A new synthetic method for the preparation of amino sugars through an allyl cyanate-to-isocyanate rearrangement

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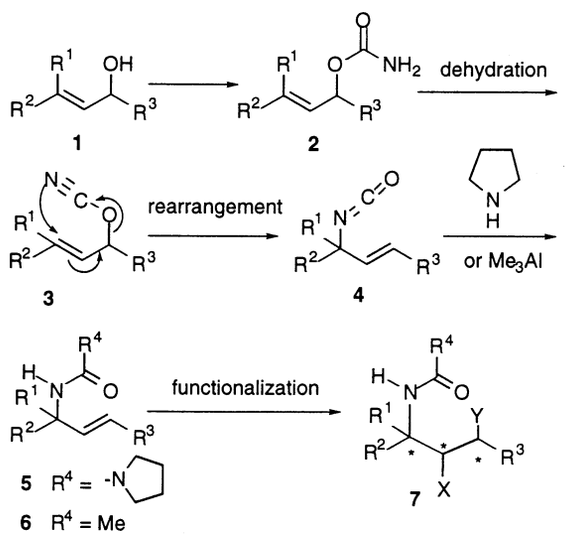
A new approach for the synthesis of amino sugars using an allyl cyanate-to-isocyanate rearrangement has been developed. The key feature in this method involves introduction of the nitrogen substituent into the pyranose framework by [3,3] sigmatropic rearrangement of an allyl cyanate. Subsequent functionalization of the allylamine moiety by either hydroxylation or cyclofunctionalization completes the synthesis of two amino sugars, D-perosamine and D-vicenisamine.

Over the last few years we have embarked on the development of the synthesis of allyl cyanate and its [3,3] sigmatropic rearrangement.[1] This reaction offers an efficient transformation of allyl alcohols into allylamines with high stereospecificity[2] even when the allyl alcohols are highly substituted at the γ-positions. We have already reported the synthesis of nitrogen-containing unsaturated sugars using an allyl cyanate-to-isocyanate rearrangement.[3] Further exploration in this field led us to a new strategy for the synthesis of amino sugars as shown in Scheme 1. The reaction sequence starts with dehydration of

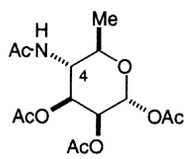


Scheme 1

the allyl carbamates **2**, to give the allyl cyanates **3** which then undergo a concerted [3,3] sigmatropic rearrangement below ambient temperature to provide the allyl isocyanates **4**. Since the allyl isocyanates **4** are prone to hydrolysis, they are transformed into stable derivatives, such as ureas[1] and acetamides.[4] Further double-bond functionalization of **5** and **6** gives the product **7** with three contiguous stereogenic centres as a structural element of amino sugars. Herein we describe the synthesis of two amino sugars, D-perosamine and D-vicenisamine, to test the idea of this strategy.

Synthesis of D-perosamine

4-Amino-4,6-dideoxy-D-mannose (D-perosamine) was first discovered in the polyene macrolide antibiotic perimycin[5] and was later recognized to be present in the lipopolysaccharide (LPS) of *Vivrio cholera* 569B (Inaba). Redmond isolated D-perosamine α-peracetate **8** by hydrolysing the LPS of *Vivrio cholera* 569B



8

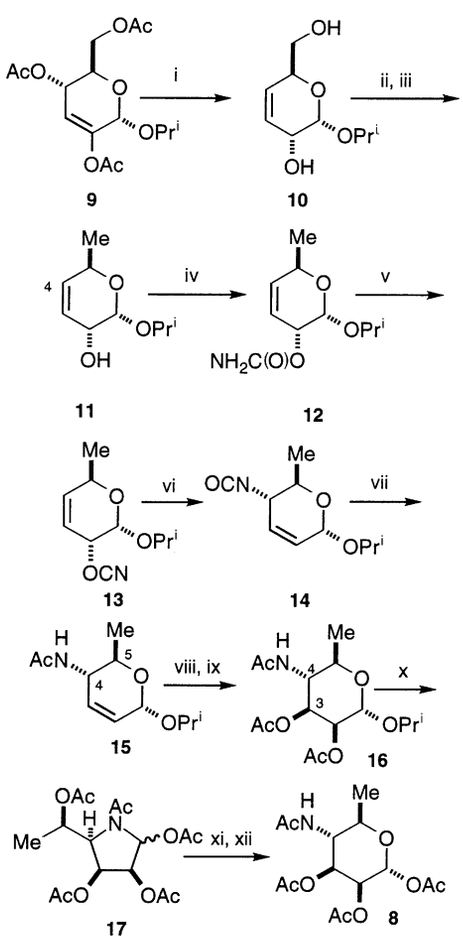
and acetylating the hydrolysis product.[6] Further investigation revealed that *N*-formylated-D-perosamine was a component of a repeating pentasaccharide unit in O-chains of the LPS of *Yersinia enterocolitica*[7] and *Brucella abortus*.[8] These findings established a molecular basis for extensive serological cross-reactivity between the various antigenic LPSs. Interest in the biological significance of naturally occurring derivatives of perosamine has prompted much work on their chemistry. Previous synthetic routes to perosamine used readily available monosaccharides as starting materials, for example, L-rhamnose by Brimacombe *et al.*[9] and D-mannose by Stevens and co-workers[10] and Eis *et al.*[11] These syntheses relied upon introducing the nitrogen substituent at C-4 either by replacement or epoxide cleavage with sodium azide. Our own synthetic route utilizes a D-glucose derivative as the starting material, and offers a new approach to the manipulation of the nitrogen substituent at C-4 by [3,3] sigmatropic rearrangement of an allyl cyanate.

We have chosen **9** as starting material because it is easily prepared from D-glucose on a multigram scale by simple synthetic operations. Treatment of **9** with lithium aluminium hydride gave the diol **10**,[12] which was selectively tosylated with toluene-*p*-sulfonyl chloride and tributylamine in dichloromethane. Use of tributylamine was crucial, because considerable amounts of a mixture of mono- and di-tosylate resulted when pyridine was used as base. Reduction of the mono-tosylate with lithium aluminium hydride in refluxing tetrahydrofuran furnished the 6-deoxy sugar **11** in 40% overall yield from **10**.

The introduction of a nitrogen substituent at the C-4 position was achieved by [3,3] sigmatropic rearrangement of an allyl cyanate. Thus, treatment of **11** with trichloroacetyl isocyanate followed by hydrolysis with potassium carbonate in aqueous methanol gave the carbamate **12**. Dehydration of **12** with tributylphosphine, carbon tetrabromide and triethylamine at −20 °C gave the allyl cyanate **13**, which underwent [3,3] sigmatropic rearrangement at room temperature after 60 min to afford the allyl isocyanate **14**. Since isolation of **14** using aqueous work-up caused a decrease in yield due to the high reactivity of the isocyanate function, the allyl isocyanate **14** was transformed *in situ* into the acetamide **15** by reaction with trimethylaluminium. The acetamide **15** was isolated in 55% overall yield from **11** after chromatographic purification. Use of triphenyl-

phosphine in the dehydration step as previously reported,[3] gave rise to difficulties in purification of the product **15** which had similar chromatographic behaviour to that of triphenylphosphine oxide. The stereochemistry of **15** was determined by ^{1}H NMR spectroscopy which showed a large vicinal coupling constant of 11 Hz between H-4 and H-5 ($J_{4,5}$) indicating that these protons were *trans*.

