A Ramberg–Bäcklund Approach to the Synthesis of *C*-Glycosides, *C*-Linked Disaccharides, and *C*-Glycosyl Amino Acids

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Synthetic applications of *exo*-glycals, derived from *S*-glycoside dioxides using the Meyers variant of the Ramberg–Bäcklund rearrangement, are described. These include a formal synthesis of a β-glycosidase inhibitor **12** and an efficient route to spirocyclic glucose derivatives **17** and **18**. The synthesis of *C*-linked disaccharides **24**, **31**, and **38** and the *C*-glycosyl amino acid **49** using the Ramberg–Bäcklund rearrangement is also reported.
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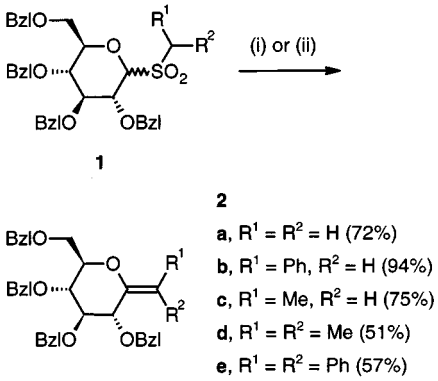
Introduction

Carba-analogues of glycosides and glycoconjugates have attracted considerable interest over the last three decades in view of their hydrolytic stability and potential enzyme inhibitory properties. Virtually the complete repertoire of carbon–carbon bond-forming reactions has been deployed for the synthesis of this class of compound and several reviews have been published on the subject.[1] Recent work in our laboratory has focussed on the use of the Ramberg–Bäcklund rearrangement of *S*-glycoside dioxides **1** as the key step in the formation of *exo*-glycals **2**,[2a,2c] (Scheme 1). Although the parent *exo*-methylenic derivatives such as **2a** are also accessible by titanium-mediated methylenation of the corresponding lactones,[3,4] it is the availability of tri- and tetra-substituted alkenes from the Ramberg–Bäcklund approach which offers an advantage over other routes. Herein we report synthetic applications of some of these alkenes and other more general extensions and applications of this methodology.



Scheme 1. Reagents: (i) KOH, CCl_4, aq. *t*BuOH, 60 °C; (ii) KOH/Al_2O_3, CBr_2F_2, *t*BuOH, DCM, 5 °C to room temp. Bzl = benzyl; DCM = dichloromethane

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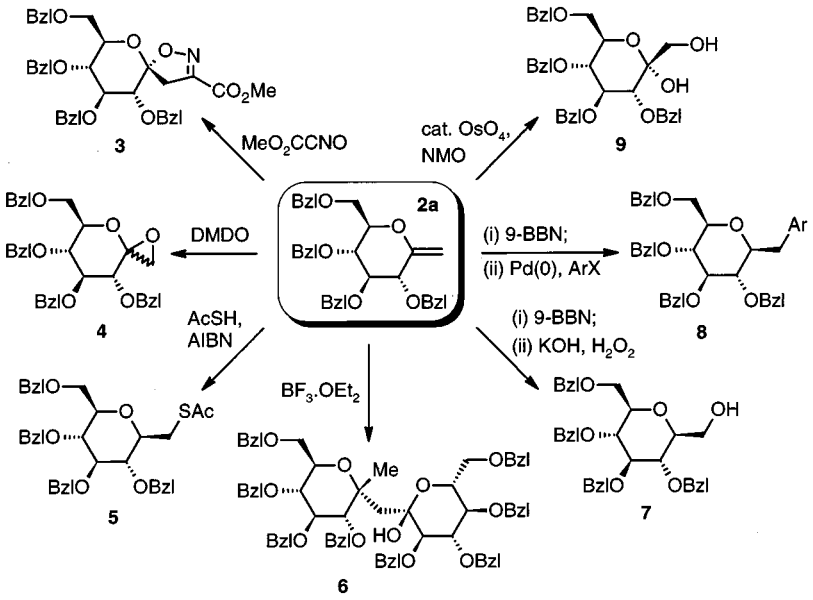
Results and Discussion

Formal Synthesis of Glycosidase Inhibitor 12

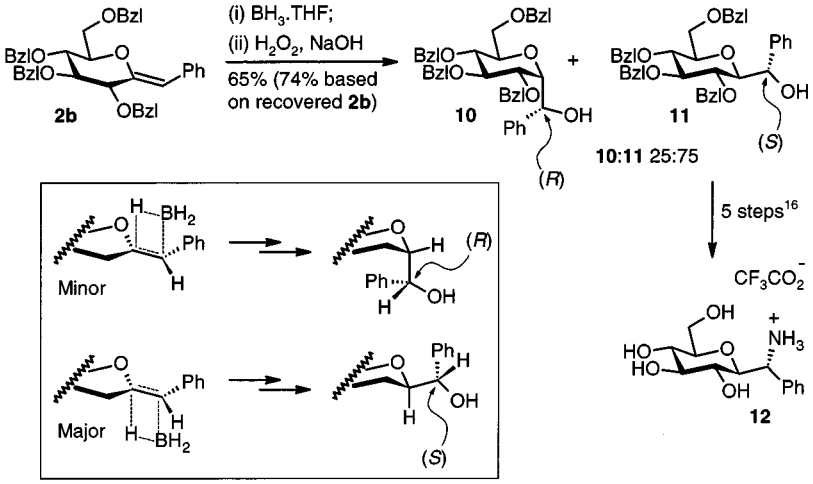
The enol ether moiety of **2a** has been extensively elaborated by other groups to produce a variety of modified glucose derivatives, as illustrated in Scheme 2. Dipolar cycloaddition using carbomethoxy nitrile oxide occurs stereoselectively to give isoxazoline **3**[3] whereas epoxidation using dimethyldioxirane (DMDO) produces a diastereomeric mixture of epoxides **4**.[5,6] Radical addition of thiolacetic acid proceeds via an anomerically-stabilised axial C1-radical to give adduct **5**[5] and boron trifluoride-catalysed dimerisation produces the *C*-linked disaccharide **6**.[7] 1-*C*-Methyl-α-*O*-disaccharides have also been prepared from *exo*-glycals by Lewis acid-catalysed reactions with glycosyl acceptors.[8] The stereoselective 9-BBN hydroboration-oxidation of **2a** to give exclusively the β-*C*-glycoside **7** was initially described by RajanBabu and Reddy;[3] Johnson and Johns have demonstrated that the intermediate organoborane can undergo palladium-catalysed cross-coupling reactions to give the aromatic *C*-glycoside derivatives **8**.[9] We have also recently reported the synthesis of a *C*-glycosyl amino acid by the Suzuki coupling of this organoborane with a vinyl iodide derived from the Garner aldehyde.[10] In addition, we have carried out the dihydroxylation of *exo*-glycal **2a** to produce the known tetrabenzyl-α-D-*gluco*-2-heptulopyranose **9** {m.p. 111 °C, ref.[11] 112.5–113.5 °C. $[\alpha]_D^{20}$ = +13.6 (*c* = 1.4, $CHCl_3$), ref.[11] +14.7 (*c* = 0.97,



Scheme 2. *exo*-Glycals are versatile intermediates for the synthesis of more highly functionalised *C*-glycosides

$CHCl_3$)}. Sigmatropic rearrangements involving the enol ether function have recently been described: a Claisen rearrangement of 6-vinyl *exo*-glycals[12] and a Claisen−Ireland rearrangement of 2-*O*-acyl *exo*-glycals[13] furnish cyclooctene and *C*-glycan derivatives, respectively. Exomethylenic sugars have also proved to be good substrates for ring-closing olefin metathesis: derivatives of **2a** bearing an unsaturated side chain at position 2 have been shown to undergo ruthenium catalysed ring closure to give bicyclic glycosylidene compounds.[14] Postema and Calimente have also exploited this powerful carbon−carbon bond-forming process for the preparation of C1-substituted glycals[15a] and *C*-linked disaccharides.[15b]

The phenyl-substituted *exo*-glycal derivative **2b** is accessible in high yield and good stereoselectivity from the tandem halogenation-Ramberg−Bäcklund rearrangement of benzyl sulfone **1b** (Scheme 1). We decided to explore the elaboration of this substrate (Scheme 3). When hydroboration of **2b** was attempted using 9-BBN, no reaction was observed, presumably for steric reasons. However, hydroboration with BH_3·THF followed by oxidative workup afforded a separable mixture of the secondary alcohols **10** and **11**; the latter, which predominates, has been converted into the novel β-glycosidase inhibitor **12** in five steps by Schmidt and Dietrich.[16] The formation of the major diastereomer **11** results from addition of borane from the lower face of the double bond, as shown in Scheme 3. The C1 configuration of **11** was established by comparison with literature data {$[\alpha]_D^{20}$ = +8.5 (*c* = 1.5, $CHCl_3$), ref.[17] +7.5 (*c* = 1.0, $CHCl_3$)} and hence, due to the demands of the stereospecific *syn*-addition of the borane, the (*Z*)-geometry of the double bond in the substrate **2b** was able to be conclusively assigned. The observation of NOEs between H−C1 and H−C3 on (*Z*)-**2b** supports this conclusion (although insufficient quantities of the pure (*E*)-isomer were available to conduct comparative experiments).



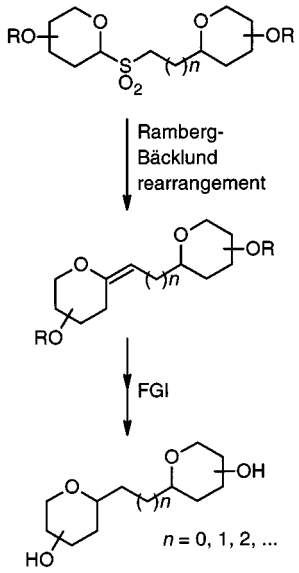
Scheme 3. Hydroboration−oxidation of *exo*-glycal **2b** to give the known *C*-glycoside **11**

Preparation of Spirocyclic Glucose Derivatives

The vinyl ether moiety of *exo*-glycals is readily protonated at the exocyclic carbon atom to form an oxycarbenium intermediate, which can be trapped by a variety of nucleophiles. Hence, our next aim was the synthesis of a trisubstituted *exo*-glycal with a pendant hydroxyl group which should undergo acid-catalysed intramolecular addition to the double bond to form spirocyclic sugars **17** and **18**. These compounds, which are simplified analogues of antiviral natural products such as papulacandin D,[18] have been prepared by a number of different routes including ring-closing metathesis of unsaturated ketosides[19] and radical cyclisation of hydroxyalkyl glycosides.[20] In our new synthesis (Scheme 4), 2,3,4,6-tetra-*O*-benzyl-1-thio-β-D-glucose[21] (**13**) was alkylated with 3-chloropropan-1-ol to give sulfide **14**, which was then oxidised to sulfone **15** with mCPBA. Pleasingly, the unprotected alcohol **15** underwent halogenative Ramberg−Bäcklund rearrangement smoothly using Chan's modified conditions[22] to give *exo*-glycal **16** in 74% yield (*Z*/*E* = 80:20). Acid-catalysed cyclisation was achieved by treatment of a methanol solution of **16** with camphorsulfonic acid (CSA) to give a separable mixture of the spiroacetals **17**[19,20] and **18**[20] (70:30) in a combined yield of 76%, with the thermodynamically more stable product predominating. Although the optical rotations of the two isomers are similar, comparison of the ^{13}C signals of the spiro centres with literature values allowed us to confirm their stereochemistry: **17**, δ_C: 107.3 (C1), ref.[20] 107.3; **18**, δ_C: 109.8 (C1), ref.[20] 109.9.

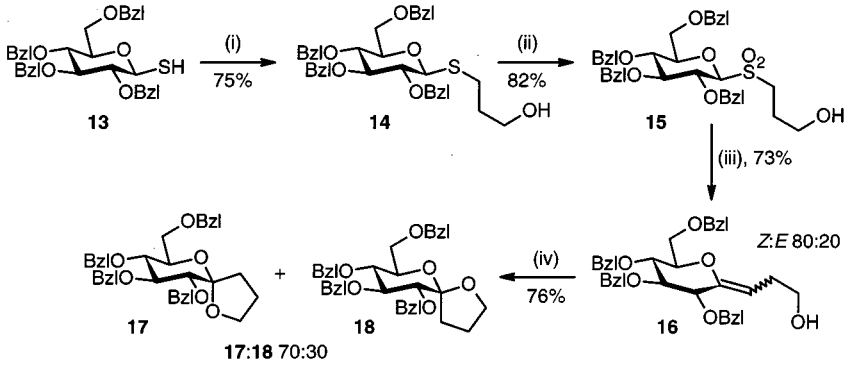
C-Linked Disaccharide Synthesis

The natural progression of this work was towards the synthesis of *C*-linked disaccharides, as outlined in Scheme 5. Our first target was a carba-analogue of isotrehalose [β-D-glucopyranosyl-(1→1′)-β-D-glucopyranose], a member of a family of disaccharides in which residues are linked through their anomeric centres. Trehalose [α-D-glucopyranosyl-(1→1′)-α-D-glucopyranose] occurs naturally as a storage carbohydrate in certain plants, algae, fungi, and yeasts and is the main carbohydrate component of the blood of many insects.[23]

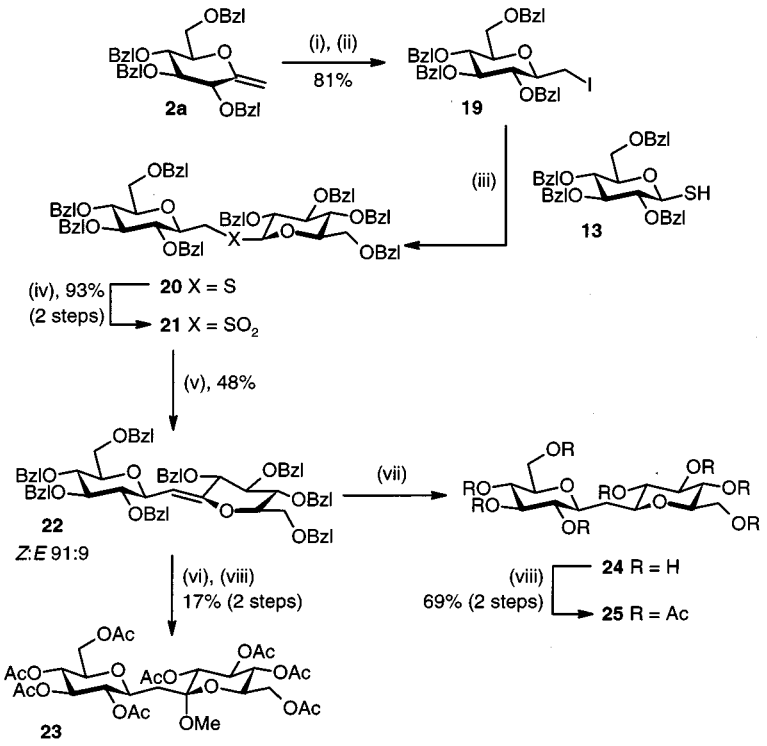


Scheme 5. Generic representation of a Ramberg−Bäcklund *exo*-glycal-based approach to *C*-disaccharide synthesis; FGI = functional group interconversion

C-Trehaloses have been prepared by the groups of Kishi[24] and Martin,[25] and recently Schmidt and Patro have reported the synthesis of novel isotrehalose analogues with a functionalised linking carbon.[26] Our strategy, outlined in Scheme 6, required the preparation of the thioglycoside-derived intermediate **20**. This compound was readily available from the coupling of the known thiol **13**[21] and iodide **19**, itself easily accessible from *exo*-glycal **2a** by hydroboration-oxidation[3] followed by iodination using the method of Garegg and Samuelsson.[27] The corresponding sulfone-linked disaccharide was then obtained by oxidation with mCPBA, providing **21** in 93% yield from **19**. Ramberg−Bäcklund rearrangement of **21** proceeded in moderate yield under Meyers' conditions[28] to afford enol ether **22**, predominantly as the (*Z*)-isomer (*Z*/*E* = 91:9). Stereochemical assignment was based on the trend that the



