph), 128.7 (2×CH, *m*-Ph), 129.4 (CH, *p*-Ph), 138.2 (C, Ph) ppm. MS (FAB^+) *m*/*z* 348 $[MH]^+$. $C_{20}H_{30}O_4N$ $[MH]^+$ requires *m*/*z* 348.2175; HR-FABMS found *m*/*z* 348.2175.

*Compound **11l**.* Colourless syrup. ^1H NMR (300 MHz, $CDCl_3$) δ_H 0.93 (3H, d, $J_{8,10}$=6.5, H_3-10(α)), 0.98 (3H, d, $J_{11,12a}$=6.8, H_3-12a), 1.10 (3H, d, $J_{11,12b}$=6.8, H_3-12b), 1.28 (1H, ddd, $^2J_{9\alpha,9\beta}$=12.9, $J_{3,9\beta}$=7.5, $J_{8\beta,9\beta}$=5.2, H-9β), 2.02 (1H, ddd, $^2J_{9\alpha,9\beta}$=13.1, $J_{8\beta,9\alpha}$=7.6, $J_{3,9\alpha}$=1.6, H-9α), 2.31 (1H, dddd, $J_{3,4}$=9.2, $J_{3,9\beta}$=7.4, $J_{2,3}$=5.9, $J_{3,9\alpha}$=1.6, H-3), 3.16 (1H, obs d, $J_{2,3}$=5.5, H-2), 3.17 (1H, obs sept, $J_{11,12a}$=$J_{11,12b}$=6.9, H-11), 3.30 (3H, s, H_3-7), 3.51 (1H, obs t, $J_{3,4}$=$J_{4,5}$=9.4, H-4), 3.56 (1H, m, H-8β), 3.61 (1H, obs t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=9.3, H-6ax), 3.68 (1H, obs td, $J_{4,5}$=$J_{5,6ax}$=10.0, $J_{5,6eq}$=4.4, H-5), 4.17 (1H, dd, $^2J_{6ax,6eq}$=9.3, $J_{5,6eq}$=4.1, H-6eq), 4.70 (1H, s, H-1), 5.43 (1H, s, H-13), 7.20–7.30 (3H, ov m, *m*-Ph, *p*-Ph), 7.36–7.43 (2H, m, *o*-Ph) ppm. ^1H NMR (400 MHz, C_6D_6) δ_H 0.90 (3H, d, $J_{8,10}$=6.4, H_3-10), 1.08 (3H, d, $J_{11,12a}$=6.9, H_3-12a), 1.20 (3H, d, $J_{11,12b}$=6.9, H_3-12b), 1.32 (1H, ddd, $^2J_{9\alpha,9\beta}$=12.4, $J_{3,9\beta}$=7.6, $J_{8,9\beta}$=4.6, H-9β), 2.26 (1H, ddd, $^2J_{9\alpha,9\beta}$=13.1, $J_{8,9\alpha}$=7.8, $J_{3,9\alpha}$=1.8, H-9α), 2.58 (1H, dddd, $J_{3,4}$=10.0, $J_{3,9\beta}$=7.7, $J_{2,3}$=5.7, $J_{3,9\alpha}$=1.9, H-3), 3.29 (4H, ov s, H_3-7, and sept, $J_{11,12a}$=$J_{11,12b}$=6.9, H-11), 3.39 (1H, d, $J_{2,3}$=5.7, H-2), 3.64 (1H, dqd, $J_{8,9\alpha}$=7.6, $J_{8,10}$=6.3, $J_{8,9\beta}$=4.8, H-8(β)), 3.72 (1H, obs t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.2, H-6ax), 3.76 (1H, obs t, $J_{3,4}$=$J_{4,5}$=9.7, H-4), 4.00 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.9, $J_{5,6eq}$=5.0, H-5), 4.32 (1H, dd, $^2J_{6ax,6eq}$=10.1, $J_{5,6eq}$=5.0, H-6eq), 4.93 (1H, s, H-1), 5.48 (1H, s, H-13), 7.20–7.32 (3H, ov m, *m*-Ph, *p*-Ph), 7.66–7.73 (2H, m, *o*-Ph). ^{13}C NMR (75.5 MHz, $CDCl_3$) δ_C 20.2 (CH_3, C-12a), 20.4 (CH_3, C-12b), 21.0 (CH_3, C-10), 35.2 (CH_2, C-9), 38.4 (CH, C-3), 46.4 (CH, C-11), 53.6 (CH, C-8), 55.1 (CH_3, C-7), 59.3 (CH, C-2), 62.7 (CH, C-5), 69.5 (CH_2, C-6), 79.9 (CH, C-4), 98.8 (CH, C-1), 102.2 (CH, C-13), 126.2 (2×CH, *o*-Ph), 128.3 (2×CH, *m*-Ph), 128.9 (CH, *p*-Ph), 138.0 (C, Ph)

ppm. MS (FAB$^+$) m/z 348 [MH]$^+$. $C_{20}H_{30}O_4N$ [MH]$^+$ requires m/z 348.2175; HR-FABMS found m/z 348.2174.

*3.4.2.4. Methyl-α-D-(R)-4,6-O-benzylidene-2-deoxy-2-C-(2-oxo-ethyl)-glucopyranosid-3-ulose (**14**).* Previously reported.

*3.4.3. General procedure for the double reductive amination using amine hydrochlorides: synthesis of compounds **11b**,**d**–**j**,**n**–**r** and **15a**–**g***

The dicarbonyl starting material **8**, **9** or **12** (1 equiv) was dissolved in dry methanol (0.5 M solution) and cooled to 0 °C. The appropriate amine hydrochloride (1.25 equiv) was added, followed by $NaCNBH_3$ (3 equiv). The reaction mixture was stirred at 0 °C for 2 h and, then, allowed to warm to rt and stirred for a further 2 h. The methanol was removed under vacuum and the residue washed with water (2 mL mmol^{-1} starting material) and satd aq NaOH solution (2×2 mL mmol^{-1} starting material). The organic product was extracted into a 10% propanol in $CHCl_3$ mixture (6×5 mL mmol^{-1} starting material). Concentration under reduced pressure gave a yellow oil that upon chromatography on silica gel afforded the ring-closed products as white solids or colourless syrups.

*3.4.3.1. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-2-N-ethyl-mannopyranoside (**11b**).* Compound **8** as starting material. Purification by flash column chromatography in 1:1 petrol–Et_2O. Yield 41%, colourless syrup. R_f (1:1 petrol–Et_2O)=0.35. ^{1}H NMR (250 MHz, $CDCl_3$) δ_H 1.03 (3H, t, $J_{10(a,b),11}$=7.1, H-11), 1.82 (2H, m, H_2-9α,β), 2.12 (1H, dq, $^2J_{10a,10b}$=13.9, $J_{10a,11}$=6.9, H-10a), 2.17 (1H, dq, $^2J_{10a,10b}$=13.9, $J_{10b,11}$=7.6, H-10b), 2.25 (1H, td, $^2J_{8\alpha,8\beta}$=$J_{8\alpha,9\beta}$=10.7, $J_{8\alpha,9\alpha}$=5.7, H-8α), 2.37 (1H, m, H-3), 2.51 (1H, d, J 6.0, H-2), 3.23 (1H, m, H-8β), 3.41 (3H, s, H_3-7), 3.55 (1H, t, $J_{3,4}$=$J_{4,5}$=9.1, H-4), 3.70 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.1, H-6ax), 3.73 (1H, td, $J_{4,5}$=$J_{5,6ax}$=10.1, $J_{5,6eq}$=5.1, H-5), 4.17 (1H, m, H-6eq), 4.60 (1H, s, H-1), 5.50 (1H, s, H-12), 7.30 (3H, m, *m*-Ph, *p*-Ph), 7.50 (2H, m, *o*-Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 13.4 (CH_3, C-11), 25.7 (CH_2, C-9), 39.9 (CH, C-3), 49.4 (CH_2, C-10), 51.6 (CH_2, C-8), 55.3 (CH_3, C-7), 63.1 (CH, C-5), 68.1 (CH, C-2), 69.6 (CH_2, C-6), 79.3 (CH, C-4), 98.6 (CH, C-1), 102.3 (CH, C-12), 126.2 (CH, *o*-Ph), 128.6 (CH, *m*-Ph), 129.3 (CH, *p*-Ph), 138.3 (C, Ph) ppm. MS (FAB$^+$) m/z 320 [MH]$^+$. $C_{18}H_{26}O_4N$ [MH]$^+$ requires m/z 320.1862; HR-FABMS found m/z 320.1862.