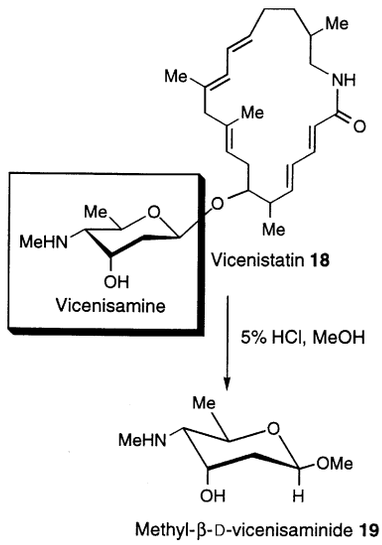
The stereochemistry of the osmylation of **15** was expected to be derived from β-attack, because of the shielding effect of the α-face as a result of the isopropyl glycoside linkage. In fact, dihydroxylation of **15** using a catalytic amount of osmium tetroxide together with *N*-methylmorpholine *N*-oxide as oxidant[13] proceeded at room temperature over 12.5 h to provide the diol which was successively treated with acetic anhydride in pyridine. After chromatographic purification, we obtained the acetate **16** exclusively in 87% overall yield from **15**. The stereochemistry of **16** was confirmed by ^{1}H NMR spectroscopy; the $J_{3,4}$ value of 11 Hz found for **16** indicates a *trans* relationship between H-3 and H-4. Finally, acetolysis of **16** using acetic anhydride in the presence of boron trifluoride–diethyl ether provided **17** which was successively hydrolysed in a mixture of water, triethylamine and methanol and then acetylated with acetic anhydride in pyridine to furnish the D-perosamine α-peracetate **8** and its β-isomer in 59% overall yield from **16**. The ^{1}H NMR spectroscopic results for our synthetic material **8** were consistent with those reported by Redmond.[6]



Scheme 2 *Reagents and conditions:* i, $LiAlH_4$, THF, 0 °C; ii, *p*-TsCl, Bu_3N, CH_2Cl_2; iii, $LiAlH_4$, THF, refluxed; iv, CCl_3CONCO, K_2CO_3, aq. MeOH; v, Bu_3P, CBr_4, Et_3N, −20 °C; vi, room temperature, 60 min; vii, Me_3Al; viii, OsO_4, NMO; ix, Ac_2O, Py; x, Ac_2O, $BF_3{\cdot}OEt_2$; xi, Et_3N, H_2O, MeOH; xii, Ac_2O, Py

Synthesis of D-vicenisamine

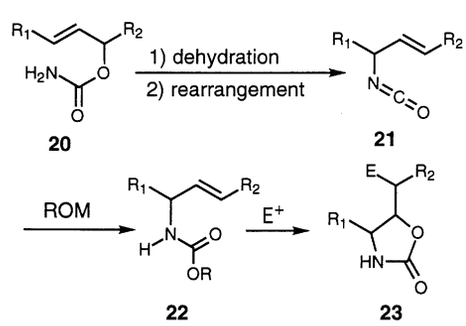
Vicenistatin **18** was isolated in 1993 from *Streptomyces* sp. HC 34 as a new antitumour antibiotic, and structual studies revealed that it contains the amino sugar vicenisamine as shown in Scheme 3.[14] A degradation study by Shindo *et al*. revealed



Scheme 3

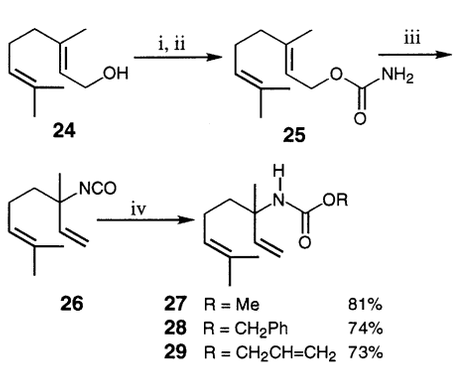
that methanolysis of **18** using methanol containing 5% hydrogen chloride yielded the methyl-β-D-vicenisaminide **19**. As an extension of our method for the synthesis of amino sugars, we identified methyl-β-D-vicenisaminide **19** as the second target molecule.

In attempting a synthesis of methyl-β-D-vicenisaminide **19**, we felt it necessary to develop a new synthetic method for the preparation of the allyl carbamate **22**; we had in mind an allyl cyanate-to-isocyanate rearrangement. We then planned a stereocontrolled cyclofunctionalization of the double bond of **22** *via* the heterocyclic intermediate **23** as depicted in Scheme 4.



Scheme 4

In this context, we initially explored the synthesis of the allyl methyl carbamates **22** (R = Me) by using geraniol as a model compound (see Scheme 5).

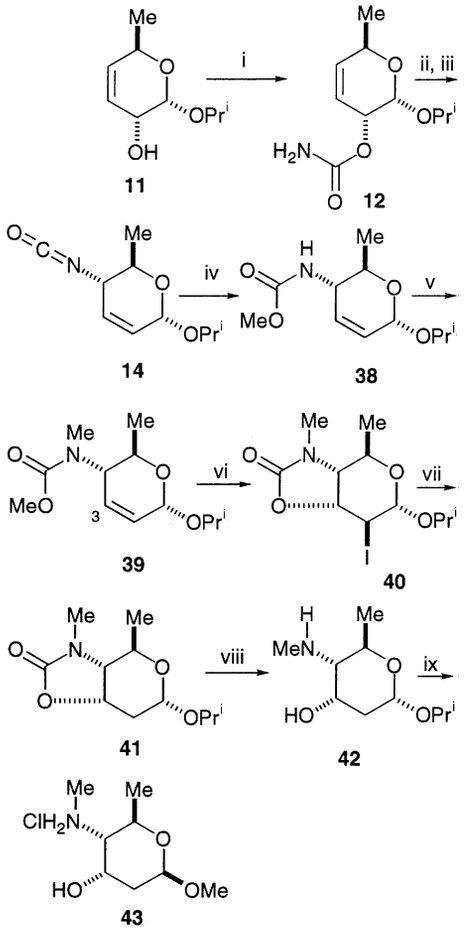


Scheme 5 *Reagents and conditions:* i, CCl_3CONCO, K_2CO_3, aq. MeOH; ii, Ph_3P, CBr_4, Et_3N; iii, ROH, Bu_3SnOR (R = Me, CH_2Ph, $CH_2CH{=}CH_2$); iv, MeOH

Reaction of geraniol **24** with trichloroacetyl isocyanate and hydrolysis provided the carbamate **25**, dehydration of which with triphenylphosphine and carbon tetrabromide in the presence of triethylamine at −20 °C gave the corresponding allyl cyanate which immediately rearranged into the allyl isocyanate **26**. Addition of an excess of methanol to the reaction mixture of **26** followed by stirring of the mixture overnight gave the methyl carbamate **27** in low yield (*ca*. 20%). The inefficiency of methanol in the presence of triethylamine emphasized the need for a more nucleophilic alkoxide in this transformation. We therefore launched a search for an alkoxide which was reactive to isocyanates, and finally decided upon the use of alkoxytributyltin as catalyst.[15] Accordingly, treatment of the reaction mixture of **26** with methanol in the presence of a catalytic amount of tributyltin methoxide (*ca*. 10 mol%) completed the transformation at room temperature for 3 h, and the resulting methyl carbamate **27** was isolated in 81% overall yield starting from geraniol **24**. Similar procedures using allyloxy- and benzyloxy-tributyltin gave the corresponding carbamates **28** and **29** in 74 and 73% yield, respectively.