Scheme 4. Synthesis of spirocyclic glucose derivatives; reagents: (i) $Cl(CH_2)_3OH$, K_2CO_3, acetone, reflux; (ii) mCPBA, Na_2HPO_4, DCM; (iii) KOH/Al_2O_3, CBr_2F_2, *t*BuOH, DCM, 5 °C to room temp.; (iv) CSA, MeOH. mCPBA = *meta*-chloroperoxybenzoic acid, CSA = camphorsulfonic acid



Scheme 6. Synthesis of *C*-isotrehalose; reagents: (i) 9-BBN, THF, 0 °C to room temp., then H_2O_2, aq. KOH; (ii) PPh_3, imidazole, I_2, toluene, 70 °C; (iii) K_2CO_3, acetone, reflux; (iv) mCPBA, Na_2HPO_4, DCM; (v) KOH, CCl_4, aq. *t*BuOH, 60 °C; (vi) H_2, Pd/C, MeOH, EtOAc; (vii) H_2, $Pd(OH)_2/C$, EtOH, EtOAc; (viii) Ac_2O, pyridine; 9-BBN = 9-borabicyclo[3.3.1]nonane

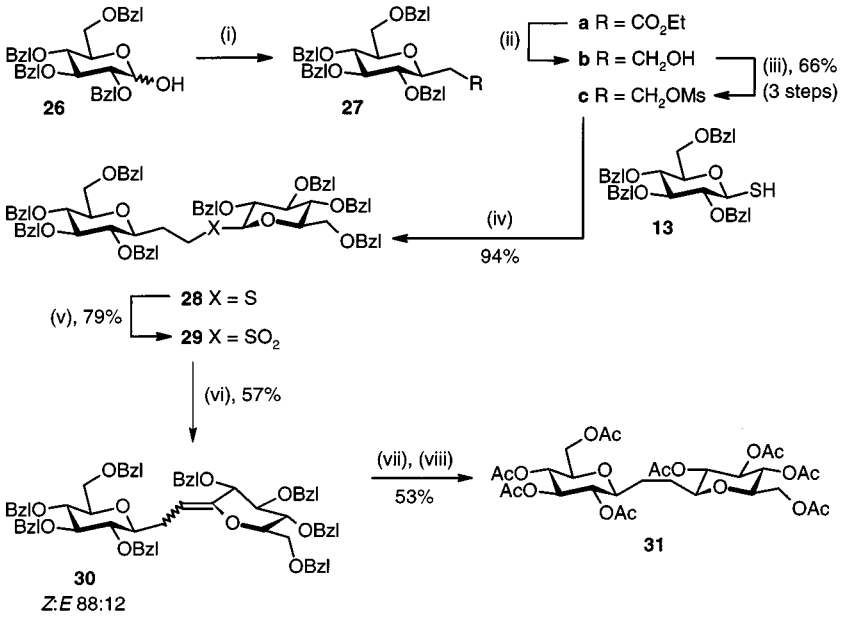
vinylic protons of (*Z*)-*exo*-glycals resonate at lower field in the ^1H NMR spectrum than those in the corresponding (*E*)-isomers.[29] Hydrogenolytic *O*-debenzylation followed by acetylation led, unintentionally, to ketal **23** as a result of acid-catalysed addition of methanol to the vinyl ether of **22**. However when ethanol was used as the co-solvent, double bond reduction and deprotection of **22** were achieved in good yield to give *C*-isotrehalose (**24**), which was converted into its peracetate derivative **25** for characterisation. The NMR spectroscopic data were consistent with the formation of a symmetrical β,β-linked disaccharide and also agreed with published data.[25]

We believe that this methodology offers a rapid, convergent and practically simple route to β,β-(1→1′)-carba-disaccharides. Although we have shown that the intermediate enol ether **22** can be elaborated further by the addition of alcohols, a variety of alternative synthetic elaborations could be attempted on this substrate, for example hydroboration, epoxidation, dihydroxylation, or dipolar cycloaddition, in order to introduce functionality to the carbon bridge.

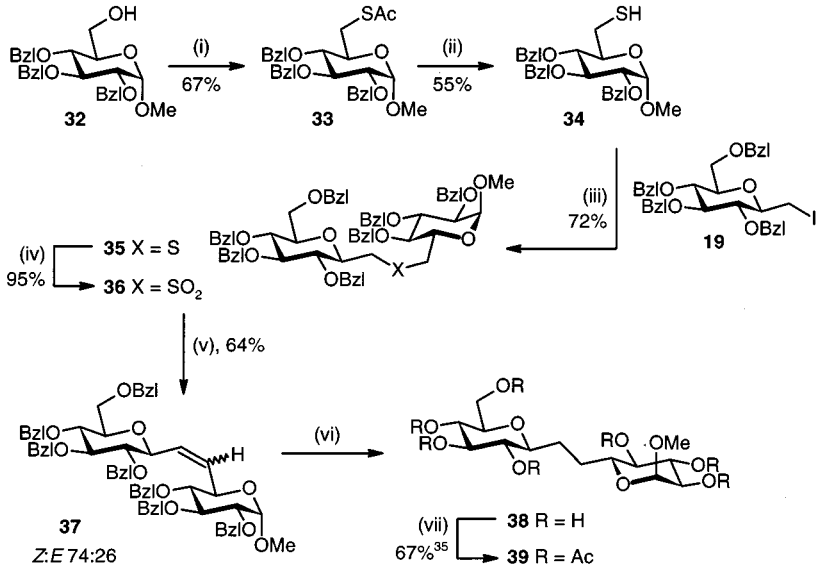
This approach is well suited to analogue synthesis simply by varying the alkylating agent. Thus, the homologated (1→1′)-carba-disaccharide **31** containing a two-carbon bridge ("homoisotrehalose") was readily prepared (Scheme 7). Lactol **26** was converted into sulfonate **27c** by a straightforward three-step sequence[30] involving Moffatt-type *C*-glycosylation[31] to give ester **27a**[30] followed by reduction and mesylation; **27c** was then coupled with thiol **13**[21] in a similar alkylation−oxidation sequence to that used previously. The resulting sulfone **29** underwent a halogenative Ramberg−Bäcklund rearrangement to give *exo*-glycal **30** as a 88:12 mixture of (*Z*)- and (*E*)-isomers in 57% yield. Subsequent reduction/debenzylation followed by acetylation produced the novel, ethylene-bridged disaccharide **31**. Again the ^1H and ^{13}C NMR spectroscopic data revealed the magnetic equivalence of each sugar residue, in agreement with a symmetrical β,β-linked structure.

We then turned our attention to the preparation of the carba-analogue of the (1→6′)-disaccharide methyl gentiobioside, which was first synthesised by Rouzaud and Sinaÿ.[32] This allowed us the opportunity to widen the scope of the methodology still further: instead of using an *S*-glycoside-derived sulfone in the key Ramberg−Bäcklund rearrangement we planned to prepare a more symmetrical sulfone-linked precursor in which the sulfonyl group was positioned centrally and flanked on each side by a methylene attached to a monosaccharide unit.

The desired substrate was readily prepared using the simple thioetherification−oxidation routine previously described (Scheme 8). With iodide **19** already at hand, we required only the complementary thiol **34**. This was obtained from alcohol **32**[33] by displacement with thiolacetic acid under Mitsunobu conditions, followed by deacetylation. *S*-Alkylation of **34** and oxidation of the resulting sulfide gave sulfone **36** in high yield. Treatment of **36** with KOH/Al_2O_3 and CBr_2F_2 gave the desired unsaturated *C*-disaccharide **37** in 64% yield (*Z*/*E* = 74:26). This alkene has been prepared previously by Kishi[34] and by Dondoni[35] who also described its hydrogenation/debenzylation to furnish methyl



Scheme 7. Synthesis of homoisotrehalose; reagents: (i) $(EtO)_2P(O)CH_2CO_2Et$, NaH, THF;[30] (ii) $LiAlH_4$, THF;[30] (iii) MsCl, Et_3N, DCM; (iv) K_2CO_3, acetone, reflux; (v) Oxone®, THF, MeOH, H_2O; (vi) KOH, CCl_4, aq. *t*BuOH, 65 °C; (vii) H_2, $Pd(OH)_2/C$, EtOH, EtOAc; (viii) Ac_2O, pyridine; Ms = mesyl = methanesulfonyl



Scheme 8. Synthesis of methyl *C*-gentiobioside; reagents: (i) PPh_3, DIAD, AcSH, THF, 0 °C to room temp.; (ii) NaOMe, MeOH; (iii) K_2CO_3, acetone, reflux; (iv) mCPBA, Na_2HPO_4, DCM; (v) KOH/Al_2O_3, CBr_2F_2, *t*BuOH, DCM, 5 °C to room temp.; (vi) H_2, $Pd(OH)_2/C$, MeOH, EtOAc; (vii) Ac_2O, pyridine;[35] DIAD = diisopropylazodicarboxylate

C-gentiobioside (**38**). We carried out the hydrogenation under the same conditions and then prepared heptaacetate **39** which displayed spectroscopic data consistent with those reported in the literature $\{[\alpha]_D^{20} = +65.1$ ($c = 0.45$, $CHCl_3$), ref.[35] $+63$ ($c = 0.7$, $CHCl_3$)$\}$.

C-Glycosyl Amino Acid Synthesis

Interest in the structure and function of glycoproteins has grown enormously in recent years.[36] However, despite their diversity in form, the core region of these molecules – the covalent linkage between the carbohydrate and peptide domains – shows relatively little variation.[37] By far the most common sites for protein glycosylation are the amide nitrogen of asparagine (Figure 1, a) and the hydroxyl group of serine and threonine (Figure 1, b). Replacement of the glycosidic nitrogen or oxygen by carbon gives the corresponding *C*-glycoside analogues (glycopeptidomimetics), the synthesis of which has been the subject of several recent publications[38] and a review article.[39] We also now report the application of our Ramberg–Bäcklund methodology to the synthesis of a carba-analogue of glucosyl serine.

The key starting material, iodide **19**, was already at hand from previous studies. Thiol **43** was the required coupling partner and although this useful building block had not

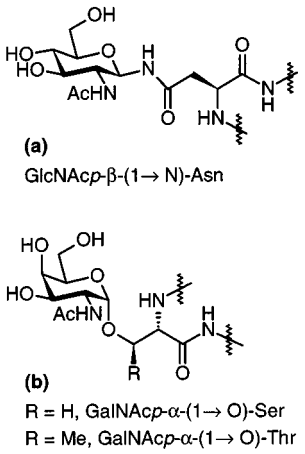


Figure 1. The two most common types of glycopeptidic linkage: (a) *N*-acetylglucosamine-asparagine; (b) *N*-acetylgalactosamine-serine/threonine

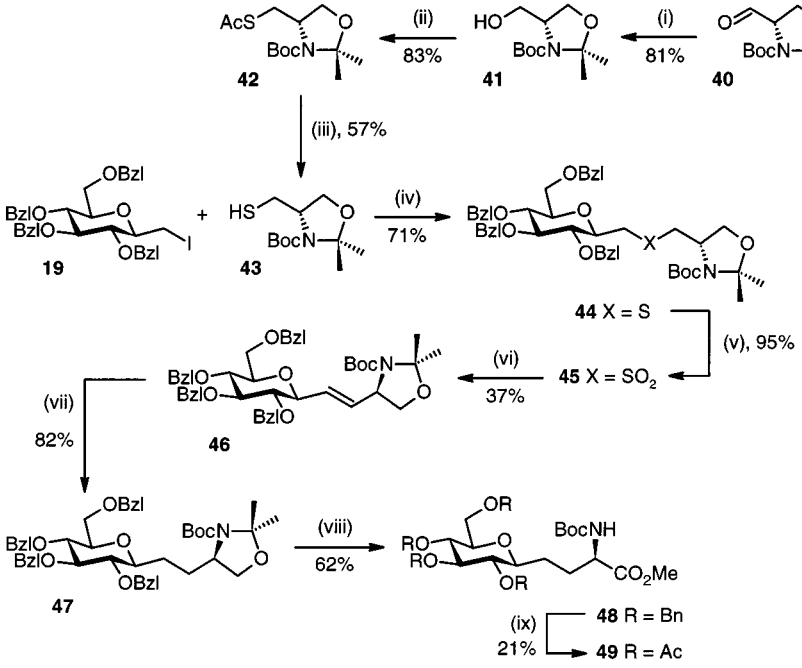
been reported previously, it was easily obtainable from the Garner aldehyde (*S*)-**40**[40] by borohydride reduction followed by Mitsunobu displacement using thiolacetic acid and then treatment with sodium methoxide (Scheme 9). Alkylation of **43** with iodide **19** followed by oxidation as before produced sulfone **45**, which was subjected to Chan's halogenative Ramberg−Bäcklund conditions to give (*E*)-alkene **46** (J_{trans} = 15.6 Hz) in 37% unoptimised yield. Alkene reduction was efficiently achieved using diimide generated in situ and the amino acid moiety was unmasked in a one-pot procedure[41] using Jones' reagent. Treatment with diazomethane afforded methyl ester **48** and, finally, debenzylation followed by acetylation gave the *C*-glucosyl serine derivative **49** as a single diastereoisomer whose spectroscopic properties were fully consistent with the structure shown.

Conclusion

In summary, we have shown that Ramberg−Bäcklund-derived *exo*-glycals can easily be transformed into functionalised *C*-glycosides of potential biological interest, such as enzyme inhibitor **12** and spirocyclic derivatives **17** and **18**. We have also established that carba-analogues of (1→1′)- and (1→6′)-linked disaccharides and glycosyl amino acids can be prepared from readily available sulfone-linked precursors using Meyers' variant of the Ramberg−Bäcklund rearrangement.

Experimental Section

General Remarks: THF was distilled from sodium diphenyl ketyl immediately prior to use. DCM was distilled from calcium hydride. Light petroleum ether refers to the fraction boiling in the range 40−60 °C and was redistilled before use. Alumina-supported potassium hydroxide (KOH/Al_2O_3) was prepared according to Chan's procedure.[22] Reactions were monitored by TLC on silica gel 60 F_{254} (Merck) with detection by charring with sulfuric acid. Organic extracts were dried over anhydrous sodium sulfate and column chromatography was carried out using 33−64 (60 Å) silica gel (ICN). Melting points (m.p.) were determined with an Electrothermal IA9100 digital melting point apparatus and are uncorrected. Specific rotations were measured on a Jasco DIP-370 digital polarimeter and are expressed in units of 10^{-2} deg·cm^{-2}·g^{-1}. Mass spectrometry was carried out on a Fisons Analytical Autospec instrument using either chemical ionisation (CI) or fast atom bom-



Scheme 9. Synthesis of a *C*-glycosyl serine analogue; reagents: (i) $NaBH_4$, MeOH; (ii) Ph_3P, DIAD, AcSH, THF; (iii) MeONa, MeOH; (iv) K_2CO_3, acetone, reflux; (vi) mCPBA, Na_2HPO_4, DCM; (vi) KOH/Al_2O_3, CBr_2F_2, *t*BuOH, 60 °C; (vii) $TsNHNH_2$, NaOAc, DME, 85 °C; (viii) 1 M Jones reagent, acetone, then CH_2N_2, Et_2O; (ix) H_2, $Pd(OH)_2$/C, EtOH, EtOAc, then Ac_2O, pyridine; DME = 1,2-dimethoxyethane

bardment (FAB) techniques; all high resolution mass spectral determinations are within 5 ppm of the calculated value. Elemental analyses were performed by Chemical Analytical Services Unit, University of Newcastle, UK using a Carlo Erba 1106 elemental analyser. NMR spectra were recorded on Jeol EX270 and Bruker AMX500 spectrometers, operating at ^{1}H frequencies of 270 and 500 MHz and ^{13}C frequencies of 67.9 and 125 MHz, respectively.