*3.4.3.2. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-2-N-phenyl-mannopyranoside (**11d**).* Compound **8** as starting material. Purification by flash column chromatography in 5:1 petrol–Et_2O. Yield 25% yield, colourless syrup. R_f (5:1 petrol–Et_2O)=0.41. ^{1}H NMR (250 MHz, $CDCl_3$) δ_H 1.71 (1H, m, H-9β), 2.05 (1H, ddd, $^2J_{9\alpha,9\beta}$=12.7, $J_{8\beta,9\alpha}$=8.2, $J_{8\alpha,9\alpha}$=5.1, H-9α), 2.64 (1H, m, H-3), 3.29 (1H, m, H-8α), 3.33 (3H, s, H_3-7), 3.50 (1H, t, $J_{3,4}$=$J_{4,5}$=9.8, H-4), 3.62 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.0, H-6ax), 3.75 (3H, m, H-2, H-5, H-8β), 4.20 (1H, dd, $^2J_{6ax,6eq}$=9.9, $J_{5,6eq}$=4.6, H-6eq), 4.60 (1H, s, H-1), 5.50 (1H, s, H-10), 6.55 (2H, d, $J_{o\text{-}Ph',m\text{-}Ph'}$=8.0, *o*-Ph′), 6.69 (1H, t, $J_{m\text{-}Ph',p\text{-}Ph'}$=7.2, *p*-Ph′), 7.16 (2H, m, *m*-Ph′), 7.29 (3H, m, *m*-Ph, *p*-Ph), 7.44 (2H, m, *o*-Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 26.8 (CH_2, C-9), 40.5 (CH, C-3), 51.4 (CH_2, C-8), 55.5 (CH_3, C-7), 61.7 (CH, C-5), 62.1 (CH, C-2), 69.7 (CH_2, C-6), 76.9 (CH, C-4), 97.4 (CH, C-1), 102.5 (CH, C-10), 114.5 (CH, *o*-Ph′), 114.9 (CH, *m*-Ph′), 118.0 (CH, *p*-Ph′), 126.6 (CH, *o*-Ph), 128.7 (CH, *m*-Ph), 129.5 (CH, *p*-Ph), 138.1 (C, Ph), 149.1 (C, Ph′). MS (FAB$^+$) m/z 368 [MH]$^+$. $C_{22}H_{25}O_4N$ [M]$^+$ requires m/z 367.1784; HR-EIMS found m/z 367.1784.

*3.4.3.3. Methyl-α-D-2-amino-2-N-benzyl-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-mannopyranoside (**11e**).* Compound **8** as starting material. Purification by flash column chromatography in 1:1 petrol–Et_2O. Yield 86%, colourless syrup. R_f (1:1 petrol–Et_2O)=0.70. ^{1}H NMR (250 MHz, $CDCl_3$) δ_H 1.76 (2H, m, H_2-9α,β), 2.25 (1H, td, $^2J_{8\alpha,8\beta}$=$J_{8\alpha,9\beta}$=10.1, $J_{8\alpha,9\alpha}$=5.7, 10.1, H-8α), 2.40 (1H, m, H-3), 2.67 (1H, d, $J_{2,3}$=5.7, H-2), 3.05 (1H, m, H-8β), 3.26 (1H, d, $J_{10a,10b}$=13.5, H-10a), 3.30 (3H, s, H_3-7), 3.58 (1H, dt, $J_{4,5}$=$J_{5,6ax}$=9.6, $J_{5,6eq}$=3.5, H-5), 3.59 (1H, t, $J_{3,4}$=$J_{4,5}$=9.5, H-4), 3.68 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=9.5, H-6ax), 3.95 (1H, d, $J_{10a,10b}$=13.3, H-10b), 4.20 (1H, dd, $^2J_{6ax,6eq}$=9.7, $J_{5,6eq}$=3.6, H-6eq), 4.63 (1H, s, H-1), 5.50 (1H, s, H-11), 7.20 (8H, m, *m*-Ph, *p*-Ph, Ph′), 7.50 (2H, m, *o*-Ph) ppm. ^{13}C NMR δ_C (62.9 MHz, $CDCl_3$) 25.5 (CH_2, C-9), 39.9 (CH, C-3), 52.6 (CH_2, C-8), 53.5 (CH_3, C-7), 59.5 (CH_2, C-10), 62.3 (CH, C-5), 67.8 (CH, C-2), 69.8 (CH_2, C-6), 79.3 (CH, C-4), 98.6 (CH, C-1), 102.4 (CH, C-11), 126.6 (2×CH, *o*-Ph), 127.4 (2×CH, *o*-Ph′), 128.0 (2×CH, *m*-Ph), 128.7 (2×CH, *m*-Ph′), 129.0 (CH, *p*-Ph), 129.4 (CH, *p*-Ph′), 138.2 (C, Ph), 139.6 (C, Ph′) ppm. MS (FAB$^+$) m/z 382 [MH]$^+$. $C_{23}H_{28}O_4N$ [MH]$^+$ requires m/z 382.2018; HR-FABMS found m/z 382.2018.

*3.4.3.4. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-2-N-(phenethyl)-mannopyranoside (**11f**).* Compound **8** as starting material. Purification by flash column chromatography in 2:1 petrol–Et_2O. Yield 27%, low melting point (<50 °C) solid. R_f (1:1 petrol–Et_2O)=0.51. ^{1}H NMR (250 MHz, $CDCl_3$) δ_H 1.85 (2H, m, H_2-9α,β), 2.38 (3H, m, H-3, H-8α, H-10a), 2.58 (1H, d, $J_{2,3}$=5.7, H-2), 2.77 (2H, m, H_2-11a,b), 2.96 (1H, m, H-8β), 3.30 (3H, s, H_3-7), 3.32 (1H, m, H-10b), 3.57 (1H, t, $J_{3,4}$=$J_{4,5}$=9.5, H-4), 3.71 (2H, m, H-5, H-6ax), 4.18 (1H, dd, $^2J_{6ax,6eq}$=9.9, $J_{5,6eq}$=4.7, H-6eq), 4.60 (1H, s, H-1), 5.50 (1H, s, H-12), 7.12 (5H, m, Ph′), 7.27 (3H, m, *m*-Ph, *p*-Ph), 7.50 (2H, m, *o*-Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 25.7 (CH_2, C-9), 35.2 (CH_2, C-11), 39.8 (CH, C-3), 52.4 (CH_2, C-10), 55.3 (CH_3, C-7), 57.6 (CH_2, C-8), 63.3 (CH, C-5), 68.3 (CH, C-2), 69.7 (CH_2, C-6), 79.0 (CH, C-4), 98.3 (CH, C-1), 102.5 (CH, C-12), 126.6 (2×CH, *o*-Ph), 128.7 (4×CH, *m*-Ph, *o*-Ph′), 128.9 (2×CH, *m*-Ph′), 129.1 (CH, *p*-Ph′), 129.3 (CH, *p*-Ph), 138.3 (C, Ph), 140.5 (C, Ph′) ppm. MS (FAB$^+$) m/z 396 [MH]$^+$. $C_{24}H_{30}O_4N$ [MH]$^+$ requires m/z 396.2175; HR-FABMS found m/z 396.2175. Crystals suitable for X-ray diffractometry were grown by slow evaporation of a sample of **11f** dissolved in 10:1 CH_2Cl_2–petrol solution (white solid, mp=82–84 °C).