We then tested the generality of this method and a summary of our results for several representative examples is given in Table 1. This synthetic method is especially useful for the preparation of sterically crowded allyl carbamates as exemplified in entries A and C. In the case of entries B, D and E, synthesis of the methyl carbamates was achieved without methoxytributyltin. Methoxytributyltin was necessary in the case of entries A and C where stereochemically congested allyl isocyanates were formed. The most impressive example in Table 1 is entry C where 3-methylcyclohex-2-enol **32** was converted into **33** in 70% yield. The efficiency of this method is evident when we remember that the [3,3] sigmatropic rearrangement of allyl imidates is limited by a competing ionic elimination in the case of 3-substituted cyclohex-2-enols.[16]

With the synthetic method shown in Scheme 5 in hand, we next explored the synthesis of vicenisamine as shown in Scheme 6 starting from the 6-deoxy-sugar **11**. Treatment of **11** with trichloroacetyl isocyanate and potassium carbonate in aqueous methanol provided the allyl carbamate **12**, dehydration of which, followed by a [3,3] sigmatropic rearrangement, yielded the allyl isocyanate **14**. This was subsequently treated with methanol in the presence of methoxytributyltin to furnish the methyl carbamate **38** in 74% overall yield from **11**. Methylation of **38** with methyl iodide and potassium hydride provided **39** in 93% yield. Introduction of a hydroxy group at C-3 was achieved through halogenocyclocarbamation.[17] Thus, treatment of **39** with bis(*sym*-collidine)iodine(I) hexafluorophosphate[18] gave the iodo carbamate **40** which was reduced with tributyltin hydride in refluxing benzene to furnish **41** in 94% overall yield from **39**. Hydrolysis of the resulting oxazolidone **41** with 5% aqueous potassium hydroxide yielded the 2-propyl-α-D-vicenisaminide **42** which was successively treated with a mixture of acetyl chloride and methanol to afford methyl-β-D-vicenisamine hydrochloride **43** and its α-isomer (2:1 ratio) in 54% combined yield. Synthetic methyl-β-D-vicenisamine hydrochloride **43** was identical in all respects (^{1}H NMR, ^{13}C NMR, TLC, $[\alpha]_D$) with that derived by degradation of natural vicenistatin.



Scheme 6 *Reagents and conditions:* i, CCl_3CONCO, K_2CO_3, aq. MeOH; ii, Ph_3P, CBr_4, Et_3N, −20 °C; iii, room temperature, 60 min; iv, MeOH, Bu_3SnOMe; v, KH, MeI; vi, (*sym*-collidine)$_2$I^I-PF_6; vii, Bu_3SnH; viii, 5% KOH, MeOH, H_2O; ix, MeOH, AcCl

Conclusions

A new synthetic method for the preparation of the amino sugar D-perosamine has been presented. We have also established a useful method for the preparation of allyl carbamates from allyl alcohols by [3,3] sigmatropic rearrangement, and this method was successfully applied to the synthesis of amino sugar D-vicenisamine. Further synthetic studies of nitrogen-containing natural products along these lines is now under study.

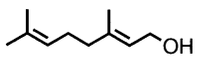
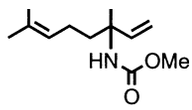
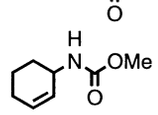
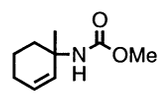
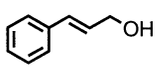
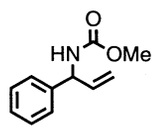
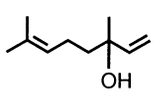
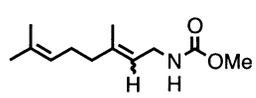
Experimental

Melting points were determined on a Yanaco MP-S3 melting point apparatus and are uncorrected. IR spectra were recorded using a JASCO FT/IR-7000S instrument for KBr discs unless otherwise stated and are reported in wavenumbers (cm^{-1}). ^{1}H NMR spectra were determined using a JEOL EX 270 spectrometer operating at 270 MHz, a Varian Gemini-2000 spectrometer operating at 300 MHz and a Bruker ARX-400 spectrometer operating at 400 MHz unless otherwise stated. ^{13}C NMR spectra were determined using a JEOL EX 270 spectrometer operating at 67.5 MHz, a Varian Gemini-2000 spectrometer operating at 75 MHz or a Bruker ARX-400 spectrometer operating at 100 MHz unless otherwise stated. Dilute solutions in [^{2}H]chloroform were used throughout unless stated otherwise, with tetramethylsilane as the internal standard. All *J* values are in Hz. High-resolution mass spectra (HRMS) were recorded on a JEOL DX-705L spectrometer and are reported in *m/z*. Elemental analyses were performed by Mr S. Kitamura in the Analytical Laboratory at the School of Agricultural Sciences, Nagoya University and is gratefully acknowledged by the authors. Optical rotations were measured on a JASCO DIP-370 digital polarimeter and are given in units of 10^{-1} deg cm^2 g^{-1}. All organic solutions during work-up were dried by brief exposure to anhydrous sodium sulfate. Column chromatography was performed on silica gel supplied by Cica-Merck (7734–5B). Preparative TLC was performed on plates prepared with a 2 mm layer of silica gel PF_{254} obtained from E. Merck (Art # 5744). Ether refers to diethyl ether.

Isopropyl 3,4,6-trideoxy-α-D-*erythro*-hex-3-enopyranoside 11

To a solution of the diol **10** (100 mg, 0.53 mmol) and tri-

Table 1 Synthesis of methyl allylcarbamates from allyl alcohols

Entry	Substrate		MeOH with or without Bu_3SnOMe	Product		Yield (%)[a]
A		**24**	MeOH with Bu_3SnOMe		**27**	81
B		**30**	MeOH		**31**	73
C		**32**	MeOH with Bu_3SnOMe		**33**	70
D		**34**	MeOH		**35**	72
E		**36**	MeOH		**37**	81

[a] Isolated yields after chromatographic purification from starting allyl alcohols.