3,4,5,7-Tetra-*O*-benzyl-α-D-*gluco*-2-heptulopyranose (9): *N*-Methylmorpholine *N*-oxide (0.12 g, 1.0 mmol) was added to a solution of *exo*-glycal **2a** (0.27 g, 0.50 mmol) in a mixture of water (2 mL) and acetone (9 mL). A solution of osmium tetroxide (0.0013 g, 0.005 mmol) in *tert*-butyl alcohol (0.5 mL) was then added and the resulting solution was stirred overnight at room temp. before being quenched with satd. aq. $NaHSO_3$ (10 mL) and stirred for a further 10 min. The product was extracted with EtOAc (2 × 20 mL) and the combined organic extracts washed with brine (40 mL), dried, and the solvent removed in vacuo. The product was purified by column chromatography (light petroleum ether/EtOAc, 4:1→1:1) to afford the product as a solid which was recrystallised from water to afford **9** as a fine powder (0.27 g, 94%); m.p. 110.8−111.3 °C, ref.[11] 112.5−113.5 °C. $[\alpha]_D^{20}$ = +13.6 (*c* = 1.4, $CHCl_3$), ref.[11] +14.7 (*c* = 0.97, $CHCl_3$).

2,6-Anhydro-3,4,5,7-tetra-*O*-benzyl-1-*C*-phenyl-D-*erythro*-L-*gulo*-heptitol (10) and 2,6-Anhydro-3,4,5,7-tetra-*O*-benzyl-1-*C*-phenyl-D-*erythro*-L-*talo*-heptitol (11): A solution of borane in THF (1 M, 2.13 mL, 2.13 mmol) was added to a solution of the alkene **2b** (0.10 g, 0.163 mmol) in THF (5 mL) and the mixture was stirred for three days. The reaction was quenched by the addition of aq. NaOH (1 M, 1 mL), followed by aq. H_2O_2 (ca. 30% v/v, 1 mL). After stirring for 30 min at room temp., the mixture was partitioned between brine (30 mL) and EtOAc (30 mL), the aqueous layer was extracted with EtOAc (2 × 20 mL) and the combined organic phases were washed with brine (20 mL), dried, and concentrated in vacuo. Column chromatography (light petroleum ether/EtOAc, 4:1→2:1) gave first unchanged starting material (0.012 g, 12%) followed by **10** as a white solid (0.017 g, 17%); R_f = 0.59 (light petroleum ether/EtOAc, 1:1); m.p. 95.5−97.5 °C. $[\alpha]_D^{20}$ = +22.7 (*c* = 1.7, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3459 (br., OH), 3030, 2866, 1496, 1453, 1362, 1213, 1065. ^{1}H NMR (270 MHz, $CDCl_3$): δ = 3.31 (br. d, $J_{7A,7B}$ = 10.1 Hz, 1 H, 7-H_A), 3.54, (dd, $J_{7B,7A}$ = 10.1, $J_{7B,6}$ = 3.2 Hz, 1 H, 7-H_B), 3.68−3.70 (m, 3 H, 5-H, 6-H, OH), 3.97 (dd, $J_{3,4}$ = 8.5, $J_{3,2}$ = 5.1 Hz, 1 H, 3-H), 4.05−4.14 (m, 2 H, 2-H, 4-H), 4.23, 4.42 (AB, *J* = 12.1 Hz, 2 H, CH_2Ph), 4.47, 4.77 (AB, *J* = 10.9 Hz, 2 H, CH_2Ph), 4.70, 4.84 (AB, *J* = 11.4 Hz, 2 H, CH_2Ph), 4.90, 4.85 (AB, *J* = 11.2 Hz, 2 H, CH_2Ph), 5.15 (d, $J_{1,2}$ = 9.0 Hz, 1 H, 1-H), 7.12−7.40 (m, 25 H, 5 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 68.6 (C7), 73.2, 74.5, 74.7, 75.0 (4 × *C*H_2Ph), 72.5, 73.5, 75.0, 77.7, 80.1, 81.8 (C1−C6), 127.1, 127.5, 127.8, 127.9, 128.2, 128.3, 128.4, 128.5, 128.7 (arom. CH), 137.0, 137.9 (× 2), 138.3, 140.6 (subst. arom. C); *m*/*z* (FAB) 653 (100) [M + Na]$^+$; found [M + Na]$^+$ 653.2875. $C_{41}H_{42}O_6$·Na requires 653.2879. − Further elution gave **11** as a colourless oil (0.050 g, 49%); R_f = 0.48 (light petroleum ether/EtOAc, 1:1). $[\alpha]_D^{20}$ = +8.5 (*c* = 1.5, $CHCl_3$), ref.[17] +7.5 (*c* = 1.0, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3430 (br., OH), 3030, 2866, 1496, 1453, 1361, 1208, 1105. ^{1}H NMR (270 MHz, $CDCl_3$): δ = 2.81 (br. s, 1 H, OH), 3.36 (t, *J* = 9.2 Hz, 1 H, 3-H), 3.46 (br. d, $J_{6,5}$ = 9.7 Hz, 1 H, 6-H), 3.58 (t, *J* = 9.7 Hz, 1 H, 5-H), 3.71−3.81 (m, 4 H, 2-H, 4-H, 7-H_A, 7-H_B), 4.47, 4.86 (AB, *J* = 10.9 Hz, 2 H, CH_2Ph), 4.48, 4.55 (AB, *J* = 12.1 Hz, 2 H, CH_2Ph), 4.58, 4.77 (AB, *J* = 10.9 Hz, 2 H, CH_2Ph), 4.80, 4.92 (AB, *J* = 10.9 Hz, 2 H, CH_2Ph), 4.94 (d, $J_{1,2}$ = 3.4 Hz, 1 H, 1-H), 7.17−7.41 (m, 25 H, 5 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 68.9 (C7), 73.3, 74.3, 74.9, 75.4 (4 × *C*H_2Ph), 74.3, 78.4, 79.0, 79.5, 81.0, 87.3 (C1−C6), 127.5, 127.6, 127.8 (× 2), 127.9, 128.1, 128.3, 128.4 (arom. CH), 137.9, 138.0, 138.2 (× 2), 140.2 (subst. arom. C); *m*/*z* (FAB): 653 (100) [M + Na]$^+$; found [M + Na]$^+$ 653.2882. $C_{41}H_{42}O_6$·Na requires 653.2879.

3′-Hydroxyprop-1′-yl 2,6-Anhydro-2,3,4,6-tetra-*O*-benzyl-1-thio-β-D-glucopyranoside (14): A mixture of 3-chloropropan-1-ol (0.4 mL, 0.45 g, 4.76 mmol), 2,3,4,6-tetra-*O*-benzyl-1-thio-β-D-glucose[21] (**13**) (1.62 g, 2.91 mmol), potassium carbonate (4.02 g, 29.1 mmol), and sodium iodide (0.1 g, 0.7 mmol) in dry, degassed acetone (60 mL) was stirred under reflux for 20 h. After cooling to 0 °C, the solids were removed by filtration and the filtrate was concentrated. The residue was then redissolved in DCM and washed with water (50 mL), brine (50 mL), dried, and the solvents evaporated in vacuo. The crude product was purified by column chromatography (light petroleum ether/EtOAc, 4:1→7:3) to give **14** as a colourless oil (1.34 g, 75%); R_f = 0.30 (light petroleum ether/EtOAc, 1:1). $[\alpha]_D^{20}$ = +12.9 (*c* = 1.0, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3500 (br., OH), 3032, 2872, 1497, 1454, 1360, 1210, 1126, 1062, 1029. ^{1}H NMR (270 MHz, $CDCl_3$): δ = 1.79−1.90 (m, 2 H, CH_2CH$_2$OH), 2.39 (br. s, 1 H, OH), 2.73−2.83 and 2.89−2.99 (2 × m, 2 H, SCH$_2$), 3.40−3.84 (m, 8 H, 2-H, 3-H, 4-H, 5-H, 6-H_A, 6-H_B, CH_2OH), 4.44 (d, *J* = 9.7 Hz, 1 H, 1-H), 4.48−4.60 and 4.72−4.94 (m, 8 H, 4 × CH_2Ph), 7.11−7.39 (m, 20 H, 4 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 27.4 (C2′), 32.6 (C1′), 60.0 (C3′), 69.0 (C6), 73.4, 75.0, 75.5, 75.7 (4 × *C*H_2Ph), 77.8, 78.7, 81.5, 85.6, 86.5 (C1−C5), 127.6, 127.7, 127.8, 128.0, 128.1, 128.3, 128.4 (arom. CH), 137.7, 137.8 (× 2), 138.4 (subst. arom. C); *m*/*z* (FAB): 637 (100) [M + Na]$^+$; found [M + Na]$^+$ 637.2601. $C_{37}H_{42}O_6S$·Na requires 637.2600.

3′-Hydroxyprop-1′-yl *S,S*-Dioxo-2,6-anhydro-2,3,4,6-tetra-*O*-benzyl-1-thio-β-D-glucopyranoside (15): mCPBA (2.97 g, 57−86% purity, 9.81−14.8 mmol) was added portionwise to a stirred mixture of thioglycoside **14** (1.85 g, 3.01 mmol) and Na_2HPO_4 (2.19 g, 15.4 mmol) in DCM (20 mL) at 0 °C. After 15 min at 0 °C, the reaction mixture was stirred overnight at room temp. after which time it was diluted with ether (30 mL), aq. $Na_2S_2O_3$ (0.1 M, 30 mL) was added and the mixture was stirred for a further 30 min. The organic layer was then washed with 10% aq. NaOH (20 mL), brine (20 mL), dried, and concentrated. The crude product was purified by column chromatography (light petroleum ether/EtOAc, 4:1→1:1) to give **15** as a colourless syrup (1.60 g, 82%); R_f = 0.25 (light petroleum ether/EtOAc, 1:1). $[\alpha]_D^{20}$ = +31.7 (*c* = 1.0, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3498 (br., OH), 3030, 2917, 2873, 1497, 1454, 1361, 1330, 1309 (SO_2), 1144 (SO_2), 1097, 1028. ^{1}H NMR (270 MHz, $CDCl_3$): δ = 1.98−2.11 (m, 3 H, CH_2CH$_2$OH, OH), 3.11−3.22 and 3.32−3.41 (m, 2 H, CH_2SO$_2$), 3.46−3.69 (m, 6 H, 4-H, 5-H, 6-H_A, 6-H_B, CH_2OH), 3.79 (t, *J* = 8.7 Hz, 1 H, 3-H), 4.10 (t, *J* = 9.0 Hz, 1 H, 2-H), 4.41 (d, $J_{1,2}$ = 9.2 Hz, 1 H, 1-H), 4.51 (A_2, 2 H, CH_2Ph), 4.52, 4.79 (AB, *J* = 10.9 Hz, 2 H, CH_2Ph), 4.77, 5.00 (AB, *J* = 9.7 Hz, 2 H, CH_2Ph), 4.86, 4.95 (AB, *J* = 11.2 Hz, 2 H, CH_2Ph), 7.12−7.38 (m, 20 H, 4 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 25.2 (*C*H$_2$CH$_2$OH), 48.2 (*C*H$_2$SO$_2$), 60.2 (*C*H$_2$OH), 68.7 (C6), 73.4, 75.1, 75.4, 75.9 (4 × *C*H_2Ph), 77.0, 79.6, 86.0 (× 2), 89.6 (C1−C5), 127.6, 127.8, 127.9, 128.0 (× 2), 128.1, 128.4, 128.5, 128.6 (arom. CH), 137.3 (× 2), 137.4, 138.0 (subst. aromatic C); *m*/*z* (FAB): 669 (30) [M + Na]$^+$, 413 (80%); found [M + Na]$^+$ 669.2508. $C_{37}H_{42}O_8S$·Na requires 669.2498.

(*E,Z*)-4,8-Anhydro-5,6,7,9-tetra-*O*-benzyl-2,3-dideoxy-D-*gluco*-non-3-enitol (16): Dibromodifluoromethane (0.5 mL, 5.5 mmol) was added dropwise over 1 min to a vigorously stirred mixture of sulfone **15** (0.27 g, 0.42 mmol), KOH/Al_2O_3 (2.60 g), *tert*-butyl alcohol

(6 mL) and DCM (3 mL) at 5 °C. The mixture was then stirred at room temp. for 3.5 h after which time it was diluted with DCM (20 mL) and the solids were removed by suction filtration through a pad of Celite®. The reaction vessel and the filter cake were rinsed thoroughly with DCM and the combined filtrates were concentrated. The crude product was then purified column chromatography (light petroleum ether/EtOAc, 4:1→1:1) to afford **16** (*Z*/*E* = 80:20) as a colourless oil (0.178 g, 73%); R_f = 0.08 (light petroleum ether/EtOAc, 4:1); $\tilde{\nu}_{max}/cm^{-1}$: 3405 (br., OH), 2875, 1471, 1381, 1171, 1070, 1028. ^1H NMR (270 MHz, $CDCl_3$): δ = 2.05−3.21 and 2.32−2.45 (m, 3 H, C*H*$_2$CH$_2$OH, O*H*), 3.60 (t, *J* = 6.5 Hz, 2 H, C*H*$_2$OH), 3.67−3.79 (m, 4 H, 6-H, 7-H, 9-H$_A$, 9-H$_B$), 3.93 (br. d, *J* = 6.5 Hz, 1 H, 5-H), 4.33−4.83 (m, 9 H, 8-H, 4 × CH$_2$Ph), 4.98 (t, *J* = 7.5 Hz, 1 H, 3-H, *Z*-isomer), 5.21 (t, *J* = 8.7 Hz, 1 H, 3-H, *E*-isomer), 7.13−7.17 and 7.24−7.36 (m, 20 H, 4 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 28.2 (*C*H$_2$CH$_2$OH), 62.2 (*C*H$_2$OH), 68.7 (C9), 72.4, 73.4, 74.1, 74.3 (4 × *C*H$_2$Ph), 77.8, 77.9, 79.03, 84.9 (C5−C8), 106.4 (C3), 127.50, 127.60, 127.64, 127.76, 127.80, 127.88, 128.04, 128.18, 128.24, 128.30 (arom. CH), 137.85, 137.95, 138.07, 138.21 (subst. arom. C), 148.6 (C4, *E*-isomer), 149.8 (C4, *Z*-isomer); *m*/*z* (FAB): 603 (100) $[M + Na]^+$; found $[M + Na]^+$ 603.2719. $C_{37}H_{40}O_6$·Na requires 603.2723.

(1*S*)-2,3,4,6-Tetra-*O*-benzyl-1-deoxy-D-glucopyranosyl-1-spiro-2′-tetrahydrofuran[20] (17) and (1*R*)-2,3,4,6-Tetra-*O*-benzyl-1-deoxy-D-glucopyranosyl-1-spiro-2′-tetrahydrofuran[20] (18): Camphorsulfonic acid (0.01 g) was added to a solution of *exo*-glycal **16** (0.223 g, 0.4 mmol) in dry methanol (10 mL) and the resulting solution was stirred for 5 h at room temp. after which time the methanol was evaporated under reduced pressure. The residue was then purified by column chromatography (light petroleum ether/EtOAc, 19:1→9:1) to afford spiroacetal **17** as a colourless oil (0.117 g, 53%); R_f = 0.41 (light petroleum ether/EtOAc, 4:1). $[\alpha]_D^{20}$ = +26.6 (*c* = 0.7, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3062, 3030, 2922, 2872, 1497, 1453, 1362, 1154, 1122, 1085, 1027. ^1H NMR (270 MHz, $CDCl_3$): δ = 1.75−3.01 (m, 4 H, C*H*$_2$C*H*$_2$CH$_2$O), 3.55−3.75 (m, 4 H), 3.82−3.90 (m, 2 H), 3.96−4.00 (m, 1 H), 4.03 (t, *J* = 9.2 Hz, 1 H), 4.49, 4.62 (AB, *J* = 12.1 Hz, 2 H, C*H*$_2$Ph), 4.54, 4.84 (AB, *J* = 10.9 Hz, 2 H, C*H*$_2$Ph), 4.68, 4.96 (AB, *J* = 11.4 Hz, 2 H, C*H*$_2$Ph), 4.90 (A$_2$, 2 H, C*H*$_2$Ph), 7.14−7.35 (m, 20 H, 4 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 24.0 (CH$_2$*C*H$_2$CH$_2$O), 33.4 (*C*H$_2$CH$_2$CH$_2$O), 68.1 (CH$_2$CH$_2$*C*H$_2$O), 68.7 (C6), 73.3, 74.7, 75.5, 75.6 (4 × *C*H$_2$Ph), 71.2, 78.5, 80.0, 84.5 (C2−C5), 107.34 (C1), 127.5, 127.7, 127.8, 127.8, 128.0, 128.3 (× 2), 128.4 (arom. CH), 138.0, 138.1, 138.4, 138.7 (subst. arom. C); *m*/*z* (CI): 598 (100) $[M + NH_4]^+$; found $[M + NH_4]^+$ 598.3153. $C_{37}H_{40}O_6$·NH_4 requires 598.3169. Further elution gave spiroacetal **18** as an oil which solidified on standing (0.050 g, 23%); R_f = 0.33 (light petroleum ether/EtOAc, 4:1); m.p. 69−71 °C, ref.[20] 69.8−71.3 °C. $[\alpha]_D^{20}$ = +29.7 (*c* = 0.4, $CHCl_3$), ref.[20] +29.8 (*c* = 0.4, $CHCl_3$).