*3.4.3.5. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-2-N-phenylamino-mannopyranoside (**11g**).* Compound **8** as starting material. Purification by flash column chromatography in 1:1 petrol–Et_2O. Yield 37%, colourless syrup. R_f (1:1 petrol–Et_2O)=0.42. ^{1}H NMR (250 MHz, $CDCl_3$) δ_H 1.90 (2H, m, H_2-9α,β), 2.25 (1H, m, H-8α), 2.38 (1H, m, H-3), 2.74 (1H, d, $J_{2,3}$=6.0, H-2), 3.27 (3H, s, H_3-7), 3.51 (1H, m, H-8β), 3.64 (1H, t, $J_{3,4}$=$J_{4,5}$=9.4, H-4), 3.71 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.1, H-6ax), 3.74 (1H, td, $J_{4,5}$=$J_{5,6ax}$=10.1, $J_{5,6eq}$=5.1, H-5), 4.12 (1H, s, H–N), 4.22 (1H, dd, $^2J_{6ax,6eq}$=9.9, $J_{5,6eq}$=4.8, H-6eq), 4.48 (1H, s, H-1), 5.51 (1H, s, H-10), 6.72 (1H, m, *p*-Ph′), 6.83 (2H, m, *m*-Ph′), 7.12 (2H, m, *o*-Ph′), 7.28 (3H, m, *m*-Ph, *p*-Ph), 7.42 (2H, m, *o*-Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 24.6 (CH_2, C-9), 37.6 (CH, C-3), 55.0 (CH_2, C-8), 55.4 (CH_3, C-7), 63.2 (CH, C-5), 69.4 (CH, C-2), 69.9 (CH_2, C-6), 80.2 (CH, C-4), 98.3 (CH, C-1), 102.5 (CH, C-10), 113.4 (2×CH, *o*-Ph′), 119.9 (2×CH, *m*-Ph′), 126.6 (2×CH, *o*-Ph), 127.5 (2×CH, *m*-Ph), 129.4 (CH, *p*-Ph), 129.5 (CH, *p*-Ph′), 138.2 (C, Ph), 149.5 (C, Ph′) ppm. MS (FAB$^+$) m/z 383 [MH]$^+$. $C_{22}H_{26}O_4N_2$ [M]$^+$ requires m/z 382.1893; HR-FABMS found m/z 382.1893.

*3.4.3.6. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-2-N-(2-ethoxycarbonyl-methyl)-mannopyranoside (**11h**).* Compound **8** as starting material. Purification by flash column chromatography using an eluant solvent gradient of 2:1 petrol–Et_2O to 1:1 petrol–Et_2O. Yield 42% yield, colourless syrup. R_f (1:1 petrol–Et_2O): 0.17. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H 1.28 (3H, t, $J_{12,13}$=7.1, H_3-13), 1.98 (2H, m, H_2-α,β), 2.50 (1H, dq, $J_{3,4}$=9.9, $J_{2,3}$=$J_{3,9\alpha}$=$J_{3,9\beta}$=5.0, H-3), 2.80 (1H, dt, $^2J_{8\alpha,8\beta}$=9.5, $J_{8\alpha,9\alpha}$=$J_{8\alpha,9\beta}$=7.4, H-8α), 3.01 (1H, d, $J_{2,3}$=5.5, H-2), 3.29 (1H, obs d, H-10a), 3.32 (3H, s, H_3-7), 3.38 (1H, obs m, H-8β), 3.53 (2H, t, $J_{3,4}$=$J_{4,5}$=9.6, H-4, and d, $^2J_{10a,10b}$=17.3, H-10b), 3.76 (1H, obs t, $J_{5,6ax}$=$^2J_{6ax,6eq}$=10.3, H-6ax), 3.80 (1H, td, $J_{4,5}$=$J_{5,6ax}$=10.2, $J_{5,6eq}$=3.7, H-5), 4.11 (2H, q, $J_{12,13}$=7.1, H_2-12), 4.19 (1H, dd, $^2J_{6ax,6eq}$=8.9, $J_{5,6eq}$=3.7, H-6eq), 4.54 (1H, s, H-1), 5.49 (1H, s, H-14), 7.24–7.35 (3H, ov m, *m*-Ph, *p*-Ph), 7.38–7.45

(2H, m, *o*-Ph) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$) δ_C 14.3 (CH_3, C-13), 25.9 (CH_2, C-9), 39.9 (CH, C-3), 51.2 (CH_2, C-8), 53.5 (CH_2, C-10), 55.0 (CH_3, C-7), 60.5 (CH_2, C-12), 62.6 (CH, C-5), 65.2 (CH, C-2), 69.2 (CH_2, C-6), 77.8 (CH, C-4), 97.7 (CH, C-1), 102.0 (CH, C-14), 126.2 (2×CH, *o*-Ph), 128.3 (2×CH, *m*-Ph), 129.0 (CH, *p*-Ph), 137.8 (C, Ph), 170.7 (C═O, C-11) ppm. MS (FAB$^+$) *m*/*z* 378 [MH]$^+$. $C_{20}H_{28}O_4N$ [MH]$^+$ requires *m*/*z* 378.1917; HR-FABMS found *m*/*z* 378.1917.

*3.4.3.7. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-2-N-(2-(4-hydroxy-phenyl)-1-(R)-methoxycarbonyl-ethyl)-mannopyranoside (**11i**).* Compound **8** as starting material. Purification by flash column chromatography using an eluant solvent gradient of 2:1 petrol–Et_2O to 1:1 petrol–Et_2O. Yield 41%, colourless syrup. R_f (1:1 petrol–Et_2O): 0.17. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H 1.83 (1H, m, H-9β), 1.98 (1H, ddd, $^2J_{9\alpha,9\beta}$=12.2, $J_{8\beta,9\alpha}$=7.1, $J_{8\alpha,9\alpha}$=3.6, H-9α), 2.49 (1H, dt, $J_{3,4}$=10.1, $J_{2,3}$=$J_{3,9\beta}$=5.9, H-3), 2.97 (1H, dd, $^2J_{11a,11b}$=14.0, $J_{10,11a}$=6.8, H-11a), 3.06 (1H, obs d, $J_{2,3}$=5.3, H-2), 3.10 (1H, dd, $^2J_{11a,11b}$=14.0, $J_{10,11b}$=7.9, H-11b), 3.20 (2H, ov m, H_2-8α,β), 3.39 (3H, s, H_3-7), 3.52 (1H, t, $J_{3,4}$=$J_{4,5}$=9.8, H-4), 3.66 (3H, s, H_3-13), 3.70 (1H, t, $J_{5,6ax}$=$^2J_{6ax,6eq}$=10.3, H-6ax), 3.74 (1H, t, $J_{10,11a}$=$J_{10,11b}$=7.4, H-10), 3.82 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.9, $J_{5,6eq}$=4.9, H-5), 4.28 (1H, dd, $^2J_{6ax,6eq}$=10.1, $J_{5,6eq}$=4.8, H-6eq), 4.65 (1H, s, H-1), 5.54 (1H, s, H-14), 6.74 (2H, br d, $J_{o\text{-}Ar,m\text{-}Ar}$=8.5, *o*-Ar), 7.10 (2H, dt, $J_{o\text{-}Ar,m\text{-}Ar}$=8.5, *m*-Ar), 7.36–7.43 (3H, ov m, *m*-Ph, *p*-Ph), 7.50–7.54 (2H, m, *o*-Ph) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$) δ_C 25.2 (CH_2, C-9), 36.4 (CH_2, C-13), 39.5 (CH, C-3), 44.6 (CH_2, C-8), 51.2 (CH_3, C-12), 55.0 (CH_3, C-7), 62.8 (CH, C-10), 62.9 (CH, C-5), 64.2 (CH, C-2), 69.3 (CH_2, C-6), 77.7 (CH, C-4), 97.5 (CH, C-1), 102.1 (CH, C-14), 115.2 (2×CH, *o*-Ar), 126.2 (2×CH, *o*-Ph), 128.3 (2×CH, *m*-Ph), 129.0 (CH, *p*-Ph), 130.1 (2×CH, *m*-Ar), 130.2 (CH, *i*-Ar), 137.7 (C, *i*-Ph), 154.3 (COH, *p*-Ar), 172.7 (C═O, C-12) ppm. MS (FAB$^+$) *m*/*z* 470 [MH]$^+$. $C_{26}H_{32}O_7N$ [MH]$^+$ requires *m*/*z* 470.2179; HR-FABMS found *m*/*z* 470.2179.