butylamine (0.38 ml, 1.59 mmol) dissolved in dichloromethane (3 ml) cooled to 0 °C under a nitrogen atmosphere was added toluene-*p*-sulfonyl chloride (132 mg, 0.69 mmol). After being stirred at room temperature overnight, the mixture was diluted with water. The separated aqueous layer was extracted with ether, and the combined organic layer and extracts were washed with 1 M aqueous HCl, saturated aqueous sodium hydrogencarbonate and brine, and then dried and concentrated. Purification of the resulting residue by silica gel chromatography (ether–hexane, 2:1) gave isopropyl 6-*O*-*p*-tolylsulfonyl-3,4-dideoxy-α-D-*erythro*-hex-3-enopyranoside (111 mg, 61%) as a white powder, $[\alpha]_D^{28}$ −12.5 (*c* 0.65, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 3469, 2978, 1358, 1172, 1097, 1019, 968, 908, 820, 666 and 555; δ_H($CDCl_3$, 300 MHz) 1.17 [3H, d, *J* 6, CH(CH_3)$_2$], 1.20 [3H, d, *J* 6, CH(CH_3)$_2$], 2.46 (3H, s, ArCH_3), 3.93 [1H, sept, *J* 6, C*H*(CH_3)$_2$], 4.00–4.12 (3H, m, H-2, 6), 4.29–4.36 (1H, m, H-5), 4.99 (1H, d, *J* 4.5, H-1), 5.61 (1H, d, *J* 11, H-3 or 4), 5.77 (1H, d, *J* 11, H-3 or 4), 7.35 (2H, d, *J* 8, ArH) and 7.80 (2H, d, *J* 8, ArH); δ_C($CDCl_3$, 75 MHz) 21.5, 21.6, 23.1, 63.5, 66.3, 70.7, 71.0, 95.0, 124.7, 128.0, 129.8, 129.9, 133.1 and 144.9 [Found: C, 56.07; H, 6.59. Calc. for $C_{16}H_{22}O_6S$ (330.12): C, 56.13; H, 6.48%].

To a solution of lithium aluminium hydride (56 mg, 1.48 mmol) in tetrahydrofuran (10 ml) cooled to 0 °C under a nitrogen atmosphere was added a solution of the tosylate (170 mg, 0.50 mmol) in tetrahydrofuran (5 ml). The cooling bath was removed, and the reaction mixture was refluxed for 1 h. The excess of lithium aluminium hydride was decomposed by careful addition of ethyl acetate and water. Aqueous potassium sodium tartrate (15%) was added to the mixture and the aqueous layer was separated and extracted with ether. The combined organic layer and extracts were washed with aqueous saturated sodium hydrogen carbonate and brine, and then dried and concentrated. Purification of the residue by silica gel chromatography (ether–hexane, 3:7) furnished the 6-deoxy sugar **11** (55 mg, 65%) as a syrup, $[\alpha]_D^{25}$ +33.2 (*c* 1.13, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 3481, 2976, 2933, 1380, 1192, 1123, 1099, 1062, 1021, 965, 893, 862, 803 and 721; δ_H($CDCl_3$, 270 MHz) 1.24 [3H, d, *J* 6, CH(CH_3)$_2$], 1.25 (3H, d, *J* 7, H-6), 1.29 [3H, d, *J* 6, CH(CH_3)$_2$], 2.27 (1H, d, *J* 11, OH), 4.03 [1H, sept, *J* 6, C*H*(CH_3)$_2$], 4.16–4.37 (2H, m, H-2, 5), 5.07 (1H, d, *J* 4.5, H-1), 5.67 (1H, d, *J* 11, H-3 or 4) and 5.73 (1H, d, *J* 11, H-3 or 4); δ_C($CDCl_3$, 67.5 MHz) 20.5, 21.7, 23.1, 63.7, 63.9, 70.2, 95.2, 126.1 and 131.4 [Found: C, 62.49; H, 9.64. Calc. for $C_9H_{16}O_3$ (172.23): C, 62.75; H, 9.37%].

Isopropyl 4-acetamido-2,3,4,6-tetradeoxy-α-D-*erythro*-hex-2-enopyranoside 15

To a solution of **11** (1.13 g, 6.57 mmol) dissolved in dichloromethane (34 ml) was added trichloroacetyl isocyanate (0.94 ml, 7.91 mmol) dropwise at 0 °C. After being stirred at 0 °C for 2 h, the mixture was evaporated and the resulting residue was dissolved in a mixture of methanol (20 ml) and water (10 ml) at 0 °C. To this solution cooled to 0 °C was added potassium carbonate (2.70 g, 19.6 mmol) portionwise. The cooling bath was removed, and the mixture was stirred at room temperature for a further 2 h. After this the methanol was evaporated and the resulting aqueous phase was extracted with dichloromethane. The combined organic layer and extracts were dried and concentrated to afford the carbamate **12** (1.36 g, 96%), which was used for the next reaction without further purification.

To a solution of the carbamate **12** (500 mg, 2.33 mmol), tributylphosphine (1.45 ml, 5.82 mmol) and triethylamine (1.30 ml, 9.34 mmol) dissolved in dichloromethane (15 ml) cooled to −20 °C was added dropwise a solution of carbon tetrabromide (2.17 g, 6.54 mmol) in dichloromethane (2 ml). After the mixture had been stirred for 1 h at −20 °C, the cooling bath was removed. Stirring was continued for 1 h at −20 °C and then for 1 h at room temperature, after which a solution of trimethylaluminium (15% hexane solution; 10 ml) was added to the mixture. After being stirred for 2.5 min at room temperature, the mixture was treated with methanol cautiously. It was then concentrated and filtered through a short column of silica gel with ether. Concentration of the filtrate followed by purification of the residue by silica gel chromatography (ether) furnished the acetamide **15** (280 mg) in 55% overall yield from **11**, mp 135–136 °C; $[\alpha]_D^{25}$ +107.3 (*c* 0.71, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 3253, 2973, 1637, 1553, 1377, 1297, 1104, 1042, 1019 and 981; δ_H($CDCl_3$, 300 MHz) 1.18 [3H, d, *J* 6, CH(CH_3)$_2$], 1.24 [3H, d, *J* 6, CH(CH_3)$_2$], 1.25 [3H, d, *J* 6, H-6], 2.00 (3H, s, Ac), 3.74 (1H, dq, *J* 9.5 and 6, H-5), 3.98 [1H, sept, *J* 6, C*H*(CH_3)$_2$], 4.42 (1H, br t, *J* 10, H-4), 5.07 (1H, br s, H-1), 5.33 (1H, br d, *J* 9, AcN*H*), 5.73 (1H, br d, *J* 10, H-2 or 3) and 5.80 (1H, br d, *J* 10, H-2 or 3); δ_C($CDCl_3$, 67.5 MHz) 18.1, 21.8, 23.2, 23.6, 49.1, 66.1, 70.0,

92.4, 127.5, 131.4 and 170.1 [Found: C, 61.96; H, 9.19; N, 6.61. Calc. for $C_{11}H_{19}O_3N$ (213.14): C, 61.95; H, 8.98; N, 6.57%].