2,6-Anhydro-3,4,5,7-tetra-*O*-benzyl-1-deoxy-1-iodo-D-*glycero*-D-*gulo*-heptitol (19): To a solution of the heptitol **8**[3] (0.695 g, 1.25 mmol) in toluene (30 mL) at 70 °C was added first triphenylphosphane (0.49 g, 1.87 mmol) followed by imidazole (0.26 g, 3.82 mmol) and finally iodine (0.45 g, 1.77 mmol). A black tar formed immediately at the bottom of the flask and the mixture was stirred at 70 °C for 30 min. After cooling, the reaction was quenched by the addition of satd. aq. $NaHCO_3$ (50 mL) and stirred vigorously for a further 15 min. The layers were separated and the aqueous was extracted again with toluene (2 × 30 mL), the combined organic phases were washed with brine (20 mL) and dried. Evaporation of the solvent under reduced pressure gave the crude product as a solid. Triphenylphosphane oxide was removed by crystallisation from hexane prior to column chromatography (light petroleum ether/EtOAc, 5:1→4:1). Iodide **19** was thus obtained as a colourless oil which slowly crystallised on standing (0.674 g, 81% from **2a** over 2 steps); R_f = 0.34 (light petroleum ether/EtOAc, 1:1); m.p. 55−57 °C. $[\alpha]_D^{20}$ = −4.0 (*c* = 1.0, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3030, 2865, 1496, 1453, 1360, 1210, 1099. ^1H NMR (270 MHz, $CDCl_3$): δ = 3.04 (ddd, $J_{2,3}$ = 9.2, $J_{2,1A}$ = 5.0, $J_{2,1B}$ = 2.7 Hz, 1 H, 2-H), 3.38 (dd, $J_{1A,1B}$ = 10.8, $J_{1A,2}$ = 5.0 Hz, 1 H, 1-H$_A$), 3.43−3.54 (m, 3 H, 3-H, 5-H, 6-H), 3.65 (t, *J* = 9.5 Hz, 1 H, 4-H), 3.72−3.79 (m, 3 H, 1-H$_B$, 7-H$_A$, 7-H$_B$), 4.57−4.95 (4 × AB, 8 H, 4 × C*H*$_2$Ph), 7.17−7.40 (m, 20 H, 4 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 7.7 (C1), 68.6 (C7), 73.5, 75.0, 75.4, 75.6 (4 × *C*H$_2$Ph), 77.2, 78.4, 79.2, 81.5, 86.6 (C2−C6), 127.5, 127.7 (× 2), 127.8, 127.9, 128.0, 128.3, 128.4, 128.5 (arom. CH), 137.8, 138.0, 138.3 (× 2) (subst. arom. C); *m*/*z* (FAB): 687 (7%, $[M + Na]^+$, 91 (100) $[C_7H_7]^+$; found $[M + Na]^+$ 687.1609. $C_{35}H_{37}IO_5$·Na requires 687.1583; found C 63.48, H 5.73. $C_{35}H_{37}IO_5$ requires C, 63.26, H 5.61%.

2,6-Anhydro-3,4,5,7-tetra-*O*-benzyl-1-*S*-(2′,3′,4′,6′-tetra-*O*-benzyl-β-D-glucopyranosyl)-1-thio-β-D-*glycero*-D-*gulo*-heptitol (20): Potassium carbonate (3 g, 21.7 mmol) was added to a solution of the thiol **13**[21] (0.25 g, 0.45 mmol) and iodide **19** (0.30 g, 0.45 mmol) in acetone (10 mL) and the mixture was heated at reflux for 30 min. On cooling, the solvent was evaporated and the residue was partitioned between EtOAc (40 mL) and H_2O (40 mL) and the aqueous layer was further extracted with EtOAc (2 × 30 mL). The organic parts were washed with brine (30 mL), dried, and concentrated in vacuo to give the crude product as a solid (0.48 g) which was used directly in the next step. An analytical sample was purified by column chromatography (light petroleum ether/EtOAc, 3:1→2:1) and then recrystallisation from hexane to give **20** as fine needles, R_f = 0.27 (light petroleum ether/EtOAc, 3:1); m.p. 116.5−117 °C. $[\alpha]_D^{20}$ = −31.2 (*c* = 1.1, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3006, 2907, 1497, 1454, 1360, 1234, 1205, 1089, 1064. ^1H NMR (270 MHz, $CDCl_3$): δ = 2.82, 3.26 (ABX, $J_{1A,1B}$ = 14.2, $J_{1A,2}$ = 5.6 Hz, $J_{1B,2}$ unresolved, 2 H, 1-H$_A$, 1-H$_B$), 3.35−3.42 (m, 3 H, 2-H, 2′-H, 5′-H), 3.53−3.68 (m, 11 H, 3-H−6-H, 7-H$_A$, 7-H$_B$, 1′-H, 3′-H, 4′-H, 6′-H$_A$, 6′-H$_B$), 4.45−4.94 (m, 16 H, 8 × C*H*$_2$Ph), 7.14−7.39 (m, 40 H, 8 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 31.1 (C1), 68.9, 69.0 (C7, C6′), 73.3, 73.5, 74.9, 75.0 (× 2), 75.1, 75.4, 75.4 (8 × *C*H$_2$Ph), 77.9, 78.3, 78.9, 79.0, 79.4, 79.8, 82.0, 84.7, 86.6, 87.1 (C2−C6, C1′−C5′), 127.5, 127.6, 127.7, 127.8 (× 2), 127.9, 128.0, 128.2, 128.3, 128.4, 128.5 (arom. CH), 138.1, 138.2, 138.6 (subst. arom. C); *m*/*z* (FAB): 1115.5 (100) $[M + Na]^+$, 181 (45%); found $[M + Na]^+$ 1115.4746. $C_{69}H_{72}O_{10}S$·Na requires 1115.4744.

***S,S*-Dioxo-2,6-anhydro-3,4,5,7-tetra-*O*-benzyl-1-*S*-(2′,3′,4′,6′-tetra-*O*-benzyl-β-D-glucopyranosyl)-1-thio-β-D-*glycero*-D-*gulo*-heptitol (21):** To a solution of the crude disaccharide **20** (0.48 g) in DCM (10 mL) was added first Na_2HPO_4 (0.31 g, 2.18 mmol) then mCPBA (0.23 g, 1.33 mmol) and the reaction mixture was stirred for 1 h. The solution was diluted with DCM (40 mL), washed successively with satd. aq. $Na_2S_2O_3$ (30 mL), aq. NaOH (1 M, 20 mL), brine (30 mL), and dried. The product was purified by column chromatography (light petroleum ether/EtOAc, 3:1) to give sulfone **21** as a foam (0.47 g, 93%); R_f = 0.22 (light petroleum ether/EtOAc, 3:1), $[\alpha]_D^{20}$ = +14.0 (*c* = 1.0, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3031, 2913, 1497, 1454, 1361, 1331, 1311 (SO_2), 1214, 1205, 1148 (SO_2), 1098, 1064. ^1H NMR (270 MHz, $CDCl_3$): δ = 2.30 (dd, $J_{1A,1B}$ = 14.9, $J_{1A,2}$ = 6.8 Hz, 1 H, 1-H$_A$), 3.40−3.48 (m, 3 H, 2-H, 3-H, 5′-H), 3.53−3.69 (m, 9 H, 1-H$_B$, 4-H, 5-H, 7-H$_A$, 7-H$_B$, 3′-H, 4′H, 6′-H$_A$, 6′-H$_B$), 3.74−3.82 (m, 1 H, 6-H), 4.02 (t, *J* = 8.7 Hz, 1 H, 2′-H), 4.42−4.59 (m, 7 H, 1′-H, 3 × C*H*$_2$Ph), 4.68−4.94 (m, 10 H, 5 × C*H*$_2$Ph), 7.14−7.38 (m, 40 H, 8 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ =

52.7 (C1), 68.4, 68.7 (C7, C6′), 73.3 (× 2), 74.9, 75.0 (× 2), 75.1, 75.5, 75.7 (8 × CH_2Ph), 74.1, 77.3, 77.9 (× 2), 78.7, 79.0, 80.0, 86.3, 87.0, 90.7 (C2−C6, C1′−C5′), 127.5, 127.6, 127.7 (× 2), 127.8, 127.9, 128.3, 128.4, 128.5 (arom. CH), 137.7, 137.8, 137.9, 138.1, 138.2, 138.3 (subst. arom. C); *m*/*z* (FAB): 1147.5 (40) [M + Na]$^+$, 625.3 (45%); found [M + Na]$^+$ 1147.4641. $C_{69}H_{72}O_{12}S{\cdot}Na$ requires 1147.4642.

(*Z*,*E*)-2,6:8,12-Dianhydro-1,3,4,5,9,10,11,13-octa-*O*-benzyl-7-deoxy-D-*glycero*-D-*gulo*-L-*gulo*-tridec-6-enitol (22): Powdered potassium hydroxide (3 g, 53.5 mmol) was added to a stirred mixture of *tert*-butyl alcohol (6 cm) and water (1.5 mL) at 60 °C. After the base had dissolved, a solution of sulfone **21** (0.367 g, 0.326 mmol) in carbon tetrachloride (6 mL) was added, and the biphasic mixture was stirred at 60 °C for 1 h. After cooling to room temp., the lower aqueous layer was removed and the pale yellow organic phase was washed with brine, dried, and the solvent was removed in vacuo. Purification by column chromatography (light petroleum ether/EtOAc, 3:1 with 1% Et_3N) gave **22** as a pale yellow oil (0.167 g, 48%, *Z*/*E* = 91:9); R_f = 0.36 (light petroleum ether/EtOAc, 3:1), $[\alpha]_D^{20}$ = +39.9 (*c* = 1.1, $CHCl_3$); $\tilde{\nu}_{max}$/cm^{-1}: 3030, 2898, 1687 (C=C), 1496, 1454, 1361, 1208, 1100, 1071, 1028. ^{1}H NMR (270 MHz, $CDCl_3$): δ = 3.35 (t, *J* = 9.0 Hz, 1 H), 3.48 (br. d, *J* = 9.2 Hz, 1 H), 3.60−3.79 (m, 10 H), 3.90 (d, *J* = 6.1 Hz, 1 H), 3.93−3.99 (m, 1 H), 4.40−4.92 (m, 14 H), 5.11 (d, *J* = 8.7 Hz, 1 H, 7-H, *Z*-isomer), 5.41 (d, *J* = 8.7 Hz, 1 H, 7-H, *E*-isomer), 7.15−7.34 (40 H, 8 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 68.7, 69.0 (C1, C13), 72.1, 73.3, 73.5, 73.8, 74.2, 74.6, 74.9, 75.6 (8 × CH_2Ph), 77.9, 78.0, 78.2, 78.7 (× 2), 83.1, 84.6, 86.7 (C2−C5, C8−C12), 108.5 (C7), 127.3, 127.6, 127.7, 127.8 (× 2), 127.9, 128.0, 128.1, 128.3 (arom. CH), 137.8, 138.2 (× 2), 138.3, 138.4, 138.6, 138.8 (subst. arom. C), 152.6 (C6); *m*/*z* (FAB): 1081.5 (40) [M + Na]$^+$, 1076.2 (35%); found [M + Na]$^+$ 1081.4863. $C_{69}H_{70}O_{10}{\cdot}Na$ requires 1081.4867.

Methyl 8,12-Anhydro-1,3,4,5,9,10,11,13-octa-*O*-acetyl-7-deoxy-D-*glycero*-D-*gulo*-α-L-*gulo*-6-trideculopyranoside (23): Palladium on carbon (5% w/w, 0.015 g) was added to a solution of alkene **22** (0.160 g, 0.150 mmol) in EtOAc (3 mL) and MeOH (3 mL) and the resulting mixture was stirred for 8 h under an atmosphere of H_2 (balloon). The supernatant layer was decanted and the remaining solids were stirred with MeOH (2 mL) for 15 min. This process was repeated until no product was detectable in the washings by TLC. The combined washings were evaporated to dryness to give a colourless oil (0.08 g) which was redissolved in a mixture of Ac_2O (2 mL) and pyridine (4 mL). After stirring overnight at room temp., the solution was evaporated to dryness in vacuo and the last traces of pyridine were removed as an azeotrope with toluene (× 2). The residue was purified by column chromatography (light petroleum ether/EtOAc, 1:2) to give first fraction as a foam (0.022 g) tentatively identified as *C*-neotrehalose octaacetate. Further elution gave **23** as a colourless oil (0.018 g, 17% from **22**); R_f = 0.36 (light petroleum ether/EtOAc, 3:1). $[\alpha]_D^{20}$ = +24.3 (*c* = 0.8, $CHCl_3$); $\tilde{\nu}_{max}$/cm^{-1}: 2859, 1747 (C=O), 1434, 1371, 1253, 1231, 1098, 1036. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.83 (dd, $J_{7A,7B}$ = 15.4, $J_{7A,8}$ = 2.6 Hz, 1 H, 7-H_A), 1.96, 1.99, 2.02, 2.03 (× 2), 2.07, 2.11, 2.13 (24 H, 7 × s, 8 × $COCH_3$), 2.04−2.05 (m, 1 H, 7-H_B), 3.27 (s, 3 H, OCH_3), 3.59−3.64 (m, 2 H, 8-H, 12-H), 3.84 (ddd, $J_{2,3}$ = 10.3, $J_{2,1A}$ = 2.7, $J_{2,1B}$ = 4.4 Hz, 1 H, 2-H), 4.12, 4.20 (ABX, $J_{13A,13B}$ = 12.3, $J_{13A,12}$ = 0, $J_{13B,12}$ = 2.2 Hz, 2 H, 13-H_A, 13-H_B), 4.13, 4.24 (ABX, $J_{1A,1B}$ = 12.2, $J_{1A,2}$ = 2.7, $J_{1B,2}$ = 4.4 Hz, 2 H, 1-H_A, 1-H_B), 4.96 (t, *J* = 9.4 Hz, 1 H, 9-H), 5.04 (t, *J* = 9.6 Hz, 1 H, 11-H), 5.09 (*J* = 9.4 Hz, 1 H, 3-H), 5.15 (t, *J* = 9.4 Hz, 1 H, 10-H), 5.25 (d, $J_{5,4}$ = 9.6 Hz, 1 H, 5-H), 5.43 (t, *J* = 9.4 Hz, 1 H, 4-H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 20.6, 20.7, 20.8, 21.0 ($COCH_3$), 33.6 (C7), 48.2 (OCH_3), 62.0, 62.3 (C1, C13), 68.4 (× 2), 68.7, 71.7, 71.8, 72.0, 73.3, 74.4, 75.8 (C2−C5, C8−C12), 99.6 (C6), 169.4, 169.5, 169.6, 169.7, 170.1, 170.3, 170.7 (× 2) ($COCH_3$); *m*/*z* (FAB): 729 (40) [M + Na]$^+$, 724 (12) [M + Na]$^+$; found [M + Na]$^+$ 729.2222. $C_{30}H_{42}O_{19}{\cdot}Na$ requires 729.2218.