*3.4.3.8. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-2-N-hydroxyl-mannopyranoside (**11j**).* Compound **8** as starting material. Purification by flash column chromatography using 1:1 petrol–Et_2O. Yield 77%, colourless syrup. R_f (1:1 petrol–Et_2O)=0.17. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 1.88 (1H, dtd, $^2J_{9\alpha,9\beta}$=14.0, $J_{8\alpha,9\alpha}$=$J_{8\beta,9\alpha}$=8.3, $J_{3,9\alpha}$=1.9, H-9α), 2.01 (1H, m, $J_{3,9\beta}$=8.4, $J_{8\beta,9\beta}$=3.4, H-9β), 2.40 (1H, dddd, $J_{3,4}$=10.0, $J_{3,9\beta}$=8.2, $J_{2,3}$=6.7, $J_{3,9\alpha}$=1.8, 3-H), 2.78 (1H, td, $^2J_{8\alpha,8\beta}$=$J_{8\alpha,9\beta}$=10.6, $J_{8\alpha,9\alpha}$=8.1, H-8α), 2.92 (1H, d, *J*=6.5, H-2), 3.34 (3H, s, H_3-7), 3.37 (1H, obs t, $J_{3,4}$=$J_{4,5}$=10.1, H-4), 3.46 (1H, td, $^2J_{8\alpha,8\beta}$=$J_{8\beta,9\alpha}$=9.2, $J_{8\beta,9\beta}$=3.7, H-8β), 3.64 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.1, H-6ax), 3.74 (1H, td, $J_{4,5}$=$J_{5,6}$=10.1, $J_{5,6eq}$=4.8, H-5), 4.19 (1H, dd, $^2J_{6ax,6eq}$=9.9, $J_{5,6eq}$=4.7, H-6eq), 4.85 (1H, s, H-1), 5.44 (1H, s, H_3-7), 7.25–7.33 (3H, m, *m*-Ph, *p*-Ph), 7.37–7.42 (2H, m, *o*-Ph), 7.90 (1H, s, HO–N) ppm. ^{13}C NMR (75.0 MHz, $CDCl_3$) δ_C 24.3 (CH_2, C-9), 36.1 (CH, C-3), 55.6 (CH_3, C-7), 56.3 (CH_2, C-8), 62.9 (CH, C-5), 69.6 (CH_2, C-6), 70.6 (CH, C-2), 80.6 (CH, C-4), 98.0 (CH, C-1), 102.5 (CH, C-10), 126.5 (2×CH, *o*-Ph), 128.7 (2×CH, *m*-Ph), 129.4 (CH, *p*-Ph), 137.9 (C, Ph) ppm. MS (FAB$^+$) *m*/*z* 307 [MH]$^+$. $C_{16}H_{21}O_5N$ [M]$^+$ requires *m*/*z* 307.1420; HR-FABMS found *m*/*z* 307.1420.

*3.4.3.9. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-2-N-ethyl-(3R)-3-methyl-mannopyranoside (**11n**).* Compound **9** as starting material. Purification by flash column chromatography using 2:1 petrol–Et_2O. Yield 67%, colourless syrup. R_f (1:1 petrol–Et_2O)=0.20. ^{1}H NMR (250 MHz, $CDCl_3$) δ_H 1.10 (3H, t, $J_{11(a,b),12}$=5.0, H_3-12), 1.32 (1H, ddd, $^2J_{9\alpha,9\beta}$=13.8, $J_{8\alpha,9\beta}$=4.7, $J_{8\beta,9\beta}$=2.9, H-9β), 1.34 (3H, s, H_3-10), 2.04 (1H, ddd, $^2J_{8\alpha,8\beta}$=7.7, $J_{8\alpha,9\beta}$=4.7, $J_{8\alpha,9\alpha}$=2.2, H-8α), 2.38 (2H, m, H_2-11(a,b)), 2.61 (1H, ov ddd, $^2J_{9\alpha,9\beta}$=13.8, $J_{8\beta,9\alpha}$=4.9, $J_{8\alpha,9\alpha}$=2.2, H-9α), 2.70 (1H, d, $J_{1,2}$=4.0, H-2), 2.74 (1H, ddd, $^2J_{8\alpha,8\beta}$=7.9, $J_{8\beta,9\alpha}$=4.9, $J_{8\beta,9\beta}$=2.9, H–8β), 3.36 (3H, s, H_3-7), 3.43 (1H, d, $J_{4,5}$=9.5, H-4), 3.59 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.0, H-6ax), 3.89 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.9, $J_{5,6eq}$=4.9, H-5), 4.23 (1H, dd, $^2J_{6ax,6eq}$=10.3, $J_{5,6eq}$=5.1, H-6eq), 4.65 (1H, br s, H-1), 5.53 (1H, s, H-13), 7.38 (3H, m, *m*-Ph, *p*-Ph), 7.49 (2H, m, *o*-Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 13.0 (CH_3, C-10), 19.9 (CH_3, C-12), 35.3 (CH_2, C-9), 43.2 (C, C-3), 49.6 (CH_2, C-8), 51.1 (CH_2, C-11), 55.6 (CH_3, C-7), 59.8 (CH, C-5), 69.8 (CH_2, C-6), 73.5 (CH, C-2), 80.8 (CH, C-4), 99.4 (CH, C-1), 102.3 (CH, C-12), 126.6 (CH, *o*-Ph), 128.6 (CH, *o*-Ph′), 128.7 (4×CH, *m*-Ph, *m*-Ph′), 129.3 (CH, *p*-Ph), 129.7 (CH, *p*-Ph′), 137.1 (C, Ph), 138.1 (C, Ph′) ppm. MS (FAB$^+$) *m*/*z* 334 [MH]$^+$. $C_{19}H_{28}O_4N$ [MH]$^+$ requires *m*/*z* 334.2018; HR-FABMS found *m*/*z* 334.2018.

*3.4.3.10. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-(3R)-3-methyl-2-N-phenyl-mannopyranoside (**11o**).* Compound **9** as starting material. Purification by flash column chromatography using 1:1 petrol–Et_2O. Yield 49%, colourless syrup. R_f (1:1 petrol–Et_2O)=0.53. ^{1}H NMR (250 MHz, $CDCl_3$) δ_H 1.29 (1H, ddd, $^2J_{9\alpha,9\beta}$=13.6, $J_{8\alpha,9\beta}$=4.7, $J_{8\beta,9\beta}$=3.0, H-9β), 1.30 (3H, s, H_3-10), 2.08 (1H, ddd, $^2J_{8\alpha,8\beta}$=7.6, $J_{8\alpha,9\beta}$=4.8, $J_{8\alpha,9\alpha}$=2.2, H-8α), 2.38 (2H, m, H_2-11(a,b)), 2.52 (1H, ddd, $^2J_{9\alpha,9\beta}$=13.6, $J_{8\beta,9\alpha}$=5.0, $J_{8\alpha,9\alpha}$=2.2, H-9α), 2.64 (1H, m, H-8β), 3.27 (1H, d, $J_{4,5}$=9.5, H-4), 3.36 (3H, s, H_3-7), 3.53 (1H, d, $J_{1,2}$=4.1, H-2), 3.80 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.5, H-6ax), 3.89 (1H, dt, $J_{4,5}$=$J_{5,6ax}$=9.8, $J_{5,6eq}$=4.8, H-5), 4.22 (1H, dd, $^2J_{6ax,6eq}$=10.2, $J_{5,6eq}$=5.2, H-6eq), 4.65 (1H, br s, H-1), 5.43 (1H, s, H-11), 6.55 (2H, d, $J_{o\text{-}Ph',m\text{-}Ph'}$=8.2, *o*-Ph′), 6.70 (1H, t, $J_{m\text{-}Ph',p\text{-}Ph'}$=7.4, *p*-Ph′), 7.20 (2H, dd, $J_{o\text{-}Ph',m\text{-}Ph'}$=8.4, $J_{m\text{-}Ph',p\text{-}Ph'}$=7.3, *m*-Ph′), 7.30 (3H, m, *m*-PH, *p*-Ph), 7.45 (2H, m, *o*-Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 19.5 (CH_3, C-10), 35.3 (CH_2, C-9), 43.5 (C, C-3), 51.4 (CH_2, C-8), 55.5 (CH_3, C-7), 58.6 (CH, C-5), 67.2 (CH, C-2), 69.8 (CH_2, C-6), 78.7 (CH, C-4), 97.5 (CH, C-1), 102.3 (CH, C-11), 125.7 (CH, *o*-Ph′), 126.6 (CH, *o*-Ph), 128.5 (CH, *m*-Ph), 129.2 (CH, m-Ph′), 129.3 (CH, *p*-Ph), 129.7 (CH, *p*-Ph′), 138.6 (C, Ph), 149.1 (C, Ph′) ppm. MS (FAB$^+$) *m*/*z* 382 [MH]$^+$. $C_{23}H_{28}O_4N$ [MH]$^+$ requires *m*/*z* 382.2018; HR-FABMS found *m*/*z* 382.2018.