Isopropyl 4-acetamido-4,6-dideoxy-2,3,-diacetyl-α-D-manno-pyranoside 16

A solution of **15** (150 mg, 0.70 mmol), 4-methylmorpholine *N*-oxide (180 mg, 1.54 mmol) and osmium tetroxide (4% in water; 30 μl, 4.91 μmol) dissolved in acetone–water (1:2; 4.5 ml) was stirred at room temperature for 12.5 h after which it was treated with saturated aqueous sodium hydrogen sulfite and filtered through Hyflo Super-Cel®. The filtrate was concentrated under reduced pressure and the resulting crude diol and 4-dimethylaminopyridine (*ca*. 2 mg) were dissolved in a mixture of pyridine (10 ml) and acetic anhydride (5 ml). After being stirred at room temperature for 30 h, the reaction mixture was concentrated. The residue was dissolved in ethyl acetate and the solution washed with 1 M aqueous HCl, saturated aqueous sodium hydrogen carbonate and brine, and then dried and concentrated. Purification of the residue by silica gel chromatography (ether–hexane, 3:1 and 1:0) furnished **16** (203 mg, 87%) as white needles, mp 119–120 °C; $[\alpha]_D^{27}$ +97.9 (*c* 0.97, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 3284, 2978, 2360, 1750, 1663, 1559, 1373, 1316, 1245, 1172, 1133 and 1075; δ_H($CHCl_3$, 300 MHz) 1.15 [3H, d, *J* 6, CH(CH_3)$_2$], 1.21 [3H, d, *J* 6, CH(CH_3)$_2$], 1.26 (3H, d, *J* 6, H-6), 1.96 (3H, s, Ac), 2.03 (3H, s, Ac), 2.16 (3H, s, Ac), 3.74 (1H, dq, *J* 10.5 and 6, H-5), 3.90 [1H, sept, *J* 6, C*H*(CH$_3$)$_2$], 4.21 (1H, ddd, *J* 11, 10.5 and 9.5, H-4), 4.85 (1H, d, *J* 1.5, H-1), 5.08 (1H, dd, *J* 3.5 and 1.5, H-2), 5.24 (1H, dd, *J* 11 and 3.5, H-3) and 5.62 (1H, br d, *J* 9.5, AcNH); δ_C($CHCl_3$, 67.5 MHz) 17.6, 20.7, 20.9, 21.3, 23.1, 23.2, 51.6, 68.2, 68.9, 69.9, 70.1, 95.5, 170.3, 170.4 and 171.4 [Found: C, 54.31; H, 7.61; N, 4.11. Calc. for $C_{15}H_{25}O_7N$ (331.16): C, 54.37; H, 7.60; N, 4.23%].

D-Perosamine α-peracetate

To a solution of **16** (50 mg, 0.15 mmol) in acetic anhydride (3 ml) under a nitrogen atmosphere was added boron trifluoride–ether (100 μl, 0.81 mmol), and the reaction mixture was stirred for 2.5 h at 0 °C. After being further stirred for 2 h at room temperature, the reaction mixture was poured into saturated aqueous sodium hydrogen carbonate (50 ml) and ethyl acetate (20 ml). The aqueous layer was separated, extracted with ethyl acetate, and the combined organic layer and extracts were washed with saturated aqueous sodium hydrogen carbonate and brine, and then dried and concentrated. Purification of the residue by silica gel chromatography (ether–hexane, 4:1) furnished **17** (42 mg, 75%) as a mixture of two anomeric isomers (10:1).

To a solution of **17** (10 mg, 0.027 mmol) in methanol (0.4 ml) was added triethylamine (0.1 ml) and water (0.1 ml), and the reaction mixture was stirred at 60 °C for 1 h. The mixture was then evaporated under reduced pressure, and the resulting crude triol and 4-dimethylaminopyridine (*ca*. 1 mg) were dissolved in a mixture of pyridine (0.4 ml) and acetic anhydride (0.2 ml). After being stirred at room temperature for 2.5 h, the reaction mixture was concentrated, and purification of the residue by preparative TLC (ethyl acetate) furnished an inseparable mixure of α- and β-D-perosamine peracetate (α:β = 77:23; 7 mg, 78%); the ^{1}H NMR spectrum of the α-isomer **8** was identical with that reported by Redmond; ν_{max}(KBr)/cm^{-1} 3289, 3081, 2989, 2935, 2857, 1752, 1664, 1553, 1372, 1224, 1154, 1028 and 967; δ_H($CHCl_3$, 300 MHz) 1.28 (3H, d, *J* 6.5, H-6), 1.96 (3H, s, Ac), 2.05 (3H, s, Ac), 2.14 (3H, s, Ac), 2.18 (3H, s, Ac), 3.78 (1H, dq, *J* 10.5 and 6.5, H-5), 4.28 (1H, ddd, *J* 11, 10.5 and 10, H-4), 5.16 (1H, dd, *J* 3.5 and 1.5, H-2), 5.24 (1H, dd, *J* 11 and 3.5, H-3), 5.34 (1H, br d, *J* 10, AcN*H*), 6.04 (1H, d, *J* 1.5, H-1); [lit.,[6] 1.28 (3H, *J* 6.1, H-6), 1.97 (3H, NAc), 2.04 (3H, s, OAc), 2.13 (3H, OAc), 2.18 (3H, OAc), 3.82 (1H, m, *J* 10.2, H-5), 4.26 (1H, m, *J* 10, H-4), 5.10–5.40 (2H, m), 5.70 (1H, br, *J* 9.6, NH) and 6.03 (1H, d, *J* 1.6, H-1)] [Found: M$^+$, 332.1330. Calc. for $C_{14}H_{22}O_8N$: *M*$^+$, 332.1345].

General procedure for the synthesis of allyl carbamate; methyl *N*-(3,7-dimethylocta-1,6-dien-3-yl)carbamate 27

To a solution of geraniol **24** (1.44 g, 6.57 mmol) in dichloromethane (40 ml) cooled to 0 °C was added trichloroacetyl isocyanate (1.33 ml, 11.2 mmol). After being stirred at room temperature for 2 h, the solution was concentrated under reduced pressure. The resulting residue was dissolved in methanol (25 ml) and the solution cooled to 0 °C and treated with water (20 ml) and potassium carbonate (3.80 g, 27.5 mmol); the cooling bath was then removed. After being stirred at room temperature for 2.5 h, the mixture was evaporated to remove the methanol and the resulting aqueous phase was extracted with dichloromethane. The combined extracts were dried and concentrated to afford the carbamate **25** quantitatively (1.84 g), which was used in the next reaction without further purification.

To a solution of the carbamate **25** (100 mg, 0.51 mmol), triethylamine (0.28 ml, 2.01 mmol) and triphenylphosphine (348 mg, 1.33 mmol) in dichloromethane (4 ml) cooled to 0 °C was added a solution of carbon tetrabromide (472 mg, 1.42 mmol) in dichloromethane (0.5 ml) under a nitrogen atmosphere. After being stirred at room temperature for 1 h, the mixture was treated with tributyltin methoxide (20 μl, 70 μmol) in methanol (1 ml), and the stirring was continued for 3 h. After this the reaction mixture was diluted with ether (10 ml) and 1 M aqueous potassium fluoride (4 ml). After being stirred overnight, the solution was washed with 1 M aqueous HCl, saturated aqueous sodium hydrogen carbonate and brine and then dried and concentrated. Purification of the residue by silica gel chromatography (ether–hexane, 1:5) furnished **27** (87 mg, 81%); ν_{max}(KBr)/cm^{-1} 3349, 2972, 2926, 1722, 1504, 1453, 1257, 1086 and 916; δ_H($CDCl_3$, 300 MHz) 1.40 (3H, s, CH_3), 1.59 (3H, br s, C=CCH_3), 1.67 (3H, br s, C=CCH_3), 3.62 (3H, s, NCO$_2$CH_3), 4.75 (1H, br, NH), 5.05–5.13 (1H), 5.09 (1H, d, *J* 18, CH=CH_{trans}), 5.11 (1H, d, *J* 11, CH=CH_{cis}) and 5.89 (1H, dd, *J* 18 and 11, C*H*=CH$_2$); δ_C($CDCl_3$, 75 MHz) 17.5, 22.4, 24.4, 25.5, 39.6, 51.5, 56.3, 112.4, 123.9, 132.0, 143.2 and 155.4 [Found: C, 68.21; H, 10.01; N, 6.58. Calc. for $C_{12}H_{21}O_2N$ (211.16): C, 68.21; H, 10.02; N, 6.63%].