Bis(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)methane[25] (25): Pearlman's catalyst (20% w/w $Pd(OH)_2$ on carbon, 0.025 g) was added to a solution of alkene **22** (0.111 g, 0.105 mmol) in EtOAc (2.5 mL) and EtOH (2.5 mL) and the resulting mixture was stirred for 48 h under an atmosphere of H_2 (balloon). The supernatant liquid was then decanted and the remaining solids were stirred with MeOH (5 mL) for 15 min. This process was repeated until no product was detectable in the washings by TLC. The combined washings were evaporated to dryness to give an oil (0.047 g) which was redissolved in a mixture of Ac_2O (2 mL) and pyridine (5 mL). After stirring overnight at room temp., the solution was evaporated to dryness in vacuo and the last traces of pyridine were removed as an azeotrope with toluene (× 3). The yellow residue was purified by column chromatography (light petroleum ether/EtOAc, 1:2) to yield **25** as a white solid (0.049 g, 69% from **22**), R_f = 0.26 (light petroleum ether/EtOAc, 1:1); m.p. 127−129 °C, ref.[25] 141.4−142.4 °C. $[\alpha]_D^{20}$ = −9.1 (*c* = 1.0, $CHCl_3$), ref.[25] −17.2 (*c* = 1.45, $CHCl_3$) [The discrepancy between our observed specific rotation and the value quoted in this publication is thought to be due to our sample being insufficiently dried. We learned from a personal communication with these authors that **25** is extremely hygroscopic.]; found [M + Na]$^+$ 699.2110. $C_{29}H_{40}O_{18}{\cdot}Na$ requires 699.2112. ^{1}H and ^{13}C NMR spectroscopic data were in excellent agreement with those reported in the literature.[25]

3,7-Anhydro-4,5,6,8-tetra-*O*-benzyl-2-deoxy-1-*O*-methanesulfonyl-D-*glycero*-D-*gulo*-octitol (27c): Methanesulfonyl chloride (0.20 mL, 2.58 mmol) was added slowly to a solution of octitol **27b**[30] (1.12 g, 1.97 mmol) in DCM containing triethylamine (0.35 mL, 2.51 mmol) and the resulting solution stirred at room temp. for 1 h after which the solvent was removed under reduced pressure. The crude product was purified by column chromatography (EtOAc/petroleum ether, 9:1→4:1) to give **27c** as colourless plates (1.09 g, 86%); R_f = 0.61 (light petroleum ether/EtOAc, 1:1); m.p. 87.5−88 °C. $[\alpha]_D^{20}$ = +8.7 (*c* = 1.0, $CHCl_3$); $\tilde{\nu}_{max}$/cm^{-1}: 3066, 3033, 2909, 2871, 1496, 1453, 1357, 1347, 1171 (SO_3), 1131, 1071, 973, 946, 736, 691. ^{1}H NMR (270 MHz, $CDCl_3$): δ = 1.70−1.82 (m, 1 H, 2-H_A), 2.21−2.33 (m, 1 H, 2-H_B), 2.86 (s, 3 H, CH_3SO_3), 3.25−3.41 (m, 3 H, 3-H, 4-H, 7-H), 3.58−3.73 (m, 4 H, 5-H, 6-H, 8-H_A, 8-H_B), 4.27−4.41 (m, 2 H, 1-H_A, 1-H_B), 4.49, 4.57 (AB, *J* = 12.1 Hz, 2 H, CH_2Ph), 4.56, 4.82 (AB, *J* = 10.9 Hz, 2 H, CH_2Ph), 4.63, 4.90 (AB, *J* = 11.2 Hz, 2 H, CH_2Ph), 4.88, 4.92 (AB, *J* = 11.2 Hz, 2 H, CH_2Ph), 7.14−7.34 (20 H, 4 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 31.2 (C2), 36.9 (CH_3SO_3), 66.6 (C1), 68.9 (C8), 73.2, 74.9, 75.2, 75.5 (4 × CH_2Ph), 74.8, 78.3, 78.8, 81.7, 87.1 (C3−C7), 127.7, 127.8, 127.9, 128.0, 128.2, 128.4, 128.5 (arom. CH), 137.8, 137.9, 138.0, 138.4 (subst. aromatic C); *m*/*z* (FAB): 669 (100) [M + Na]$^+$; found [M + Na]$^+$ 669.2495. $C_{37}H_{42}O_8S{\cdot}Na$ requires 669.2498.

3,7-Anhydro-4,5,6,8-tetra-*O*-benzyl-1-*S*-(2′,3′,4′,6′-tetra-*O*-benzyl-β-D-glucopyranosyl)-2-deoxy-1-thio-β-D-*glycero*-D-*gulo*-octitol (28): A solution of thiol **13** (2.09 g, 3.75 mmol) and mesylate **27c** (1.01 g, 1.56 mmol) in acetone (60 mL) containing anhydrous potassium carbonate (2.16 g, 15.2 mmol) was stirred under reflux for 36 h. The reaction mixture was cooled to 5−10 °C, the solids removed by filtration and washed with DCM. The filtrate was then concentrated and the residue was purified by column chromatography

(EtOAc/petroleum ether 9:1→4:1) to afford **28** as a colourless oil (1.63 g, 94%); R_f = 0.32 (light petroleum ether/EtOAc, 4:1). $[\alpha]_D^{20}$ = +56.2 (c = 1.6, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3066, 3032, 2908, 2870, 1496, 1453, 1359, 1210, 1138, 1124, 1083, 1047. ^1H NMR (270 MHz, $CDCl_3$): δ = 1.75−1.90 (m, 1 H, 2-H_A), 2.11−2.24 (m, 1 H, 2-H_B), 2.76−2.88 (m, 1 H, 1-H_A), 2.93−3.04 (m, 1 H, 1-H_B), 3.27 (t, J = 9.0 Hz, 1 H), 3.37−3.47 (m, 4 H), 3.58−3.72 (m, 8 H), 4.41−4.63 and 4.71−4.94 (m, 17 H, 8 × CH_2Ph, 1′-H), 7.14−7.39 (m, 40 H, 8 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 26.7 (CH_2CH_2S), 31.95, (CH_2CH_2S), 68.9 (C6′, C8), 73.3, 73.5, 73.6, 74.9, 75.0, 75.4, 75.5, 75.7 (8 × CH_2Ph), 77.7, 77.8, 78.3, 78.8, 79.0, 81.7, 82.1, 84.8, 86.5, 87.1 (C3−C7, C1′−C5′), 127.5, 127.6, 127.7, 127.8, 127.9, 128.1, 128.2, 128.3 (arom. CH), 137.95, 138.1, 138.2, 138.5, 138.6 (subst. arom. C); found $[M + NH_4]^+$ 1124.3102. $C_{70}H_{74}O_{10}S{\cdot}NH_4$ requires 1124.3006.

***S,S*-Dioxo-3,7-Anhydro-4,5,6,8-tetra-*O*-benzyl-1-*S*-(2′,3′,4′,6′-tetra-*O*-benzyl-β-D-glucopyranosyl)-2-deoxy-1-thio-β-D-*glycero*-D-*gulo*-octitol (29):** A solution of Oxone® (4.43 g, 7.21 mmol) in water (10 mL) was added to a solution of *S*-linked disaccharide **28** (1.55 g, 1.40 mmol) in methanol (10 mL) and tetrahydrofuran (30 mL) and the resulting mixture stirred at 60 °C for 3.5 h. After cooling to room temp., the mixture was diluted with ether (50 mL), stirred for a further 0.5 h, and then the layers separated. The aqueous layer was extracted with ether (30 mL) and the combined ethereal extracts washed with water (50 mL) and brine (50 mL), and then dried and concentrated. The crude product was purified by column chromatography (light petroleum ether/EtOAc, 9:1→4:1) to give **29** as a solid (1.26 g, 79%); R_f = 0.41 (light petroleum ether/EtOAc, 1:1); m.p. 68−69 °C. $[\alpha]_D^{20}$ = +32.6 (c = 0.7, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3066, 3033, 2911, 2871, 1497, 1454, 1361, 1331, 1309, 1134, 1112 (SO_2) 1069, 1028. ^1H NMR (270 MHz, $CDCl_3$): δ = 1.86−1.99 (m, 1 H, 2-H_A), 2.35−3.49 (m, 1 H, 2-H_B), 3.15−3.37 (m, 5 H), 3.44−3.70 (m, 8 H), 3.76 (t, J = 8.7 Hz, 1 H), 4.09 (t, J = 9.2 Hz, 1 H), 4.34 (d, J = 9.5 Hz, 1 H, 1′-H), 4.43−4.63 and 4.75−5.02 (16 H, 2 × m, 8 × CH_2Ph), 7.14−7.39 (m, 40 H, 8 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 23.95 ($CH_2CH_2SO_2$), 47.9 ($CH_2CH_2SO_2$), 68.45, 68.8 (C8, C8′), 73.3, 73.35, 75.0, 75.1, 75.20, 75.3, 75.5, 75.8 (8 × CH_2Ph), 76.95, 77.1, 77.2, 78.3, 78.8 (× 2), 81.8, 86.0, 86.9, 89.4 (C3−C7, C1′−C5′), 127.6, 127.7 (× 2), 127.9 (× 2), 128.0, 128.1, 128.4, 128.5, 128.6 (arom. CH), 137.5, 137.65, 137.8, 137.9, 138.0, 138.05, 138.1, 138.5 (subst. arom. C); found $[M + Na]^+$ 1161.4807. $C_{70}H_{74}O_{12}S{\cdot}Na$ requires 1161.4799.

(*E,Z*)-3,7-Anhydro-1-(2′,3′,4′,6′-tetra-*O*-benzyl-D-glucopyranosylidene)-1,2-dideoxy-4,5,6,8-tetra-*O*-benzyl-D-*glycero*-D-*gulo*-octitol (30): A mixture of sulfone-linked disaccharide **29** (0.35 g, 0.31 mmol) in carbon tetrachloride (5 mL), *tert*-butyl alcohol (5 mL) and water (1 mL) containing powdered potassium hydroxide (0.41 g, 7.32 mmol) was stirred at 65 °C for 5 h. The reaction mixture was then cooled to 0 °C, diluted with DCM, filtered through Celite®, and the filtrate was dried and concentrated. The residue was purified by column chromatography (light petroleum ether/EtOAc, 9:1→4:1) to give **30** (*Z*/*E* = 88:12) as a colourless oil (0.15 g, 57%); R_f = 0.71 (light petroleum ether/EtOAc, 4:1). $[\alpha]_D^{20}$ = +32.6 (c = 0.7, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3030, 3009, 2960, 2936, 1665 (C=C), 1492, 1451, 1361. ^1H NMR (270 MHz, $CDCl_3$): δ = 2.42−2.53 (m, 1 H, allylic H_A), 2.84 (br. dd, 1 H, J = 14.3, 7.5 Hz, allylic H_B), 3.34−3.44 (m, 3 H), 3.58−3.81 (m, 9 H), 3.94 (d, J = 7.0 Hz, 1 H), 4.36−4.89 (m, 16 H, 8 × CH_2Ph), 5.24 (t, J = 7.0 Hz, 1 H, CH=C, *Z*-isomer), 7.10−7.35 (m, 40 H, 8 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 26.4, (CH_2CH=C), 68.7, 69.1 (C6′, C8), 72.6, 73.4 (× 2), 74.3 (× 2), 75.0, 75.1, 75.5 (CH_2Ph), 77.7, 78.2, 78.6, 78.7, 78.9, 79.2, 81.4, 85.1, 87.2 (C1′−C5′, C3−C7), 105.8 (C1), 127.3−128.3 (arom. CH), 138.0, 138.1, 138.2 (× 2), 138.3, 138.4, 138.5, 138.7 (subst. aromatic C), 149.4 (C1′); m/z (FAB): 1095.5 (100) $[M + Na]^+$.

1,2-Bis(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)ethane (31): Pearlman's catalyst (20% w/w $Pd(OH)_2$ on carbon, 0.025 g) was added to a solution of alkene **30** (0.16 g, 0.15 mmol) in ethanol (2 mL) and ethyl acetate (2 mL) and the mixture was stirred at room temp. under an atmosphere of hydrogen (balloon) for 26 h. The catalyst was then removed by filtration and the filtrate was evaporated. The residue was then taken up in pyridine (5 mL) and acetic anhydride (1 mL) added to it and stirred for a further 16 h. The solvent was removed under reduced pressure and the residue taken up in ethyl acetate (10 mL) and washed with 10% aq. hydrochloric acid (10 mL), 10% aq. NaOH (10 mL), water (2 × 10 mL), dried, and concentrated in vacuo. The crude product was then purified by column chromatography (light petroleum ether/EtOAc, 4:1→1:1) to give **31** as a colourless solid (0.055 g, 53%); R_f = 0.23 (light petroleum ether/EtOAc, 1:1); m.p. 56.5−57.5 °C. $[\alpha]_D^{20}$ = −10.9 (c = 0.5, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 2959, 2869, 1744 (C=O), 1433, 1367, 1237, 1106, 1043. ^1H NMR (270 MHz, $CDCl_3$): δ = 1.64 (br. s, 4 H, CH_2CH_2), 2.00, 2.03, 2.05, 2.10 (4 × s, 24 H, 8 × $COCH_3$), 3.41−3.51 (m, 2 H, 1-H), 3.61 (ddd, $J_{5,4}$ = 9.7, $J_{5,6B}$ = 4.6, $J_{5,6A}$ = 2.2 Hz, 2 H, 5-H), 4.09, 4.23 (ABX, $J_{6A,6B}$ = 12.1, $J_{6A,5}$ = 2.2, $J_{6B,5}$ = 4.6 Hz, 2 H, 6-H_A, 6-H_B), 4.88 (t, J = 9.5 Hz, 2 H, 4-H), 5.04 (t, J = 9.7 Hz, 2 H, 2-H), 5.16 (t, J = 9.5 Hz, 2 H, 3-H). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 20.55, 20.6, 20.7 (COCH_3), 25.8 (CH_2CH_2), 62.1 (C6), 68.5, 71.3, 74.3, 75.6, 76.8 (C1−C5), 169.4, 169.6, 170.3, 170.6 ($COCH_3$); m/z (CI): 708 (100) $[M + NH_4]^+$; found $[M + NH_4]^+$ 708.2715. $C_{30}H_{42}O_{18}{\cdot}NH_4$ requires 708.2715.

Methyl 6-*S*-Acetyl-2,3,4-tri-*O*-benzyl-6-thio-α-D-glucopyranoside (33): Diisopropyl azodicarboxylate (0.81 mL, 4.10 mmol) was added dropwise to a solution of triphenylphosphane (1.08 g, 4.12 mmol) in THF (30 mL) at 0 °C and the mixture was stirred for 20 min at this temperature after which time a white precipitate had formed. A solution of alcohol **32**[33] (0.952 g, 2.05 mmol) and thiolacetic acid (0.30 mL, 4.10 mmol) in THF (20 mL) was then added and the reaction mixture stirred for 1 h at 0 °C and then allowed to warm to room temp. overnight. The solvent was evaporated in vacuo and the resulting red residue was purified by column chromatography (light petroleum ether/EtOAc, 5:1→3:1) followed by recrystallisation of the main fraction from hexane to afford **33** as a crystalline solid (0.556 g, 52%). The mother liquor was rechromatographed to give a further 0.167 g (67% overall yield) of **33**, R_f = 0.40 (light petroleum ether/EtOAc, 2:1); m.p. 83.5−84.5 °C. $[\alpha]_D^{20}$ = +23.4 (c = 1.0, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3031, 2913, 1693 (C=O), 1497, 1454, 1359, 1155, 1136, 1092, 1072, 1050. ^1H NMR (270 MHz, $CDCl_3$): δ = 2.32 (s, 3 H, $COCH_3$), 3.03, 3.43 (ABX, $J_{6A,6B}$ = 13.6, $J_{6A,5}$ = 7.8, $J_{6B,5}$ = 3.2 Hz, 2 H, 6-H_A, 6-H_B), 3.30 (dd, $J_{4,3}$ = 9.6, $J_{4,5}$ = 8.7 Hz, 1 H, 4-H), 3.36 (s, 3 H, OCH_3), 3.50 (dd, $J_{2,3}$ = 9.6, $J_{2,1}$ = 3.6 Hz, 1 H, 2-H), 3.72−3.79 (m, 1 H, 5-H), 3.97 (t, J = 9.6 Hz, 1 H, 3-H), 4.40 (d, $J_{1,2}$ = 3.6 Hz, 1 H, 1-H), 4.61, 4.89 (AB, J = 10.7 Hz, 2 H, CH_2Ph), 4.64, 4.78 (AB, J = 12.1 Hz, 2 H, CH_2Ph), 4.81, 4.98 (AB, J = 10.7 Hz, 2 H, CH_2Ph), 7.28−7.37 (m, 15 H, 3 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 30.5 (SCOCH_3), 30.8 (C6), 55.1 (OCH_3), 73.3, 75.1, 75.7 (3 × CH_2Ph), 69.3, 79.9, 80.4, 81.8 (C2−C5), 97.8 (C1), 127.6, 127.8, 127.9, 128.0, 128.1, 128.4 (× 2) (arom. CH), 137.9, 138.0, 138.6 (subst. arom. C), 194.8, S$COCH_3$); m/z (CI): 540 (100) $[M + NH_4]^+$, 491 (20%), 91 (20) $[C_7H_7]^+$; found $[M + NH_4]^+$ 540.2421. $C_{30}H_{34}O_6S{\cdot}NH_4$ requires 540.2420.