*3.4.3.11. Methyl-α-D-2-amino-2-N-benzyl-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-(3R)-3-methyl-mannopyranoside (**11p**).* Compound **9** as starting material. Purification by flash column chromatography using 1:1 petrol–Et_2O. Yield 86%, colourless syrup. R_f (1:1 petrol–Et_2O)=0.15. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H 1.22 (3H, s, H_3-10), 1.26 (1H, ddd, $^2J_{9\alpha,9\beta}$=14.7, $J_{8\alpha,9\beta}$,=12.1, $J_{8\beta,9\beta}$=2.6, H-9β), 2.08 (1H, ddd, $^2J_{9\alpha,9\beta}$=15.0, $J_{8\beta,9\alpha}$=4.9, $J_{8\alpha,9\alpha}$=2.1, H-9α), 2.63 (1H, td, $^2J_{8\alpha,8\beta}$=$J_{8\alpha,9\beta}$=13.2, $J_{8\alpha,9\alpha}$=2.0, H-8α), 2.73 (1H, ddd, $^2J_{8\alpha,8\beta}$=12.7, $J_{8\beta,9\alpha}$=4.9, $J_{9\beta,8\beta}$=2.9, H-8β), 3.13 (1H, d, $J_{4,5}$=9.5, H-4), 3.36 (3H, s, H_3-7), 3.43 (1H, d, $J_{1,2}$=4.1, H-2), 3.59 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.2, H-6ax), 3.68 (1H, d, $^2J_{11a,11b}$=12.8, H-11a), 3.72 (1H, d, $^2J_{11a,11b}$=12.8, H-11b), 3.89 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.9, $J_{5,6eq}$=4.9, H-5), 4.23 (1H, dd, $^2J_{6ax,6eq}$=10.3, $J_{5,6eq}$=5.1, H-6eq), 4.67 (1H, d, $J_{1,2}$=4.1, H-1), 5.43 (1H, s, H-12), 7.15–7.33 (8H, ov m, *m*-Ph, *p*-Ph, *o*-Ph′, *m*-Ph′ *p*-Ph′), 7.38–7.45 (2H, m, *o*-Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 12.5 (CH_3, C-10), 39.1 (CH_2, C-9), 42.0 (C, C-3), 44.3 (CH_2, C-8), 53.6 (CH_2, C-11), 55.9 (CH_3, C-7), 59.3 (CH, C-5), 69.6 (CH_2, C-6), 74.0 (CH, C-2), 83.9 (CH, C-4), 100.7 (CH, C-1), 102.2 (CH, C-12), 127.7 (CH, *o*-Ph), 127.9 (CH, *o*-Ph′), 128.7 (CH, *m*-Ph), 128.9 (CH, *m*-Ph′), 129.2 (CH, *p*-Ph), 129.5 (CH, *p*-Ph′), 137.1 (C, Ph), 138.1 (C, Ph′). MS (FAB$^+$) *m*/*z* 396 [MH]$^+$. $C_{24}H_{30}O_4N$ [MH]$^+$ requires *m*/*z* 396.2175; HR-FABMS found *m*/*z* 396.2174.

*3.4.3.12. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-(3R)-3-methyl-2-N-(phenylamino)-mannopyranoside (**11q**).* Compound **9** as starting material. Purification by flash column chromatography using 1:1 petrol–Et_2O. Yield 58%, colourless syrup. R_f (1:1 petrol–Et_2O)=0.47. ^{1}H NMR (250 MHz, $CDCl_3$) δ_H 1.30 (3H, s, H_3-10), 1.49 (1H, br s, H–N), 1.58 (1H, m, H-9β), 2.04 (1H, ddd, $^2J_{9\alpha,9\beta}$=13.5, $J_{8\beta,9\alpha}$=9.1, $J_{8\alpha,9\alpha}$=7.2, H-9α), 2.37 (1H, ddd, $^2J_{8\alpha,8\beta}$=9.8, $J_{8\alpha,9\beta}$=11.0, $J_{8\alpha,9\alpha}$=6.9, H-8α), 2.50 (1H, s, H-2), 3.28 (3H, s, H_3-7), 3.52 (1H, td, $^2J_{8\alpha,8\beta}$=$J_{8\beta,9\alpha}$=9.1, $J_{8\beta,9\beta}$=4.4, H-8β), 3.74 (1H, t,

$^2J_{6ax,6eq}$=$J_{5,6ax}$=10.1, H-6ax), 3.78 (1H, d, $J_{4,5}$=9.4, H-4), 3.85 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.8, $J_{5,6eq}$=4.9, H-5), 4.25 (1H, dd, $^2J_{6ax,6eq}$=10.1, $J_{5,6eq}$=4.7, H-6eq), 4.65 (1H, s, H-1), 5.60 (1H, s, H-11), 6.72 (1H, t, $J_{m\text{-}Ph',p\text{-}Ph'}$=7.3, *p*-Ph′), 6.84 (2H, d, $J_{m\text{-}Ph',p\text{-}Ph'}$=7.5, *m*-Ph′), 7.15 (2H, m, *o*-Ph′), 7.30 (3H, m, *m*-Ph, *p*-Ph), 7.45 (2H, m, *o*-Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 19.9 (CH_3, C-10), 34.1 (CH_2, C-9), 40.8 (C, C-3), 53.8 (CH_2, C-8), 55.5 (CH_3, C-7), 59.9 (CH, C-5), 67.4 (CH, C-2), 68.6 (CH_2, C-6), 82.1 (CH, C-4), 98.9 (CH, C-1), 102.4 (CH, C-11), 126.7 (CH, *o*-Ph), 128.7 (CH, *m*-Ph), 129.2 (CH, *p*-Ph), 129.4 (CH, *o*-Ph′), 129.5 (CH, *m*-Ph′), 131.3 (CH, *p*-Ph′), 138.4 (C, Ph), 149.5 (C, Ph′). MS (FAB^+) *m*/*z* 323 $[MH]^+$. $C_{23}H_{28}O_4N_2$ $[M]^+$ requires *m*/*z* 396.2049; HR-FABMS found *m*/*z* 396.2049.

*3.4.3.13. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-2-N-hydroxyl-(3R)-3-methyl-mannopyranoside (**11r**).* Compound **9** as starting material. Purification by flash column chromatography using 2:1 petrol–Et_2O. Yield 93%, colourless syrup. R_f (2:1 petrol–Et_2O)=0.21. ^{1}H NMR (250 MHz, $CDCl_3$) δ_H 1.28 (3H, s, H_3-10), 1.60 (1H, ddd, $^2J_{9\alpha,9\beta}$=13.5, $J_{8\alpha,9\beta}$=11.3, $J_{8\beta,9\beta}$=3.8, H-9β), 1.97 (1H, dt, $^2J_{9\alpha,9\beta}$=13.2, $J_{8(\alpha,\beta),9\alpha}$=8.5, H-9α), 2.62 (1H, s, H-2), 2.84 (1H, ddd, $J_{8\alpha,9\beta}$=11.3, $^2J_{8\alpha,8\beta}$=10.1, $J_{8\alpha,9\alpha}$=8.5, H-8α), 3.35 (3H, s, H_3-7), 3.42 (1H, obs td, $^2J_{8\alpha,8\beta}$=$J_{8\beta,9\alpha}$=9.1, $J_{8\beta,9\beta}$=3.4, H-8β), 3.50 (1H, d, $J_{4,5}$=9.8, H-4), 3.64 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.3, H-6ax), 3.87 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.8, $J_{5,6eq}$=5.2, H-5), 4.21 (1H, dd, $^2J_{6ax,6eq}$=10.2, $J_{5,6eq}$=5.2, H-6eq), 4.78 (1H, s, H-1), 5.42 (1H, s, H-11), 5.72 (1H, br s, HO–N), 7.35 (3H, m, *m*-Ph, *p*-Ph), 7.50 (2H, m, *o*-Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 13.0 (CH_3, C-10), 38.6 (CH_2, C-9), 42.0 (C, C-3), 54.3 (CH_3, C-7), 54.9 (CH_2, C-8), 58.4 (CH, C-5), 68.5 (CH_2, C-6), 74.5 (CH, C-2), 81.3 (CH, C-4), 100.4 (CH, C-1), 101.0 (CH, C-11), 125.2 (2×CH, *o*-Ph), 127.2 (2×CH, *m*-Ph), 128.0 (CH, *p*-Ph), 138.5 (C, Ph) ppm. MS (FAB^+) *m*/*z* 322 $[MH]^+$. $C_{17}H_{24}O_5N$ $[MH]^+$ requires *m*/*z* 322.1654; HR-FABMS found *m*/*z* 322.1654.