Benzyl *N*-(3,7-dimethylocta-1,6-dien-3-yl)carbamate 28

The carbamate **25** (100 mg) was transformed into the benzyl carbamate **28** (108 mg) in 74% overall yield from geraniol **24** by employing triphenylphosphine (348 mg, 1.33 mmol), carbon tetrabromide (472 mg, 1.42 mmol), dichloromethane (0.5 ml), triethylamine (0.28 ml, 2.01 mmol), dichloromethane (4 ml), benzyloxytributyltin (10 μl) and benzyl alcohol (1 ml); ν_{max}(KBr)/cm^{-1} 3349, 2971, 2929, 1713, 1500, 1455, 1252, 1071, 915, 739 and 697; δ_H($CDCl_3$, 300 MHz) 1.41 (3H, s, CH_3), 1.57 (3H, br s, C=CCH_3), 1.66 (3H, br s, C=CCH_3), 4.85 (1H, br, NH), 5.04–5.13 (5H), 5.90 (1H, dd, *J* 17.5 and 11, C*H*=CH$_2$) and 7.30–7.38 (5H, m, ArH); δ_C($CDCl_3$, 75 MHz) 17.5, 22.4, 24.4, 25.5, 39.5, 56.5, 66.1, 112.5, 123.9, 128.06, 128.12, 128.5, 132.0, 136.8, 143.2 and 154.6 [Found: C, 75.18; H, 8.80; N, 4.90.Calc. for $C_{18}H_{25}O_2N$ (287.19): C, 75.23; H, 8.77; N, 4.87%].

Allyl *N*-3,7-dimethylocta-1,6-dien-3-ylcarbamate 29

The carbamate **25** (100 mg) was transformed into **29** (87 mg) in 73% overall yield from geraniol **24** by employing triphenylphosphine (348 mg, 1.33 mmol), carbon tetrabromide (472 mg, 1.42 mmol), dichloromethane (0.5 ml), triethylamine (0.20 ml, 2.01 mmol), dichloromethane (4 ml), allyloxytributyltin (10 μl) and allyl alcohol (1 ml); ν_{max}(KBr)/cm^{-1} 3351, 2972, 2928, 2366, 1716, 1501, 1252, 1075 and 917; δ_H($CDCl_3$, 300 MHz) 1.41 (3H, s, CH_3), 1.59 (3H, br s, C=CCH_3), 1.67 (3H, br s, C=CCH_3), 4.52 (2H, br d, *J* 5.5, NCO$_2$CH_2), 4.84 (1H, br, NH), 5.06–5.12 (3H), 5.20 (1H, dq, *J* 10.5 and 1.5, OCH$_2$CH=CH_{cis}), 5.30 (1H, dq, *J* 17.5 and 1.5, OCH$_2$CH=CH_{trans}), 5.90 (1H, dd, *J* 17.5 and 11, C*H*=CH$_2$) and 5.93 (1H, ddd, *J* 17.5, 10.5 and 1.5, OCH$_2$-C*H*=CH$_2$); δ_C($CDCl_3$, 75 MHz) 17.5, 22.4, 24.4, 25.5, 39.5,

56.4, 64.9, 112.4, 117.5, 123.9, 132.0, 133.1, 143.2 and 154.5 [Found: C, 70.85; H, 9.78; N, 5.91. Calc. for $C_{14}H_{23}O_2N$ (237.17): C, 70.85; H, 9.77; N, 5.90%].

Methyl *N*-cyclohex-2-enylcarbamate 31

To a solution of cyclohex-2-enol **30** (200 mg, 2.04 mmol) in dichloromethane (10 ml) cooled to 0 °C was added trichloroacetyl isocyanate (0.29 ml, 2.45 mmol). After being stirred at room temperature for 2 h, the solution was concentrated under reduced pressure. The resulting residue was dissolved in methanol (5 ml) and the solution cooled to 0 °C. Water (5 ml) and potassium carbonate (844 mg, 6.12 mmol) were then added to it and the cooling bath was removed. After being stirred at room temperature for 2.5 h, the mixture was evaporated and the resulting aqueous phase was extracted with dichloromethane. The combined extracts were dried and concentrated to afford the carbamate quantitatively (288 mg), a portion of which was used in the next reaction without further purification.

To a solution of the carbamate (50 mg, 0.36 mmol), triethylamine (0.20 ml, 1.44 mmol) and triphenylphosphine (232 mg, 0.89 mmol) in dichloromethane (2.5 ml) cooled to 0 °C was added a solution of carbon tetrabromide (330 mg, 0.99 mmol) in dichloromethane (0.4 ml) under a nitrogen atomosphere. After being stirred at room temperature for 1 h, the mixture was treated with methanol (0.2 ml) and stirring was continued for 7 h. The reaction mixture was then washed with 1 M aqueous HCl, saturated aqueous sodium hydrogen carbonate and brine, and then dried and concentrated. Purification of the residue by silica gel chromatography (ether–hexane, 1:5) furnished **31** (43 mg, 73%); ν_{max}(KBr)/cm^{-1} 3329, 2940, 1700, 1534, 1455, 1310, 1241, 1070 and 1043; δ_H($CDCl_3$, 75 MHz) 3.67 (3H, br s, OCH_3), 4.71 (1H, br s, NH), 5.60 (1H, br d, *J* 10, olefinic) and 5.84 (1H, br d, *J* 10, olefinic); δ_C($CDCl_3$, 75 MHz) 19.5, 24.6, 29.6, 46.2, 51.8, 127.8, 130.8 and 156.4 [Found: MH^+, 156.1010. Calc. for MH^+, 156.1024 ($C_8H_{14}O_2N$].