Methyl 2,3,4-Tri-*O*-benzyl-6-thio-α-D-glucopyranoside (34): A methanolic solution of sodium methoxide (25% w/w, 0.04 mL,

0.17 mmol) was added to a solution of the *S*-acetate **33** (0.10 g, 0.19 mmol) in degassed MeOH (5 mL) and the mixture was stirred for 2 h. Amberlyst 15 ion-exchange resin was then added until the pH of the solution became neutral, the resin was removed by filtration and the filtrate evaporated in vacuo to give **34** as a colourless oil (0.050 g, 55%); R_f = 0.33 (light petroleum ether/EtOAc, 3:1). $[\alpha]_D^{20}$ = +57.1 (*c* = 0.9, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3031, 2907, 2576 (SH), 1496, 1453, 1360, 1270, 1186, 1155, 1137, 1070. ^1H NMR (270 MHz, $CDCl_3$): δ = 1.51 (dd, $J_{SH,6B}$ = 8.6, $J_{SH,6A}$ = 7.8 Hz, 1 H, S*H*), 2.60 (dt, $J_{6A,6B}$ = 13.3, $J_{6A,5}$ = $J_{6A,SH}$ = 7.8 Hz, 1 H, 6-H_A), 2.72 (ddd, $J_{6B,6A}$ = 13.3, $J_{6B,SH}$ = 8.6, $J_{6B,5}$ = 2.7 Hz,1 H, 6-H_B), 3.40 (s, 3 H, OCH_3), 3.44 (dd, $J_{4,3}$ = 9.7, $J_{4,5}$ = 9.0 Hz, 1 H, 4-H), 3.52 (dd, $J_{2,3}$ = 9.7, $J_{2,1}$ = 3.6 Hz, 1 H, 2-H), 3.68−3.75 (m, 1 H, 5-H), 4.00 (t, *J* = 9.7 Hz, 1 H, 3-H), 4.57 (d, $J_{1,2}$ = 3.6 Hz, 1 H, 1-H), 4.61, 4.91 (AB, *J* = 11.2 Hz, 2 H, CH_2Ph), 4.66, 4.80 (AB, *J* = 12.1 Hz, 2 H, CH_2Ph), 4.81, 5.00 (AB, *J* = 10.9 Hz, 2 H, CH_2Ph), 7.23−7.33 (m, 15 H, 3 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 26.3 (C6), 55.2 (OCH_3), 73.3, 75.0, 75.7 (3 × *C*H_2Ph), 70.6, 79.6, 80.1, 81.9 (C2−C5), 97.9 (C1), 127.6, 127.8, 127.9, 128.0, 128.4 (× 2) (arom. CH), 138.0 (× 2), 138.6 (subst. arom. C); *m*/*z* (CI): 498 (100) $[M + NH_4]^+$, 341 (90%), 251 (30%), 235 (45%), 91 (85) $[C_7H_7]^+$; found $[M + NH_4]^+$ 498.2311. $C_{28}H_{32}O_5S{\cdot}NH_4$ requires 498.2314.

Methyl 2,3,4-Tri-*O*-benzyl-6-*S*-(2′,6′-anhydro-3′,4′,5′,7′-tetra-*O*-benzyl-1′-deoxy-D-*glycero*-D-*gulo*-heptitol-1-yl)-6-thio-α-D-glucopyranoside (35): Potassium carbonate (3 g, 21.7 mmol) was added to a solution of the thiol **34** (0.094 g, 0.19 mmol) and iodide **19** (0.130 g, 0.19 mmol) in acetone (20 mL) and the mixture was heated at reflux for 4 h. On cooling, the solvent was evaporated and the residue partitioned between EtOAc (40 mL) and H_2O (40 mL) and the aqueous portion further extracted with EtOAc (2 × 30 mL). The organic parts were washed with brine (30 mL), dried and concentrated in vacuo to give the crude product as an oil which was chromatographed on silica (light petroleum ether/EtOAc, 5:1→3:1) to give **35** as a colourless oil (0.14 g, 72%); R_f = 0.40 (light petroleum ether/EtOAc, 2:1). $[\alpha]_D^{20}$ = +8.6 (*c* = 1.0, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3031, 2909, 1497, 1454, 1360, 1208, 1154, 1137, 1091, 1069. ^1H NMR (270 MHz, $CDCl_3$): δ = 2.71, 3.00 (ABX, $J_{1'A,1'B}$ = 13.6, $J_{1'A,2'}$ = 7.5 Hz, $J_{1'B,2'}$ unresolved, 2 H, 1′-H_A, 1′-H_B), 2.81, 3.00 (ABX, $J_{6A,6B}$ = 13.6, $J_{6A,5}$ = 7.5 Hz, $J_{6B,5}$ unresolved, 2 H, 6-H_A, 6-H_B), 3.36 (s, 3 H, OCH_3), 3.31−3.72 (m, 9 H, 2-H, 4-H, 2′-H to 6′-H, 7′-H_A, 7′-H_B), 3.80 (ddd, $J_{5,4}$ = 7.5, $J_{5,6A}$ = 7.5, $J_{5,6B}$ = 2.2 Hz, 1 H, 5-H), 3.96 (t, *J* = 9.2 Hz, 1 H, 3-H), 4.45−4.99 (m, 15 H, 1-H, 7 × CH_2Ph), 7.14−7.37 (m, 35 H, 7 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 34.9, 35.2 (C6, C1′), 55.0 (OCH_3), 69.0 (C7′), 73.2, 73.4, 74.9, 75.0 (× 2), 75.4, 75.6 (7 × *C*H_2Ph), 70.9, 78.4, 78.9, 79.9 (× 2), 80.6 (× 2), 81.9, 87.0 (C2−C5, C2′−C6′), 97.7 (C1), 127.5 (× 2), 127.6, 127.7, 127.8, 128.0, 128.1, 128.2, 128.3 (× 2) (arom. CH), 138.0 (× 2), 138.1, 138.2, 138.5, 138.6 (subst. arom. C); *m*/*z* (FAB): 1039.5 (100) $[M + Na]^+$; found $[M + Na]^+$ 1039.4430. $C_{63}H_{68}O_{10}S{\cdot}Na$ requires 1039.4431.

Methyl *S,S*-Dioxo-2,3,4-tri-*O*-benzyl-6-*S*-(2′,6′-anhydro-3′,4′,5′,7′-tetra-*O*-benzyl-1′-deoxy-D-*glycero*-D-*gulo*-heptitol-1-yl)-6-thio-α-D-glucopyranoside (36): To a solution of the disaccharide **35** (0.132 g, 0.13 mmol) in DCM (8 mL) was added first Na_2HPO_4 (0.09 g, 0.63 mmol) then a solution of mCPBA (0.06 g, 0.35 mmol) in DCM (2 mL) and the reaction mixture was stirred for 3 h. The solution was diluted with DCM (40 mL), washed with satd. aq. $Na_2S_2O_3$ (20 mL), aq. NaOH (1 M, 20 mL), brine (30 mL), and dried. The crude product obtained on evaporation of the solvent was chromatographed on silica (light petroleum ether/EtOAc, 2:1) to give **36** as an opaque oil (0.13 g, 95%); R_f = 0.25 (light petroleum ether/EtOAc, 2:1). $[\alpha]_D^{20}$ = +17.5 (*c* = 0.84, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3031, 2924, 1497, 1454, 1361, 1314 (SO_2), 1207, 1134, 1115 (SO_2), 1095, 1071. ^1H NMR (270 MHz, $CDCl_3$): δ = 3.02−3.14 (m, 2 H), 3.24−3.83 (m, 11 H), 3.43 (s, 3 H, OCH_3), 3.95 (t, *J* = 9.2 Hz, 1 H, 3-H), 4.18−4.25 (m, 1 H, 5-H), 4.38−4.98 (m, 15 H, 1-H, 7 × CH_2Ph), 7.13−7.35 (m, 35 H, 7 × Ph). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 55.7 (OCH_3), 56.4, 56.6 (C6, C1′), 65.3, 74.3, 78.1, 78.5, 79.4 (× 2), 80.1, 81.6, 86.9 (C2−C5, C2′−C6′), 69.0 (C7′), 73.2 (× 2), 73.3, 74.7, 75.0, 75.6 (× 2) (7 × *C*H_2Ph), 97.9 (C1), 127.4, 127.6, 127.7, 127.8 (× 2), 127.9, 128.0, 128.3, 128.4, 128.5 (arom. CH), 137.4, 137.6, 137.7, 138.0 (× 2), 138.2, 138.5 (subst. arom. C); *m*/*z* (FAB): 1071 (15) $[M + Na]^+$, 711 (8%), 271 (15%), 181 (100%); found $[M + Na]^+$ 1071.4338. $C_{63}H_{68}O_{12}S{\cdot}Na$ requires 1071.4329.

(*Z*,*E*)-Methyl 8,12-Anhydro-2,3,4,9,10,11,13-hepta-*O*-benzyl-6,7-dideoxy-α-D-*glycero*-D-*gulo*-D-*gluco*-tridec-6-enopyranoside (37): A solution of the sulfone **36** (0.046 g, 0.04 mmol) in DCM (0.5 mL) was added to a stirred suspension of KOH/Al_2O_3 (25% w/w, 2.0 g) in *tert*-butyl alcohol (3 mL) at 5 °C. CBr_2F_2 (0.5 mL, 5.47 mmol) was then added over a period of 2 min and the reaction mixture was stirred at this temperature for 2 h. More KOH/Al_2O_3 (1.5 g) and CBr_2F_2 (0.5 mL, 5.47 mmol) was added and stirring continued for a further 1 h at 5 °C and then for 2 h at room temp. The mixture was diluted with DCM (40 mL), stirred for 10 min, filtered through Celite®, and the filtrate was evaporated under reduced pressure. The residue was chromatographed on a silica gel column (light petroleum ether/EtOAc, 4:1→3:1) to yield **37** as a white solid (0.025 g, 64%, *Z*/*E* = 74:26). ^1H NMR (270 MHz, $CDCl_3$): selected data for (*Z*)-isomer: δ = 5.65 (dd, *J* = 11.2 Hz, 1 H, 6.1, 6-H *or* 7-H), 5.70 (dd, *J* = 11.6 Hz, 1 H, 6.3, 6-H *or* 7-H); selected data for (*E*)-isomer, 5.96 (appt. t, *J* = 4.1 Hz, 2 H, 6-H *or* 7-H). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = selected data for (*Z*)-isomer, 132.9, 132.6 (C6, C7); selected data for (*E*)-isomer: 130.4, 130.7 (C6, C7); *m*/*z* (FAB): 1005.5 (100) $[M + Na]^+$; found $[M + Na]^+$ 1005.4545. $C_{63}H_{66}O_{10}{\cdot}Na$ requires 1005.4554.

Methyl 2,3,4,9,10,11,13-Hepta-*O*-acetyl-8,12-anhydro-6,7-dideoxy-α-D-*glycero*-D-*gulo*-D-*gluco*-tridecopyranoside[35] (39): Pearlman's catalyst (20% w/w $Pd(OH)_2$ on carbon, 0.02 g) was added to a solution of alkene **37** (0.10 g, 0.10 mmol) in EtOAc (2 mL) and EtOH (2 mL) and the resulting mixture was stirred for 8 h under an atmosphere of H_2 (balloon). The supernatant layer was decanted and the remaining solids were stirred with MeOH (2 mL) for 15 min. This process was repeated until no product was detectable in the washings by TLC. The combined washings were evaporated to dryness and triturated with DCM to give a waxy solid (0.019 g), which was redissolved in a mixture of Ac_2O (1 mL) and pyridine (2 mL). After stirring overnight at room temp., the solution was evaporated to dryness in vacuo and the last traces of pyridine were removed as an azeotrope with toluene (× 3). The residue was purified by column chromatography (light petroleum ether/EtOAc, 1:1) to yield **39** as a white solid (0.008 g, 12% from **37**); R_f = 0.18 (light petroleum ether/EtOAc, 1:1). $[\alpha]_D^{20}$ = +65.1 (*c* = 0.45, $CHCl_3$), ref.[35] +63 (*c* = 0.7, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3023, 2951, 1747 (C=O), 1434, 1371, 1225, 1171, 1104, 1047, 1069; . ^1H NMR (500 MHz, $CDCl_3$): δ = 1.41−1.46 (m, 2 H, 6-H_A, 7-H_A), 1.76−1.84 (m, 2 H, 6-H_B, 7-H_B), 2.00 (× 2), 2.03, 2.04, 2.05, 2.07, 2.09 (6 × s, 21 H, 7 × $COCH_3$), 3.36 (s, 3 H, OCH_3), 3.38−3.41 (m, 1 H, 8-H), 3.62 (ddd, $J_{12,11}$ = 10.0, $J_{12,13B}$ = 5.3, $J_{12,13A}$ = 2.2 Hz, 1 H, 12-H), 3.72−3.76 (m, 1 H, 5-H), 4.08, 4.23 (ABX, $J_{13A,13B}$ = 12.3, $J_{13A,12}$ = 2.2, $J_{13B,12}$ = 5.3 Hz, 2 H, 13-H_A, 13-H_B), 4.81−4.88 (m, 4 H, 1-H, 2-H, 4-H, 9-H), 5.03 (appt. t, $J_{11,12}$ = 10.0, $J_{11,10}$ = 9.5 Hz, 1 H, 11-H), 5.17 (t, *J* = 9.5 Hz, 1 H, 10-H), 5.43 (t, *J* = 9.7

Hz, 1 H, 3-H). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 20.59, 20.62, 20.66 (× 2), 20.69, 20.71, 20.72 (7 × CO*C*H$_3$), 26.81, 27.04 (C6, C7), 55.23 (OCH$_3$), 62.33 (C13), 68.41, 68.71, 70.12, 71.15, 71.81, 72.23, 74.29, 75.73, 77.88 (C2−C5, C8−C12), 96.48 (C1), 169.51, 169.66, 169.92, 170.01, 170.20, 170.34, 170.65 (7 × *C*OCH$_3$); *m*/*z* (FAB): 671 (100) [M + Na]$^+$; found [M + Na]$^+$ 671.2155. $C_{28}H_{40}O_{17}$·Na requires 671.2163.