*3.4.3.14. Methyl-α-D-3-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-C,3-N-(ethane-1,2-diyl)-3-N-ethyl-allopyranoside (**15a**).* Compound **12** as starting material. Purification by flash column chromatography using 74:24:2 petrol–Et_2O–Et_3N. Yield 37%, colourless syrup. R_f (74:24:2 petrol–Et_2O–Et_3N)=0.27. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H 1.20 (3H, obs t, H_3-11), 1.50 (1H, dt, $^2J_{8\alpha,8\beta}$=14.6, $J_{2,8\alpha}$=$J_{8\alpha,9\alpha}$=7.4, H-8α), 1.62 (1H, dt $^2J_{8\alpha,8\beta}$=14.7, $J_{2,8\beta}$=$J_{8\beta,9\alpha}$=7.4, H-8β), 2.12 (1H, dt, $^2J_{9\alpha,9\beta}$=10.8, $J_{8\alpha,9\alpha}$=$J_{8\beta,9\alpha}$=7.4, H-9α), 2.44 (3H, m, H-2, H_2-10), 3.20 (1H, m, H-9β), 3.35 (3H, s, H_3-7), 3.65 (1H, dd, $J_{4,5}$=9.4, $J_{3,4}$=2.8, H-4), 3.73 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=9.9, H-6ax), 3.90 (1H, br s, H-3), 4.14 (1H, dt, $J_{4,5}$=$J_{5,6ax}$=9.9, $J_{5,6eq}$=5.1, H-5), 4.25 (1H, dd, $^2J_{6ax,6eq}$=9.6, $J_{5,6eq}$=5.1, H-6eq), 4.60 (1H, s, H-1), 5.70 (1H, s, H-12), 7.35 (3H, m, *m*-Ph, *p*-Ph), 7.50 (2H, m, *o*-Ph). ^{1}H NMR (100 MHz, $CDCl_3$) δ_C 11.6 (CH_3, C-11), 27.6 (CH_2, C-8), 43.8 (CH, C-2), 47.0 (CH_2, C-10), 52.0 (CH_2, C-9), 55.6 (CH_3, C-7), 58.5 (CH, C-5), 69.4 (CH and CH_2, C-3, C-6), 76.6 (CH, C-4), 102.3 (CH, C-1), 102.4 (CH, C-12), 126.3 (2×CH, *o*-Ph), 128.3 (2×CH, *m*-Ph), 129.1 (CH, *p*-Ph), 135.2 (C, *i*-Ph). MS (FAB^+) *m*/*z* 320 $[MH]^+$. $C_{18}H_{26}O_4N$ $[MH]^+$ requires *m*/*z* 320.1862; HR-FABMS found *m*/*z* 320.1862.

*3.4.3.15. Methyl-α-D-3-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-C,3-N-(ethane-1,2-diyl)-3-N-phenyl-allopyranoside (**15b**).* Compound **12** as starting material. Purification by flash column chromatography using 49:49:2 petrol–Et_2O–Et_3N. Yield 36%, colourless syrup. R_f (49:49:2 petrol–Et_2O–Et_3N)=1.7. ^{1}H NMR (250 MHz, $CDCl_3$) δ_H 1.75 (2H, m, H_2-8α,β), 2.28 (1H, ddd, $J_{2,8\alpha}$=8.3, $J_{2,3}$=6.2, $J_{2,8\beta}$=2.5, H-2), 3.20 (2H, t, $J_{2,3}$=$J_{3,4}$=7.1, H_2-9α,β), 3.40 (3H, s, H_3-7), 3.68 (1H, dd, $J_{4,5}$=9.6, $J_{3,4}$=2.8, H-4), 3.78 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6eq}$=9.9, H-6ax), 4.02 (1H, m, H-3), 4.22 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.9, $J_{5,6eq}$=5.1, H-5), 4.32 (1H, dd, *J* 5.1, 9.9, H-6eq), 4.60 (1H, s, H-1), 5.61 (1H, s, H-10), 6.65 (2H, t, $J_{o\text{-}Ph',m\text{-}Ph'}$=$J_{m\text{-}Ph',p\text{-}Ph'}$=7.3, *m*-Ph′), 6.78 (1H, t, $J_{m\text{-}Ph',p\text{-}Ph'}$=7.8, *p*-Ph′), 7.10 (2H, d, $J_{o\text{-}Ph',m\text{-}Ph'}$=7.3, *o*-Ph′), 7.40 (3H, m, *m*-Ph, *p*-Ph), 7.55 (2H, m, *o*-Ph) ppm. ^{1}H NMR (62.9 MHz, $CDCl_3$) δ_C 30.1 (CH_2, C-8), 42.6 (CH_2, C-9), 43.7 (CH, C-2), 55.9 (CH_3, C-7), 58.9 (CH, C-5), 68.7 (CH, C-3), 69.8 (CH_2, C6), 78.0 (CH, C4), 102.4 (CH, C7), 102.7 (CH, C1), 113.2 (2×CH, *o*-Ph′), 118.1 (2×CH, *m*-Ph′), 126.7 (2×CH, *o*-Ph), 128.7 (2×CH, *m*-Ph), 129.5 (CH, *p*-Ph′), 129.8 (CH, *p*-Ph), 137.7 (C, *i*-Ph), 148.2 (C, *i*-Ph′) ppm. MS (FAB^+) *m*/*z* 368 $[MH]^+$. $C_{22}H_{26}O_4N$ $[MH]^+$ requires *m*/*z* 368.1862; HR-FABMS found *m*/*z* 368.1862.

*3.4.3.16. Methyl-α-D-3-amino-3-N-benzyl-(R)-4,6-O-benzylidene-2,3-dideoxy-2-C,3-N-(ethane-1,2-diyl)-allopyranoside (**15c**).* Compound **12** as starting material. Purification by flash column chromatography using 49:49:2 petrol–Et_2O–Et_3N. Yield 62%, colourless syrup. R_f (49:49:2 petrol–Et_2O–Et_3N)=0.25. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H 1.77 (2H, m, H-8α, H-8β), 2.34 (1H, td, $^2J_{9\alpha,9\beta}$=$J_{8\beta,9\alpha}$=8.9, $J_{8\alpha,9\alpha}$=5.1, H-9α), 2.61 (1H, dtd, $J_{2,8\alpha}$=8.4, $J_{1,2}$=$J_{2,3}$=5.7, $J_{2,8\beta}$=3.2, H-2), 3.24 (1H, q, $^2J_{9\alpha,9\beta}$=$J_{8\alpha,9\alpha}$=$J_{8\beta,9\alpha}$=8.0, H-9β), 3.30 (1H, t, $J_{2,3}$=$J_{3,4}$=4.2, H-3), 3.42 (4H, s and d, $^2J_{10a,10b}$=13.1, H_3-7, H-10a), 3.76 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.5, H-6ax), 3.96 (1H, dd, $J_{4,5}$=9.5, $J_{3,4}$=3.5, H-4), 4.38 (1H, dd, $^2J_{6ax,6eq}$=10.3, $J_{5,6eq}$=5.5, H-6eq), 4.53 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.9, $J_{5,6eq}$=5.4, H-5), 4.60 (1H, d, $^2J_{10a,10b}$=13.5, H-10b), 4.67 (1H, d, $J_{1,2}$=5.3, 1-H), 5.55 (1H, s, H-11), 7.30 (6H, m, *m*-Ph, *p*-Ph, *m*-Ph′, *p*-Ph′), 7.43 (4H, m, *o*-Ph, *o*-Ph′) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$) δ_C 24.7 (CH_2, C-8), 43.9 (CH, C-2), 54.6 (CH_2, C-9), 55.1 (CH_3, C-7), 57.9 (CH, C-5), 60.7 (CH_2, C-10), 60.9 (CH, C-3), 69.8 (CH_2, C-6), 80.9 (CH, C-4), 99.6 (CH, C-1), 102.7 (CH, C-11), 126.3 (CH, *o*-Ph), 128.0 (2×CH, *o*-Ph′), 128.3 (2×CH, *m*-Ph), 128.8 (4×CH, *m*-Ph, *p*-Ph′), 129.0 (CH, *p*-Ph), 137.8 (2×C, Ph, Ph′) ppm. MS (FAB^+) *m*/*z* 382 $[MH]^+$. $C_{23}H_{28}O_4N$ $[MH]^+$ requires *m*/*z* 382.2018; HR-FABMS found *m*/*z* 382.2018.