Methyl *N*-(3-methylcyclohex-2-enyl)carbamate 33

Starting from 3-methylcyclohex-2-enol **32** (500 mg, 4.46 mmol), trichloroacetyl isocyanate (0.64 ml, 5.38 mmol), dichloromethane (20 ml), potassium carbonate (1800 mg, 13.0 mmol), methanol (14 ml) and water (15 ml), the corresponding carbamate was obtained in 91% yield. A portion of this carbamate (100 mg) was transformed into the methyl carbamate **33** (84 mg) in 70% overall yield from **32** by employing triphenylphosphine (422 mg, 1.61 mmol), carbon tetrabromide (600 mg, 1.81 mmol), dichloromethane (0.5 ml), triethylamine (0.36 ml, 2.59 mmol), dichloromethane (5 ml), tributyltin methoxide (20 μl, 70 μmol) and methanol (0.2 ml); ν_{max}(KBr)/cm^{-1} 3347, 2936, 1717, 1522, 1449, 1368, 1283, 1227, 1190, 1088, 1025 and 780; δ_H($CDCl_3$, 300 MHz) 1.41 (3H, s, CH_3), 3.61 (3H, s, NCO_2CH_3), 4.67 (1H, br, NH), 5.68 (1H, br d, *J* 10, olefinic) and 5.76 (1H, dt, *J* 10 and 3.5, olefinic); δ_C($CDCl_3$, 75 MHz) 18.9, 24.7, 27.0, 34.5, 51.2, 51.3, 128.7, 132.4 and 155.3 [Found: C, 63.97; H, 8.94; N, 8.05. Calc. for $C_9H_{15}O_2N$ (169.11): C, 63.88; H, 8.93; N, 8.23%].

Methyl *N*-(1-phenylprop-2-enyl)carbamate 35

Starting from 3-phenylprop-2-en-1-ol **34** (200 mg, 1.49 mmol), trichloroacetyl isocyanate (0.22 ml, 1.85 mmol), dichloromethane (7.5 ml), potassium carbonate (620 mg, 4.49 mmol), methanol (5 ml) and water (5 ml), the corresponding carbamate was obtained quantitatively (267 mg). A portion of this carbamate (50 mg) was transformed into **35** (39 mg) in 72% overall yield from **34** by employing triphenylphosphine (185 mg, 0.71 mmol), carbon tetrabromide (263 mg, 0.79 mmol), dichloromethane (0.4 ml), triethylamine (0.16 ml, 1.15 mmol), dichloromethane (2 ml) and methanol (0.15 ml); ν_{max}(KBr)/cm^{-1} 3321, 3032, 2955, 1701, 1534, 1456, 1243, 1194, 1080, 1038, 993, 926, 843, 764 and 700; δ_H($CDCl_3$, 300 MHz) 3.61 (3H, s, NCO_2CH_3), 5.03 (1H, br, NH), 5.24 (1H, br d, *J* 17.5, CH=CH_{trans}), 5.25 (1H, br d, *J* 10, CH=CH_{cis}), 6.01 (1H, ddd, *J* 17.5 and 10 and 5.5, C*H*=CH_2), 7.25–7.39 (5H, m, ArH); δ_C($CDCl_3$, 75 MHz) 52.2, 57.0, 115.7, 127.0, 127.7, 128.7, 137.7, 140.8 and 156.3 [Found: C, 69.19; H, 6.77; N, 7.32. Calc. for $C_{11}H_{13}O_2N$ (191.09): C, 69.09; H, 6.85; N, 7.32%].

Methyl *N*-(3,7-dimethylocta-2,6-dienyl)carbamate 37

Starting from linalool **36** (200 mg, 1.30 mmol), trichloroacetyl isocyanate (0.19 ml, 1.60 mmol), dichloromethane (6.5 ml), potassium carbonate (540 mg, 3.91 mmol), methanol (5 ml) and water (5 ml), the corresponding carbamate was obtained quantitatively (254 mg). A portion of this carbamate (50 mg) was transformed into **37** (44 mg) in 81% overall yield from linalool **36** as an inseparable mixture by employing triphenylphosphine (166 mg, 0.63 mmol), carbon tetrabromide (236 mg, 0.71 mmol), dichloromethane (0.5 ml), triethylamine (0.14 ml, 1.01 mmol), dichloromethane (2 ml) and methanol (0.15 ml).

Isopropyl 2,3,4,6-tetradeoxy-4-methoxycarbonylamino-α-D-*erythro*-hex-2-enopyranoside 38

To a solution of **12** (1200 mg, 5.58 mmol) and triphenylphosphine (3670 mg, 14.0 mmol) in dichloromethane (36 ml) cooled to −20 °C under a nitrogen atmosphere was added triethylamine (3.12 ml, 22.4 mmol) and carbon tetrabromide (5200 mg, 15.7 mmol) in dichloromethane (3 ml). After being stirred at 0 °C for 1 h, the mixture was treated with a solution of tributyltin methoxide (100 μl, 0.35 mmol) in methanol (4 ml) and then further stirred, first at 0 °C for 2 h and then at room temperature for 30 min. The resulting reaction mixture was washed with 1 M aqueous HCl, aqueous saturated sodium hydrogen carbonate and brine and then dried and concentrated. Purification of the resulting residue by silica gel chromatography (ether–hexane, 1:5 and 1:1) furnished the methyl carbamate **38** (980 mg, 74%), mp 86–88 °C; $[\alpha]_D^{26}$ +102 (*c* 1.05, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 3293, 2972, 1709, 1546, 1467, 1324, 1284, 1245, 1198, 1047, 840 and 728; δ_H($CDCl_3$, 270 MHz) 1.16 [3H, d, *J* 6, $CH(CH_3)_2$], 1.22 [3H, d, *J* 6, $CH(CH_3)_2$], 1.26 (3H, d, *J* 6, H-6), 3.65–3.78 (1H, m, H-5), 3.68 (3H, s, NCO_2CH_3), 3.96 [1H, sept, *J* 6, $CH(CH_3)_2$], 4.08 (1H, t, *J* 10, H-4), 4.55 (1H, br d, *J* 10, NH), 5.05 (1H, s, H-1) and 5.75–5.78 (2H, m, H-2,5); δ_C($CDCl_3$, 75 MHz) 18.0, 21.8, 23.6, 51.1, 52.1, 66.4, 70.2, 92.4, 127.6, 131.7 and 156.9 [Found: C, 57.61; H, 8.51; N, 6.03. Calc. for $C_{11}H_{19}O_4N$ (229.13): C, 57.61; H, 8.36; N, 6.11%].

Isopropyl 2,3,4,6-tetradeoxy-4-(*N*-methoxycarbonyl-*N*-methylamino)-α-D-*erythro*-hex-2-enopyranoside 39

To a suspension of potassium hydride (35% wt. dispersion in mineral oil, washed twice with hexane before use; 822 mg, 7.18 mmol) in tetrahydrofuran (9 ml) under a nitrogen atmosphere was added methyl iodide (1.98 ml, 31.2 mmol) and a solution of **38** (716 mg, 3.13 mmol) in tetrahydrofuran (6 ml). Stirring was continued first at 0 °C for 1.5 h and then at room temperature for 1 h. The mixture was treated with water cautiously, and then concentrated. The aqueous phase was separated and extracted with dichloromethane and the combined extracts were dried and concentrated to afford a residue which was purified by silica gel chromatography (ether–hexane, 1:1) to give the *N*-methylcarbamate **39** (703 mg, 93%). NMR analysis of **39** proved to be difficult, because it existed as a mixture of two rotational isomers; $[\alpha]_D^{27}$ +50.0 (*c* 1.16, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 2976, 1709, 1457, 1390, 1305, 1150, 1016, 772 and 729 [Found: C, 59.44; H, 8.73; N, 5.77. Calc. for $C_{12}H_{21}O_4N$ (243.15): C, 59.22; H, 8.70; N, 5.76%].