(*S*)-*S*-Acetyl-*N*-(*tert*-butoxycarbonyl)-2,2-dimethyl-4-(thiomethyl)-1,3-oxazolidine (42): Diisopropyl azodicarboxylate (0.85 mL, 4.32 mmol) was added dropwise to a solution of triphenylphosphane (1.13 g, 4.31 mmol) in THF (30 mL) at 0 °C and the mixture was stirred for 30 min at this temperature after which time a white precipitate had formed. A solution of alcohol **41**[42] (0.50 g, 2.16 mmol) and thiolacetic acid (0.31 mL, 4.34 mmol) in THF (20 mL) was added and the resulting yellow mixture was stirred for 1 h at 0 °C. The solvent was evaporated in vacuo and the resulting residue treated with a mixture of light petroleum ether and EtOAc (5:1) causing triphenylphosphane to crystallise. The supernatant was purified by column chromatography (light petroleum ether/EtOAc, 5:1→4:1) to give a mixture of the desired product and triphenylphosphane sulfide. The contaminant was removed by crystallisation from hexane to leave **42** as a colourless oil (0.517 g, 83%); R_f = 0.32 (light petroleum ether/EtOAc, 3:1). $[\alpha]_D^{20}$ = −15.0 (*c* = 1.0, $CHCl_3$); $\tilde{\nu}_{max}$/cm^{-1}: 2980, 2878, 1752 (C=O, *S*-acetate), 1702 (C=O, carbamate), 1479, 1456, 1384, 1367, 1295, 1260, 1208, 1174, 1133, 1097, 1079, 1050. ^{1}H NMR (270 MHz, [D$_6$]DMSO, 80 °C): δ = 1.43, 1.54 [2 × s, 6 H, C(CH$_3$)$_2$], 1.47 [s, 9 H, OC(CH$_3$)$_3$], 2.36 (s, 3 H, COCH$_3$), 2.99−3.06 (m, 1 H, C*H*$_A$H$_B$SAc), 3.23 (br. d, $J_{HA,HB}$ = 12.8 Hz, 1 H, CH$_A$*H*$_B$SAc), 3.68 (br. d, $J_{5A,5B}$ = 7.3 Hz, 1 H, 5-H$_A$), 3.87, 3.93−4.02 (m, 2 H, 4-H, 5-H$_B$). ^{13}C NMR (67.9 MHz, [D$_6$]DMSO, 80 °C): δ = 23.6 (br), 26.6 [C(*C*H$_3$)$_2$], 28.0 [OC(*C*H$_3$)$_3$], 30.3 (CO*C*H$_3$), 30.7 (*C*H$_2$SAc), 56.1 (C4), 66.1 (C5), 79.4 [O*C*(CH$_3$)$_3$], 93.4 (C2), 151.1 (*t*BuO*C*ON), 194.0 (*C*OCH$_3$); *m*/*z* (CI): 290 (20) [M + H]$^+$, 234 (15%), 190 (100) [M − Boc + H]$^+$; found [M + H]$^+$ 290.1426. $C_{13}H_{23}NO_4S$.H requires 290.1426.

(*S*)-*N*-(*tert*-butoxycarbonyl)-2,2-dimethyl-4-(thiomethyl)-1,3-oxazolidine (43): A methanolic solution of sodium methoxide (25% w/w, 0.26 mL, 1.14 mmol) was added to a solution of the *S*-acetate **42** (0.33 g, 1.14 mmol) in degassed MeOH (5 mL) and the mixture was stirred for 4 h. Amberlyst 15 ion-exchange resin was then added until the pH of the solution became neutral, the resin was removed by filtration and the filtrate was evaporated in vacuo. Purification by column chromatography (light petroleum ether/EtOAc, 5:1→4:1) gave first **43** as a colourless oil (0.162 g, 57%); R_f = 0.37 (light petroleum ether/EtOAc, 4:1). $[\alpha]_D^{20}$ = −25.8 (*c* = 1.2, $CHCl_3$); $\tilde{\nu}_{max}$/cm^{-1}: 2979, 2878, 2562 (SH), 1694 (C=O), 1478, 1456, 1386, 1367, 1310, 1296, 1261, 1245, 1207, 1174, 1147, 1102, 1081, 1061. ^{1}H NMR (270 MHz, [D$_6$]DMSO, 80 °C): δ = 1.41, 1.49 [2 × s, 6 H, C(CH$_3$)$_2$], 1.43 [s, 9 H, OC(CH$_3$)$_3$], 2.24 (br. t, *J* = 8.5 Hz, 1 H, SH), 2.52 (dt, $J_{HA,HB}$ = 12.6, $J_{HA,4}$ = $J_{HA,SH}$ 8.5 Hz, 1 H, C*H*$_A$H$_B$SH), 2.72−2.81 (m, 1 H, CH$_A$*H*$_B$SH), 3.81−3.88 (m, 1 H, 4-H), 3.89, 3.95 (ABX, $J_{5A,5B}$ = 9.2, $J_{5A,4}$ = 2.2, $J_{5B,4}$ = 5.6 Hz, 2 H, 5-H$_A$, 5-H$_B$). ^{13}C NMR (67.9 MHz, [D$_6$]DMSO, 80 °C): δ = 23.3 (br), 26.4 [C(*C*H$_3$)$_2$], 25.3 (*C*H$_2$SH), 27.6 [OC(*C*H$_3$)$_3$], 58.9 (C4), 65.0 (C5), 78.9 [O*C*(CH$_3$)$_3$], 93.0 (C2), 150.8 (*t*BuO*C*ON); *m*/*z* (CI): 248 (35) [M + H]$^+$, 192 (65%); 148 (100) [M − Boc + H]$^+$; found [M + H]$^+$ 248.1322. $C_{11}H_{21}NO_3S$.H requires 248.1320. Further elution gave an oil (0.038 g) tentatively identified as the dimeric disulfide of **43**.

(4*S*)-*S*-(2′,6′-Anhydro-3′,4′,5′,7′-tetra-*O*-benzyl-1′-deoxy-D-*glycero*-D-*gulo*-heptitol-1′-yl)-*N*-(*tert*-butoxycarbonyl)-2,2-dimethyl-4-(thiomethyl)-1,3-oxazolidine (44): Potassium carbonate (3 g, 21.7 mmol) was added to a solution of the thiol **43** (0.25 g, 1.01 mmol) and iodide **19** (0.287 g, 0.43 mmol) in acetone (25 mL) and the mixture was heated at reflux for 4.5 h. After cooling, the solids were removed by filtration, the solvent was evaporated and the residue was partitioned between EtOAc (50 mL) and H_2O (50 mL). The aqueous layer was further extracted with EtOAc (2 × 25 mL) and the organic parts were washed with brine (30 mL), dried, and concentrated in vacuo to give the crude product as an oil. Purification by column chromatography (light petroleum ether/EtOAc, 4:1) gave **44** as a colourless oil (0.239 g, 71%); R_f = 0.23 (light petroleum ether/EtOAc, 4:1). $[\alpha]_D^{20}$ = −30.7 (*c* = 1.2, $CHCl_3$); $\tilde{\nu}_{max}$/cm^{-1}: 2978, 2871, 1695 (C=O), 1496, 1477, 1454, 1386, 1365, 1308, 1260, 1245, 1208, 1171, 1143, 1099, 1071, 1028. ^{1}H NMR (270 MHz, [D$_6$]DMSO, 80 °C): δ = 1.47, 1.55 [2 × s, 6 H, C(CH$_3$)$_2$], 1.49 [s, 9 H, OC(CH$_3$)$_3$], 2.55−2.69 (m, 2 H, SC*H*$_2$oxaz.), 2.79 (dd, $J_{1'A,1'B}$ = 13.7, $J_{1'A,2}$ = 6.5 Hz, 1 H, 1′-H$_A$), 3.00 (br. t, $J_{1'B,1'A}$ = 13.7 Hz, 1 H, 1′-H$_B$), 3.46−3.62 and 3.69−3.82 (2 × m, 8 H, 4-H, 2′-H, 3′-H, 4′-H, 5′-H, 6′-H, 7′-H$_A$, 7′-H$_B$), 3.91−4.02 (2 H, 5-H$_A$, 5-H$_B$), 4.55−4.90 (m, 8 H, 4 × C*H*$_2$Ph), 7.27−7.40 (m, 20 H, 4 × Ph). ^{13}C NMR (67.9 MHz, [D$_6$]DMSO, 80 °C): δ = 23.4 (br), 26.5 [C(*C*H$_3$)$_2$], 27.7 [OC(*C*H$_3$)$_3$], 33.6 (C1′), 34.7 (*C*H$_2$oxaz.), 56.4 (C4), 65.7 (C5), 68.9 (C7′), 72.2, 73.4, 73.5, 73.9 (4 × *C*H$_2$Ph), 78.1 (× 2), 80.2, 85.5 (× 2) (C2′−C6′), 78.9 [O*C*(CH$_3$)$_3$], 92.9 (C2), 126.9, 127.0 (× 2), 127.1, 127.2, 127.7 (arom. CH), 138.0 (× 2), 138.1, 138.3 (subst. arom. C), 150.7 (*t*BuO*C*ON); *m*/*z* (FAB): 806 (100) [M + Na]$^+$, 684 (35) [M − Boc+H]$^+$, 181 (30%); found [M + Na]$^+$ 806.3707. $C_{46}H_{57}NO_8S$·Na requires 806.3703.

(4*S*)-*S*-(2′,6′-Anhydro-3′,4′,5′,7′-tetra-*O*-benzyl-1′-deoxy-D-*glycero*-D-*gulo*-heptitol-1′-yl)-*N*-(*tert*-butoxycarbonyl)-2,2-dimethyl-4-(sulfonylmethyl)-1,3-oxazolidine (45): To a solution of sulfide **44** (0.554 g, 0.707 mmol) in DCM (20 mL) was added first Na_2HPO_4 (0.501 g, 3.53 mmol) then mCPBA (0.366 g, 2.12 mmol) and the reaction mixture was stirred for 3 h. The solution was diluted with DCM (50 mL), washed with satd. aq. $Na_2S_2O_3$ (30 mL), aq. NaOH (1 M, 20 mL), brine (30 mL), and dried. On evaporation of the solvent the crude sulfone was obtained as a gum (0.551 g, 95%) which was > 95% pure according to ^{1}H NMR analysis. An analytical sample was chromatographed on silica (light petroleum ether/EtOAc, 4:1) to give **45** as a white foam, R_f = 0.09 (light petroleum ether/EtOAc, 4:1). $[\alpha]_D^{20}$ = −30.1 (*c* = 0.6, $CHCl_3$); $\tilde{\nu}_{max}$/cm^{-1}: 2980, 2876, 1694 (C=O), 1497, 1454, 1387, 1314 (SO_2), 1261, 1248, 1210, 1170, 1106, 1052, 1028. ^{1}H NMR (270 MHz, [D$_6$]DMSO, 80 °C): δ = 1.44, 1.55 [2 × s, 15 H, C(CH$_3$)$_2$, OC(CH$_3$)$_3$], 3.21 (dd, 1 H, $J_{A,B}$ = 15.0, $J_{A,4}$ = 1.5 Hz, SO$_2$C*H*$_A$H$_B$oxaz.), 3.39−3.58 (m, 6 H, SO$_2$CH$_A$*H*$_B$oxaz., 1′-H$_A$, 1′-H$_B$, 3′-H, 4′-H, 5′-H), 3.70 (br. s, 2 H, 7′-H$_A$, 7′-H$_B$), 3.78−3.91 (m, 2 H, 2′-H, 6′-H), 4.00−4.09 (ABX, $J_{5A,5B}$ = 9.2, $J_{5A,4}$ = 5.3, $J_{5B,4}$ = 1.5 Hz, 2 H, 5-H$_A$, 5-H$_B$), 4.32−4.40 (m, 1 H, 4-H), 4.48, 4.55 (AB, *J* = 12.4 Hz, 2 H, C*H*$_2$Ph), 4.59, 4.82 (AB, *J* = 10.7 Hz, 2 H, C*H*$_2$Ph), 4.67, 4.74 (AB, *J* = 11.4 Hz, 2 H, C*H*$_2$Ph), 4.81, 4.86 (AB, *J* = 11.4 Hz, 2 H, C*H*$_2$Ph), 7.18−7.37 (m, 20 H, 4 × Ph). ^{13}C NMR (67.9 MHz, [D$_6$]DMSO, 80 °C): δ = 23.4 (br), 26.5 [C(*C*H$_3$)$_2$], 27.7 [OC(*C*H$_3$)$_3$], 51.1 (C4), 55.6 (SO$_2$*C*H$_2$oxaz.), 55.9 (C1′), 66.1 (C5), 68.6 (C7′), 72.3, 73.4, 73.5, 73.9 (4 × *C*H$_2$Ph), 73.3, 77.6, 77.9, 79.5, 85.2 (C2′−C6′), 79.4 [O*C*(CH$_3$)$_3$], 92.4 (C2), 126.9, 127.0, 127.1, 127.2, 127.5, 127.7, 127.8, 128.1 (arom. CH), 137.6 137.8 (× 2), 138.1 (subst. arom. C), 150.5 (*t*BuO*C*ON); *m*/*z* (FAB): 838 (100) [M + Na]$^+$; found [M + Na]$^+$ 838.3608. $C_{46}H_{57}NO_{10}S$·Na requires 838.3601.

(*E*)-5,9-Anhydro-6,7,8,10-tetra-*O*-benzyl-1,2-*N*,*O*-isopropylidene-2-(*tert*-butoxycarbonylamino)-2,3,4-trideoxy-D-*erythro*-L-*talo*-dec-3-

enitol (46): KOH/Al_2O_3 (25% w/w, 5.0 g) was added to a solution of the sulfone **45** (0.46 g, 0.56 mmol) in *tert*-butyl alcohol (8 mL) and the mixture was heated to 60 °C. CBr_2F_2 (0.5 mL, 5.47 mmol) was added and the reaction was stirred at this temperature for 15 min. Two portions of CBr_2F_2 (0.5 mL, 5.47 mmol each) were added over the next 2.5 h but some starting material still remained. Therefore, more KOH/Al_2O_3 (3.0 g) was added, followed by CBr_2F_2 (0.5 mL, 5.47 mmol) after 15 min. The mixture was diluted with DCM (40 mL), stirred for 10 min, filtered through Celite®, and the filtrate was evaporated under reduced pressure. The residue was chromatographed on a silica column (light petroleum ether/EtOAc, 4:1→3:1) to yield a solid which crystallised upon trituration with light petroleum ether to afford **46** as a white crystalline solid (0.155 g, 37%), R_f = 0.14 (light petroleum ether/EtOAc, 3:1); m.p. 109−110 °C. $[\alpha]_D^{20} = -11.9$ (c = 1.0, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 2979, 2869, 1695 (C=O), 1606 (C=C), 1497, 1454, 1384, 1366, 1254, 1207, 1168, 1098, 1067, 1028. ^1H NMR (270 MHz, [D$_6$]DMSO, 80 °C): δ = 1.36 [s, 9 H, OC(CH$_3$)$_3$], 1.47, 1.53 [2 × s, 6 H, C(CH$_3$)$_2$], 3.26 (t, J = 9.2 Hz, 1 H, 8-H), 3.47−3.54 (m, 2 H, 10-H$_A$, 10-H$_B$), 3.62−3.74 (m, 4 H, 1-H$_A$, 1-H$_B$, 6-H, 9-H), 3.86 (dd, $J_{7,8}$ = 9.5, $J_{7,6}$ = 5.6 Hz, 1 H, 7-H), 4.01 (dd, $J_{5,6}$ = 9.0, $J_{5,4}$ = 6.0 Hz, 1 H, 5-H), 4.37 (br. t, J = 5.8 Hz, 1 H, 2-H), 4.51, 4.56 (AB, J = 12.1 Hz, 2 H, CH_2Ph), 4.59, 4.76 (AB, J = 11.2 Hz, 2 H, CH_2Ph), 4.62, 4.69 (AB, J = 11.2 Hz, 2 H, CH_2Ph), 4.79, 4.84 (AB, J = 11.4 Hz, 2 H, CH_2Ph), 5.72 (dd, $J_{3,4}$ = 15.6, $J_{3,2}$ = 5.8 Hz, 1 H, 3-H), 5.84 (dd, $J_{4,3}$ = 15.6, $J_{4,5}$ = 6.0 Hz, 1 H, 4-H), 7.20−7.34 (m, 20 H, 4 × Ph). ^{13}C NMR (67.9 MHz, [D$_6$]DMSO, 80 °C): δ = 23.5 (br), 26.4 [C(*C*H$_3$)$_2$], 27.6 [OC(*C*H$_3$)$_3$], 57.6 (C2), 67.1 (C1), 69.1 (C10), 72.2, 73.4 (× 2), 73.9 (4 × *C*H$_2$Ph), 77.7 (× 2), 77.9, 82.0, 85.4 (C5−C9), 78.7 [O*C*(CH$_3$)$_3$], 92.7 [*C*(CH$_3$)$_2$], 126.8, 126.9 (× 2), 127.0, 127.1, 127.2, 127.4, 127.6, 127.7 (× 2), 128.2, 128.4 (arom. CH), 128.6, 131.4 (C3, C4), 138.0 (× 2), 138.1, 138.4 (subst. arom. C), 150.9 (*t*BuO*C*ON); *m*/*z* (FAB): 772.5 (100) [M + Na]$^+$; found [M + Na]$^+$ 772.3829. $C_{46}H_{55}NO_8$·Na requires 772.3825.