*3.4.3.17. Methyl-α-D-3-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-C,3-N-(ethane-1,2-diyl)-3-N-(phenethyl)-allopyranoside (**15d**).* Compound **12** as starting material. Purification by flash column chromatography using 49:49:2 petrol–Et_2O–Et_3N. Yield 62%, colourless syrup. R_f (49:49:2 petrol–Et_2O–Et_3N)=0.44. ^{1}H NMR (250 MHz, $CDCl_3$) δ_H 1.80 (1H, m, H-8α), 1.99 (1H, m, H-8β), 2.50 (1H, dtd, $J_{2,8\alpha}$=8.3, $J_{2,3}$=$J_{2,8\beta}$=6.6, $J_{1,2}$=0.9, H-2), 2.9 (6H, m, H-9α, H-9β, H_2-10, H_2-11), 3.30 (3H, s, H-7), 3.30 (1H, m, H-3), 3.63 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=9.1, H-6ax), 3.71 (1H, m, H-4), 3.79 (1H,,td, $J_{4,5}$=$J_{5,6ax}$=9.1, $J_{5,6eq}$=4.3, H-5), 4.28 (1H, m, H-6eq), 4.49 (1H, s, H-1), 5.55 (1H, s, H-12), 7.02 (2H, m, *m*-Ph′), 7.15 (3H, m, *o*-Ph′, *p*-Ph), 7.40 (3H, m, *m*-Ph, *p*-Ph), 7.55 (2H, m, *o*-Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 24.9 (CH_2, C-8), 32.2 (CH_2, C-11), 41.2 (CH, C-2), 49.3 (CH_2, C-10), 52.7 (CH_3, C-7), 54.3 (CH_2, C-9), 58.2 (CH, C-5), 59.0 (CH, C-3), 67.3 (CH_2, C-6), 76.1 (CH, C-4), 98.5 (CH, C-1), 99.5 (CH, C-12), 123.7 (2×CH, *o*-Ph′), 124.2 (CH, 2×*m*-Ph′), 124.3 (CH, *p*-Ph′), 126.5 (2×CH, *o*-Ph), 126.7 (2×CH, *m*-Ph), 126.9 (CH, *p*-Ph), 135.6 (C, *i*-Ph′), 138.4 (C, *i*-Ph) ppm. MS (FAB^+) *m*/*z* 396 $[MH]^+$. $C_{24}H_{30}O_4N$ $[MH]^+$ requires *m*/*z* 396.2175; HR-FABMS found *m*/*z* 396.2175.

*3.4.3.18. Methyl-α-D-3-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-C,3-N-(ethane-1,2-diyl)-3-N-(phenylamino)-allopyranoside (**15e**).* Compound **12** as starting material. Purification by flash column chromatography using 74:24:2 petrol–Et_2O–Et_3N. Yield 72%, colourless syrup. R_f (74:24:2 petrol–Et_2O–Et_3N)=0.48. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H 1.70 (2H, m, H_2-8α,β), 2.51 (1H, m, H-2), 2.68 (1H, dd, $^2J_{9\alpha,9\beta}$=10.1, $J_{8\alpha,9\alpha}$=5.8, H-9α), 2.87 (1H, td, $^2J_{9\alpha,9\beta}$=$J_{8\alpha,9\beta}$ 9.8, $J_{8\beta,9\beta}$=5.6, H-9β), 3.32 (1H, t, $J_{2,3}$=$J_{4,5}$ H-3), 3.35 (3H, s, H_3-7), 3.65 (2H, m, H-4, H-6ax), 3.90 (1H, m, H-5), 4.30 (1H, dd, $^2J_{6ax,6eq}$=10.0, $J_{5,6eq}$=4.8, 6eq-H), 4.48 (1H, s, H-1), 5.60 (1H, s, H-10), 7.28 (2H, m, *o*-Ph′), 7.30 (3H, m, *m*-Ph′, *p*-Ph′), 7.35 (3H, m, *m*-Ph, *p*-Ph), 7.50 (2H, m, *o*-Ph) ppm. ^{13}C NMR (100 MHz, $CDCl_3$) δ_C 26.4 (CH_2, C-8), 43.1 (CH, C-2), 54.8 (CH_3, C-7), 58.9 (CH_2, C-9), 61.3 (CH, C-5), 61.9 (CH, C-3), 69.5 (CH_2, C-6), 78.8 (CH, C-4), 101.3 (CH, C-1), 102.7 (CH, C-10), 125.0 (2×CH, *o*-Ph′), 126.1 (2×CH, *m*-Ph′), 126.3 (CH, *p*-Ph′), 126.8 (2×CH, *o*-Ph), 128.2 (2×CH, *m*-Ph), 128.8 (CH, *p*-Ph), 135.2 (C, Ph′), 137.8 (C, Ph) ppm. MS (FAB^+) *m*/*z* 383 $[MH]^+$. $C_{22}H_{27}O_4N_2$ $[M]^+$ requires *m*/*z* 383.1971; HR-FABMS found *m*/*z* 383.1970.

*3.4.3.19. Methyl-α-D-3-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-C,3-N-(ethane-1,2-diyl)-3-N-hydroxyl-allopyranoside (**15f**).* Compound **12** as starting material. Purification by flash column chromatography using 49:49:2 petrol–Et_2O–Et_3N. Yield 44%, colourless syrup. R_f (65:33:2 Et_2O–petrol–Et_3N)=0.47. ^1H NMR (400 MHz, $CDCl_3$) δ_H 1.74–1.77 (2H, m, H_2-8α,β), 2.57 (1H, dtd, $J_{2,8\alpha}$=8.5, $J_{1,2}$=$J_{2,3}$=6.0, $J_{2,8\beta}$=1.8, H-2), 2.75 (1H, ddd, $J_{9\alpha,8\beta}$=11.2, $^2J_{9\alpha,9\beta}$=10.3, $J_{8\alpha,9\alpha}$=6.4, H-9α), 3.27 (1H, dd, $J_{2,3}$=6.3, $J_{4,3}$=4.2, H-3), 3.33 (3H, s, H_3-7), 3.51 (1H, td, $^2J_{9\alpha,9\beta}$=$J_{8\alpha,9\beta}$=9.4, $J_{8\beta,9\beta}$=5.4, H-9β), 3.66 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=9.4, H-6ax), 3.84 (1H, dd, $J_{4,5}$=9.4, $J_{3,4}$=4.2, H-4), 4.21 (2H, ov m, H-5, H-6eq), 4.46 (1H, d, $J_{1,2}$=5.7, H-1), 5.22 (1H, s, HO–N), 5.50 (1H, s, H-10), 7.23–7.35 (3H, m, *m*-Ph, *p*-Ph), 7.23–7.35 (2H, m, *o*-Ph) ppm. ^{13}C NMR (100.6 MHz, $CDCl_3$) δ_C 22.3 (CH_2, C-8), 41.3 (CH, C-2), 56.3 (CH_3, C-7), 56.8 (CH_2, C-9), 58.0 (CH, C-5), 66.2 (CH, C-3), 69.9 (CH_2, C-6), 79.5 (CH, C-4), 99.5 (CH, C-1), 102.9 (CH, C-10), 126.6 (2×CH, *o*-Ph), 128.7 (2×CH, *m*-Ph), 129.5 (CH, *p*-Ph), 138.0 (C, Ph) ppm. MS (FAB^+) *m*/*z* 307 $[MH]^+$. $C_{16}H_{22}O_5N$ $[MH]^+$ requires *m*/*z* 308.1498; HR-FABMS found *m*/*z* 308.1498.