Isopropyl 3′-methyl-2′-oxo-3,4-(1′-oxa-3′-azapropano)-2,4,6-trideoxy-2-iodo-α-D-altropyranoside 40

To a solution of **39** (584 mg, 2.40 mmol) in dichloromethane (34 ml) was added bis(*sym*-collidine)iodine(I) hexafluorophosphate (2470 mg, 4.81 mmol) under a nitrogen atmosphere. Additional bis(*sym*-collidine)iodine(I) hexafluorophosphate

(494 mg, 0.96 mmol) was added every 24 h over 4 days at room temperature. The resulting reaction mixture was washed with 1 M aqueous HCl, aqueous saturated sodium hydrogen carbonate and brine and then dried and concentrated. Purification of the resulting residue by silica gel chromatography (ether–hexane, 1:1) furnished **40** (714 mg, 84%, 94% based on recovery) and recovered **39** (62 mg), mp 96–97 °C; $[\alpha]_D^{27}$ −24.5 (*c* 0.82, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 2976, 1764, 1427, 1377, 1201, 1109, 1045, 968, 835, 762 and 669; δ_H($CDCl_3$, 270 MHz) 1.17 [3H, d, *J* 6, $CH(CH_3)_2$], 1.19 [3H, d, *J* 6, $CH(CH_3)_2$], 1.38 (3H, d, *J* 6, H-6), 2.86 (3H, s, NCH_3), 3.52 (1H, t, *J* 8.5, H-4), 3.89 [1H, sept, *J* 6, $CH(CH_3)_2$], 3.96–4.06 (1H, m, H-5), 4.01 (1H, dd, *J* 10.5 and 6.5, H-2), 4.71 (1H, dd, *J* 10.5 and 8.5, H-3) and 5.18 (1H, d, *J* 6.5, H-1); δ_C($CDCl_3$, 75 MHz) 20.3, 21.3, 23.3, 25.3, 30.9, 62.8, 65.3, 70.7, 75.7, 101.2 and 157.4 [Found: C, 37.20; H, 5.11; N, 3.76. Calc. for $C_{11}H_{18}O_4NI$ (355.03): C, 37.18; H, 5.11; N, 3.94%].

Isopropyl 3′-methyl-2′-oxo-3,4-(1′-oxa-3′-azapropano)-2,4,6-trideoxy-α-D-ribohexapyranoside 41

A solution of **40** (500 mg, 1.41 mmol), tributyltin hydride (1.50 ml, 5.58 mmol) and 2,2′-azoisobutyronitrile (*ca*. 2 mg) in benzene (30 ml) was refluxed for 1.5 h under a nitrogen atmosphere. Benzene was removed by evaporation from the mixture, and the resulting residue was purified by silica gel chromatography (ether–hexane, 0:1, 1:1, 2:1 and 4:1) to give the oxazolidone **41** quantitatively (327 mg), $[\alpha]_D^{26}$ +79.7 (*c* 1.08, $CHCl_3$); ν_{max}-(KBr)/cm^{-1} 2975, 1762, 1429, 1382, 1271, 1109 and 1026; δ_H($CDCl_3$, 300 MHz) 1.14 [3H, d, *J* 6, $CH(CH_3)_2$], 1.20 [3H, d, *J* 6, $CH(CH_3)_2$], 1.36 (3H, d, *J* 6, H-6), 1.89 (1H, ddd, *J* 14.5, 10.5 and 7.5, H-2), 2.29 (1H, ddd, *J* 14.5, 6 and 5.5, H-2), 2.89 (3H, s, NCH_3), 3.42 (1H, t, *J* 8.5, H-4), 3.92 [1H, sept, *J* 6, $CH(CH_3)_2$], 3.93–4.03 (1H, m, H-5), 4.56 (1H, ddd, *J* 10.5, 8.5 and 5.5, H-3) and 4.96 (1H, dd, *J* 7.5 and 6, H-1); δ_C($CDCl_3$, 75 MHz) 20.3, 21.5, 23.4, 30.8, 31.5, 62.1, 65.2, 69.2, 69.7, 93.6 and 158.5 [Found: C, 57.68; H, 8.47; N, 6.13. Calc. for $C_{11}H_{19}O_4N$ (229.13): C, 57.61; H, 8.36; N, 6.11%].

Methyl β-D-vicenisaminide 43

A solution of **41** (30 mg, 0.13 mmol) dissolved in 5% aqueous potassium hydroxide (0.87 ml) was refluxed for 30 min after which it was cooled, neutralized by addition of solid CO_2 and then concentrated *in vacuo*. The resulting residue was extracted with hot ethyl acetate, and the combined extracts were then concentrated to give crude **42**. This was successively dissolved in methanol containing hydrogen chloride [prepared by addition of acetyl chloride (0.70 ml, 9.84 mmol) to methanol (8 ml) at 0 °C]. The reaction mixture was refluxed under a nitrogen atmosphere for 1 h, and then concentrated. The resulting residue was purified by silica gel chromatography (chloroform–methanol, 10:1) to furnish the methyl D-vicenisaminide (α:β = 1:2; 15 mg, 54%). A portion of methyl β-D-vicenisaminide **43** was isolated in this purification procedure, mp 181–183 °C (decomp.) (lit.,[14] 183–185 °C); $[\alpha]_D^{26}$ −5.7 (*c* 0.28, MeOH) (natural sample, $[\alpha]_D^{29}$ −3.1, *c* 0.33, MeOH); δ_H(CD_3OD, 400 MHz) 1.36 (3H, d, *J* 6.4, H-6), 1.67 (1H, ddd, *J* 14, 9.2 and 2.9, H-2), 2.03 (1H, ddd, *J* 14, 4.2 and 2.3, H-2), 2.73 (3H, s, NCH_3), 2.89 (1H, dd, *J* 9.3 and 3.2, H-4), 3.44 (3H, s, OCH_3), 4.00 (1H, dq, *J* 9.3 and 6.4, H-5), 4.35 (1H, ddd, *J* 4.2, 3.2 and 2.9, H-3) and 4.75 (1H, dd, *J* 9.2 and 2.3, H-1), [lit.,[14] 1.36 (d, *J* 6.5, H-6), 1.67 (ddd, *J* 14.5, 9.5 and 2.8, H-2), 2.03 (ddd, *J* 14.5, 4.2 and 2.5, H-2), 2.74 (s, NCH_3), 2.91 (dd, *J* 9.0 and 2.8, H-4), 3.44 (s, OCH_3), 4.01 (1H, dq, *J* 9.0 and 6.5, H-5), 4.35 (ddd, *J* 4.2, 3.0 and 2.8, H-3), 4.75 (dd, *J* 9.5 and 2.5, H-1)]; δ_C(CD_3OD, 100 MHz) 18.7, 31.4, 38.8, 56.7, 62.5, 63.4, 68.1 and 100.4, (lit.,[14] δ_C 18.7, 31.3, 38.8, 56.7, 62.4, 63.3, 68.0 and 100.4) [Found: MH^+, 176.1280. Calc. for MH^+, 176.1287 ($C_8H_{18}O_3N$)].

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