*3.4.4. Removal of the hydroxyl group on compounds **11m** and **15g***

*3.4.4.1. Methyl-α-D-2-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-N,3-C-(ethane-1,2-diyl)-mannopyranoside (**11m**).* Compound **11j** (252 mg, 0.82 mmol) was dissolved in 1:1 methanol–water (2 mL). This solution was degassed with N_2 three times before adding palladium on carbon (5%) catalyst. The mixture was allowed to stir at rt for 1 h under H_2 atmosphere until TLC analysis showed no starting material. The catalyst was filtered off and washed with MeOH (10×2 mL). The solvent was removed under high vacuum, and FC using 12:12:1 petrol–Et_2O–Et_3N afforded 229 mg of **11m** (94% yield) as a colourless oil. R_f (12:12:1 petrol–Et_2O–Et_3N)=0.20. ^1H NMR (250 MHz, $CDCl_3$) δ_H 1.72 (1H, br s, H–N), 1.73 (1H, obs m, H-9β), 1.96 (1H, ddd, $^2J_{9\alpha,9\beta}$=12.5, $J_{8\beta,9\alpha}$=8.0, $J_{8\alpha,9\alpha}$=4.0, H-9α), 2.33 (1H, dt, $J_{3,4}$=9.9, $J_{2,3}$=$J_{3,9\beta}$=5.5, H-3), 2.96 (1H, td, $^2J_{8\alpha,8\beta}$=$J_{8\alpha,9\beta}$=10.4, $J_{8\alpha,9\alpha}$=4.1, H-8α), 3.09 (1H, obs dt, $^2J_{8\alpha,8\beta}$=10.6, $J_{8\beta,9\alpha}$=$J_{8\beta,9\beta}$=8.0, H-8β), 3.15 (1H, d, $J_{2,3}$=5.5, H-2), 3.34 (3H, s, H_3-7), 3.38 (1H, t, $J_{3,4}$=$J_{4,5}$=9.6, H-4), 3.65 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.0, H-6ax), 3.73 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.4, $J_{5,6eq}$=4.7, H-5), 4.20 (1H, dd, $^2J_{6ax,6eq}$=9.4, $J_{5,6eq}$=4.2, H-6eq), 4.60 (1H, s, H-1), 5.45 (1H, s, H-10), 7.25–7.33 (3H, m, *m*-Ph, *p*-Ph), 7.36–7.44 (2H, m, *o*-Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$) δ_C 28.1 (CH_2, C-9), 39.4 (CH, C-3), 44.0 (CH_2, C-8), 55.3 (CH_3, C-7), 62.5 (CH, C-2), 62.9 (CH, C-5), 69.7 (CH_2, C-6), 78.5 (CH, C-4), 99.9 (CH, C-1), 102.6 (CH, C-10), 128.5 (2×CH, *o*-Ph), 128.7 (2×CH, *m*-Ph), 129.3 (CH, *p*-Ph), 138.1 (C, Ph) ppm. MS (FAB^+) *m*/*z* 292 $[MH]^+$. $C_{16}H_{22}O_4N$ $[MH]^+$ requires *m*/*z* 292.1549; HR-FABMS found *m*/*z* 292.1549.

*3.4.4.2. Methyl-α-D-3-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-C,3-N-(ethane-1,2-diyl)-allopyranoside (**15g**).* Hydroxylamine **15f** (25 mg, 0.081 mmol) was dissolved in 3:1 MeOH–MeCN (1 mL). Molybdenum hexacarbonyl (32.3 mg, 1.22 mmol) was added and the solution heated to reflux until TLC showed no starting material. The reaction mixture was filtered through a silica gel plug and washed with CH_2Cl_2 (3×2 mL) and Et_3N (3×2 mL). This was further filtered through Celite and the solvents removed under high vacuum. Column chromatography on silica gel with 98:2 Et_2O–Et_3N yielded 20.2 mg (85% yield) of **15g** as a colourless syrup. R_f (98:2 Et_2O–Et_3N)=0.59. ^1H NMR (400 MHz, $CDCl_3$) δ_H 1.78 (1H, m, H-8α), 1.90 (1H, m, H-8β), 1.98 (1H, br s, H–N), 2.48 (1H, m, H-2), 2.96 (1H, td, $^2J_{9\alpha,9\beta}$=$J_{8\alpha,9\alpha}$=10.1, $J_{8\beta,9\alpha}$=4.6, H-9α), 3.20 (1H, ddd, $^2J_{9\alpha,9\beta}$=9.9 $J_{8\beta,9\beta}$=9.0 $J_{8\alpha,9\beta}$=6.4, H-9β), 3.35 (3H, s, H_3-7), 3.41 (1H, t, $J_{2,3}$=$J_{3,4}$=4.8, H-3), 3.73 (1H, t, $^2J_{6ax,6eq}$=$J_{5,6ax}$=10.1, 6ax-H), 3.87 (1H, dd, $J_{4,5}$=9.8, $J_{3,4}$=4.5, H-4), 4.14 (1H, td, $J_{4,5}$=$J_{5,6ax}$=9.9, $J_{5,6eq}$=5.0, H-5), 4.30 (1H, dd, $^2J_{6ax,6eq}$=10.1, $J_{5,6eq}$=5.0, H-6eq), 4.59 (1H, d, $J_{1,2}$=5.5, 1-H), 5.60 (1H, s, H-10), 7.35 (3H, s, *m*-Ph, *p*-Ph), 7.50 (2H, m, *o*-Ph) ppm. ^{13}C NMR (400 MHz, $CDCl_3$) δ_C 26.2 (CH_2, C-8), 42.8 (CH, C-2), 46.0 (CH_2, C-9), 55.9 (CH_3, C-7), 56.8 (CH, C-5), 57.7 (CH, C-3), 69.6 (CH_2, C-6), 78.8 (CH, C-4), 100.4 (CH, C-1), 102.6 (CH, C-10), 126.5 (2×CH, *o*-Ph), 128.2 (2×CH, *m*-Ph), 129.1 (CH, *p*-Ph), 137.6 (C, *i*-Ph) ppm. MS (FAB^+) *m*/*z* 292 $[MH]^+$. $C_{16}H_{22}O_4N$ $[MH]^+$ requires *m*/*z* 292.1549; HR-FABMS found *m*/*z* 292.1548.

*3.4.4.3. Synthesis of methyl-α-D-3-amino-(R)-4,6-O-benzylidene-2,3-dideoxy-2-C,3-N-(ethane-1,2-diyl)-3-N-hydroxyl-allopyranoside (**16**).* Compound **15f** (67 mg, 0.218 mmol) was dissolved in 80% aq AcOH (1 mL) and heated to reflux for 4 h. The solvent was removed in vacuo and the residue was dissolved in methanol (2 mL), and K_2CO_3 added. Column chromatography on silica gel with 49:49:2 petrol–Et_2O–Et_3N as the eluent yielded 21 mg of **15f** (0.096 mmol, 44% yield) as a colourless syrup. R_f 0.47, petroleum ether–diethyl ether (1:2), 1% triethylamine. ^1H NMR (300 MHz, $CDCl_3$) δ_H 1.65 (1H, m, H-8α), 1.82 (1H, m, $J_{8\beta,9\beta}$=4.3, H-8β), 2.43 (1H, dtd, $J_{2,8\alpha}$=9.2, $J_{1,2}$=$J_{2,3}$=5.6, $J_{2,8\beta}$=1.5, H-2), 2.77 (1H, ddd, $J_{9\alpha,8\beta}$=11.2, $^2J_{9\alpha,9\beta}$=9.9, $J_{8\alpha,9\alpha}$=7.0, H-9α), 3.22 (3H, s, H_3-7), 3.26 (1H, dd, $J_{2,3}$=6.4, $J_{4,3}$=2.8, H-3), 3.51 (1H, td, $^2J_{9\alpha,9\beta}$=$J_{8\alpha,9\beta}$=9.3, $J_{8\beta,9\beta}$=4.3, H-9β), 3.74 (1H, dd, $^2J_{6a,6b}$=11.8, $J_{5,6a}$=4.5, H-6a), 3.83 (2H, ov m, H-4, H-5), 3.87 (1H, dd, $^2J_{6a,6b}$=11.8, $J_{5,6b}$=2.1, H-6a), 4.42 (1H, d, $J_{1,2}$=5.2, H-1) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$) δ_C 22.3 (CH_2, C-8), 41.3 (CH, C-2), 56.3 (CH_3, C-7), 56.8 (CH_2, C-9), 58.0 (CH, C-5), 66.2 (CH, C-3), 69.9 (CH_2, C-6), 79.5 (CH, C-4), 99.5 (CH, C-1), 102.9 (CH, C-10), 126.6 (2×CH, *o*-Ph), 128.7 (2×CH, *m*-Ph), 129.5 (CH, *p*-Ph), 138.0 (C, Ph) ppm. MS (FAB^+) *m*/*z* 220 $[MH]^+$, $C_9H_{18}O_5N$ $[MH]^+$ requires *m*/*z* 220.1185; HR-FABMS found *m*/*z* 220.1185.

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