5,9-Anhydro-6,7,8,10-tetra-*O*-benzyl-1,2-*N*,*O*-isopropylidene-2-(*tert*-butoxycarbonylamino)-2,3,4-trideoxy-D-*erythro*-L-*talo*-decitol (47): A mixture of alkene **46** (0.168 g, 0.22 mmol) and freshly recrystallised tosylhydrazide (0.125 g, 0.67 mol) was dissolved in DME (10 mL) and the solution was heated to 85 °C. A solution of aq. NaOAc (1 M, 0.67 mL, 0.67 mmol) was added in three equal portions over a period of 3 h and the mixture was stirred for a further 8 h, although TLC showed that some starting material remained. More tosylhydrazide (0.042 g, 0.23 mmol) and aq. sodium acetate (1 M, 0.22 mL, 0.22 mmol) were added and stirring was continued at 85 °C for a further 8 h. The reaction mixture was then diluted with water (30 mL) and extracted with DCM (3 × 20 mL), the organic parts were dried and the solvents evaporated in vacuo. Column chromatography (light petroleum ether/EtOAc, 4:1) gave **47** as a colourless oil (0.138 g, 82%); R_f = 0.20 (light petroleum ether/EtOAc, 4:1). $[\alpha]_D^{20} = -12.8$ (c = 1.0, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 2977, 2868, 1693 (C=O), 1497, 1454, 1389, 1365, 1257, 1208, 1171, 1100, 1028. ^1H NMR (270 MHz, [D$_6$]DMSO, 80 °C): δ = 1.41 [s, 9 H, OC(CH$_3$)$_3$], 1.42, 1.50 [2 × s, 6 H, C(CH$_3$)$_2$], 1.35−1.45, 1.64−1.81 (2 × m, 4 H, 3-H$_A$, 3-H$_B$, 4-H$_A$, 4-H$_B$), 3.22−3.33 (m, 2 H, 6-H, 8-H), 3.47−3.54 (m, 2 H, 5-H, 7-H), 3.60−3.74 (m, 4 H, 1-H$_A$, 9-H, 10-H$_A$, 10-H$_B$), 3.79−3.91 (m, 2 H, 2-H, 1-H$_B$), 4.54 (A$_2$, 2 H, CH_2Ph), 4.60, 4.76 (AB, J = 11.2 Hz, 2 H, CH_2Ph), 4.64, 4.81 (AB, J = 11.0 Hz, 2 H, CH_2Ph), 4.83 (A$_2$, 2 H, CH_2Ph), 7.21−7.34 (m, 20 H, 4 × Ph). ^{13}C NMR (67.9 MHz, [D$_6$]DMSO, 80 °C): δ = 23.4 (br), 26.5 [C(*C*H$_3$)$_2$], 27.5, 28.8 (C3, C4), 27.7 [OC(*C*H$_3$)$_3$], 56.6 (C2), 66.3 (C1), 69.1 (C10), 72.2, 73.4, 73.5, 73.8 (4 × *C*H$_2$Ph), 77.7, 77.9, 78.3, 81.4, 85.8 (C5−C9), 78.4 [O*C*(CH$_3$)$_3$], 92.4 [*C*(CH$_3$)$_2$], 126.6, 126.8, 126.9, 127.1, 127.3, 127.4, 127.7, 127.9 (arom. CH), 138.0 (× 2), 138.1, 138.4 (subst. arom. C), 150.9 (*t*BuO*C*ON); *m*/*z* (FAB): 774.4 (100) [M + Na]$^+$, 652.3 (35) [M − Boc + H]$^+$; found [M + Na]$^+$ 774.3979. $C_{46}H_{57}NO_8$·Na requires 774.3982.

Methyl 5,9-Anhydro-6,7,8,10-tetra-*O*-benzyl-2-(*tert*-butoxycarbonylamino)-2,3,4-trideoxy-D-*erythro*-L-*talo*-deconate (48): Freshly prepared Jones reagent (1 M, 0.26 mL, 0.26 mmol) was added dropwise to a solution of **47** (0.051 g, 0.068 mmol) in acetone (1.5 mL) cooled to 5 °C and the mixture was stirred at this temperature for 15 min before being allowed to warm to room temp. Stirring was continued for 6 h after which excess Jones reagent was quenched by the addition of 2-propanol (0.2 mL). The solution pH was made neutral with satd. aq. $NaHCO_3$, ether (50 mL) was added and the resulting solution was washed with brine (2 × 10 mL), dried, and the solvent was evaporated in vacuo. The residue (0.05 g) was redissolved in ether (10 mL), cooled to 5 °C, and an ethereal solution of diazomethane (ca. 2 M, 1 mL) was added in three portions over a period of 30 min. The reaction mixture was warmed to room temp. and excess diazomethane was quenched by the addition of AcOH. Evaporation of the solvent gave the crude product as a cream solid which was purified by column chromatography (light petroleum ether/EtOAc, 4:1→3:1) afforded **48** as a white solid (0.031 g, 62%); R_f = 0.39 (light petroleum ether/EtOAc, 3:1); m.p. 134−136 °C. $[\alpha]_D^{20} = -8.2$ (c = 1.5, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3360 (NH), 3031, 2903, 2863, 1757 (ester C=O), 1682 (carbamate C=O), 1515, 1453, 1366, 1307, 1218, 1199, 1158, 1104, 1056, 1027. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.41 [s, 9 H, OC(CH$_3$)$_3$], 1.46−1.54 (m, 1 H, 4-H$_A$), 1.66−1.73 (m, 1 H, 4-H$_B$), 1.85−1.91 (m, 1 H, 3-H$_A$), 2.01−2.10 (m, 1 H, 3-H$_B$), 3.18−3.26 (m, 2 H, 5-H, 6-H), 3.38 (br. d, $J_{9,8}$ = 9.4 Hz, 1 H, 9-H), 3.59 (t, J = 9.2 Hz, 1 H, 8-H), 3.64−3.72 (m, 3 H, 7-H, 10-H$_A$, 10-H$_B$), 3.67 (s, 3 H, CO_2CH_3), 4.25−4.31 (m, 1 H, 2-H), 4.40, 4.61 (AB, J = 12.2 Hz, 2 H, CH_2Ph), 4.56, 4.80 (AB, J = 10.9 Hz, 2 H, CH_2Ph), 4.59, 4.85 (AB, J = 10.7 Hz, 2 H, CH_2Ph), 4.89 (A$_2$, C2 H, H_2Ph), 5.13 (br. d, $J_{NH,2}$ = 7.9 Hz, 1 H, NH), 7.15−7.17 (m, 2 H, 2 × arom. H), 7.24−7.34 (m, 18 H, 18 × arom. H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 27.6, 28.7 (C3, C4), 28.3 [OC(*C*H$_3$)$_3$], 52.1 (CO_2CH_3), 53.5 (C2), 68.9 (C10), 73.4, 74.9, 75.3, 75.5 (4 × *C*H$_2$Ph), 78.5, 78.7, 78.9, 82.0, 87.2 (C5−C9), 79.7 [O*C*(CH$_3$)$_3$], 127.6 (× 2), 127.7 (× 2), 127.9, 128.1, 128.3, 128.4 (× 2), 128.5 (arom. CH), 137.9, 138.1, 138.2, 138.6 (subst. arom. C), 155.4 (*t*BuO*C*ON), 173.2 (CO_2CH_3); *m*/*z* (FAB): 762.5 (100) [M + Na]$^+$, 706.5 (30%); found [M + Na]$^+$ 762.3614. $C_{44}H_{53}NO_9$·Na requires 762.3618.

Methyl 5,9-Anhydro-6,7,8,10-tetra-*O*-acetyl-2-(*tert*-butoxycarbonylamino)-2,3,4-trideoxy-D-*erythro*-L-*talo*-deconate (49): Pearlman's catalyst (20% w/w $Pd(OH)_2$ on carbon, 0.01 g) was added to a solution of **48** (0.057 g, 0.077 mmol) in EtOAc (1.5 mL) and MeOH (1.5 mL) and the resulting mixture was stirred overnight under an atmosphere of H_2 (balloon). The supernatant layer was decanted and the remaining solids were stirred with MeOH (5 mL) for 15 min. This process was repeated until no product was detectable in the washings by TLC. The combined washings were evaporated to dryness to give an oil (0.033 g) which was redissolved in a mixture of Ac_2O (1 mL) and pyridine (2 mL). After stirring overnight at room temp., the solution was evaporated to dryness in vacuo and the last traces of pyridine were removed as an azeotrope with toluene (× 4). The residue was purified by column chromatography (light petroleum ether/EtOAc, 1:1) to yield **49** as a white solid (0.009 g, 21% from **48**), R_f = 0.19 (light petroleum ether/EtOAc, 1:1); m.p. 145−146.5 °C. $[\alpha]_D^{20} = -18.0$ (c = 0.45, $CHCl_3$); $\tilde{\nu}_{max}/cm^{-1}$: 3405 (NH), 2903, 1745 (ester C=O), 1690 (carbamate C=O), 1558, 1506, 1382, 1259, 1227, 1158, 1034. ^1H NMR (270 MHz,

$CDCl_3$): δ = 1.44 [s, 9 H, $OC(CH_3)_3$], 1.50−1.80 (m, 4 H, 3-H_A, 3-H_B, 4-H_A, 4-H_B), 2.00, 2.02, 2.04, 2.10 (4 × $COCH_3$), 3.39−3.47 (m, 1 H, 5-H), 3.62 (ddd, $J_{9,8}$ = 9.9, $J_{9,10B}$ = 5.1, $J_{9,10A}$ = 2.4 Hz, 1 H, 9-H), 3.74 (s, 3 H, CO_2CH_3), 4.09, 4.22 (ABX, $J_{10A,10B}$ = 12.4, $J_{10A,9}$ = 2.4, $J_{10B,9}$ = 5.1 Hz, 2 H, 10-H_A, 10-H_B), 4.21−4.30 (m, 1 H, 2-H), 4.87 (t, J = 9.7 Hz, 1 H, 8-H), 5.03 (t, J = 9.5 Hz, 1 H, 6-H), 5.16 (t, J = 9.5 Hz, 1 H, 7-H), 5.13 (br. d, $J_{NH,2}$ = 8.1 Hz, 1 H, NH). ^{13}C NMR (67.9 MHz, $CDCl_3$): δ = 20.6 (× 2), 20.7 ($COCH_3$), 27.4, 28.1 (C3, C4), 28.3 [$OC(CH_3)_3$], 52.3 (CO_2CH_3), 53.2 (C2), 62.3 (C10), 68.6, 71.7, 74.3, 75.7 (× 2) (C5−C9), 80.0 [$OC(CH_3)_3$], 155.3 (*t*BuO*C*ON), 169.5, 169.6, 170.4, 170.7 ($COCH_3$), 172.9 (CO_2CH_3); *m/z* (FAB): 570 (100) $[M + Na]^+$, 548 (22) $[M + H]^+$, 448 (80%), 706.5 (30%), 329 (35%); found $[M + Na]^+$ 762.3614. $C_{24}H_{37}NO_{13}$·Na requires 762.3618.

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[1] [1a] M. H. D. Postema, *C-Glycoside Synthesis*, CRC press, Boca Raton, **1995**. [1b] D. E. Levy, C. Tang, *The Chemistry of C-Glycosides*, Pergamon, Oxford, **1995**. [1c] Y. Du, R. J. Linhardt, I. R. Vlahov, *Tetrahedron* **1998**, *54*, 9913−9959. [1d] T. Skrydstrup, B. Vauzeilles, J.-M Beau, in: *Carbohydrates in Chemistry and Biology*, (Eds.: B. Ernst, G. W. Hart, P. Sinaÿ); Wiley-VCH: Weinheim, **2000**, Part I, Vol. 1, Ch. 20, pp. 495−528. [1e] For a review of radical approaches to *C*-glycosides, see: H. Togo, W. He, Y. Waki, M. Yokoyama, *Synlett* **1998**, 700−717. [1f] For a review of approaches involving glycosyl anions, see: L. Somsák, *Chem. Rev.* **2001**, *101*, 81−135.

[2] [2a] F. K. Griffin, P. V. Murphy, D. E. Paterson, R. J. K. Taylor, *Tetrahedron Lett.* **1998**, *39*, 8179−8182. [2b] M.-L. Alcaraz, F. K. Griffin, D. E. Paterson, R. J. K. Taylor, *Tetrahedron Lett.* **1998**, *39*, 8183−8186 and references therein. [2c] F. K. Griffin, D. E. Paterson, P. V. Murphy, R. J. K. Taylor, *Eur. J. Org. Chem.* **2002**, 1305−1322, previous paper in this issue. [2d] See also: P. S. Belica, R. W. Franck, *Tetrahedron Lett.* **1998**, *39*, 8225−8228; G. Yang, R. W. Franck, H.-S. Byun, R. Bittman, P. Samadder, G. Arthur, *Org Lett.* **1999**, *1*, 2149−2151.

[3] T. V. RajanBabu, G. S. Reddy, *J. Org. Chem.* **1986**, *51*, 5458−5461 and references therein.

[4] R. Csuk, B. I. Glänzer, *Tetrahedron* **1991**, *47*, 1655−1664 and references therein.

[5] J. Gervay, T. M. Flaherty, D. Holmes, *Tetrahedron* **1997**, *53*, 16355−16364.

[6] F. Nicotra, L. Panza, G. Russo, *Tetrahedron Lett.* **1991**, *32*, 4035−4038.

[7] L. Lay, F. Nicotra, L. Panza, G. Russo, E. Caneva, *J. Org. Chem.* **1992**, *57*, 1304−1306.

[8] X. Li, H. Otake, H. Takahashi, S. Ikegami, *Tetrahedron* **2001**, *57*, 4283−4295.

[9] C. R. Johnson, B. A. Johns, *Synlett* **1997**, 1406−1408.

[10] A. D. Campbell, D. E. Paterson, T. M. Raynham, R. J. K. Taylor, *Chem. Commun.* **1999**, 1599−1600.

[11] B. Aebischer, J. H. Bieri, R. Prewo, A. Vasella, *Helv. Chim. Acta* **1982**, *65*, 2251−2271.

[12] W. Wang, Y. Zhang, M. Sollogoub, P. Sinaÿ, *Angew. Chem. Int. Ed.* **2000**, *39*, 2466−2467.

[13] T. Vidal, A. Haudrechy, Y. Langlois, *Tetrahedron Lett.* **1999**, *40*, 5677−5680.

[14] O. Dirat, T. Vidal, Y. Langlois, *Tetrahedron Lett.* **1999**, *40*, 4801−4802.

[15] [15a] D. Calimente, M. H. D. Postema, *J. Org. Chem.* **1999**, *64*, 1770−1771. [15b] M. H. D. Postema, D. Calimente, *Tetrahedron Lett.* **1999**, *40*, 4755−4759.

[16] R. R. Schmidt, H. Dietrich, *Angew. Chem. Int. Ed. Engl.* **1991**, *30*, 1328−1329.

[17] Prof. R. R. Schmidt, Universität Konstanz, personal communication. ^{1}H NMR spectra were identical.

[18] A. G. M. Barrett, M. Peña, J. A. Willardsen, *J. Chem. Soc., Chem. Commun.* **1995**, 1147−1148 and references therein.

[19] P. A. V. van Hooft, M. A. Leeuwenburgh, H. S. Overkleeft, G. A. van der Marel, C. A. A. van Boeckel, J. H. van Boom, *Tetrahedron Lett.* **1998**, *39*, 6061−6064.

[20] A. Martín, J. A. Salazar, E. Suárez, *J. Org. Chem.* **1996**, *61*, 3999−4006. These authors assigned the anomeric configuration on the basis of ROESY experiments.

[21] Prepared according to: S. A. Holick, L. Anderson, *Carbohydr. Res.* **1974**, *34*, 208−213.

[22] T.-L. Chan, S. Fong, Y. Li, T.-O. Man, C. D. Poon, *J. Chem. Soc., Chem. Commun.* **1994**, 1771−1772.

[23] A. D. Elbein, *Adv. Carbohydr. Chem. Biochem.* **1974**, *30*, 227−256 and references therein.

[24] A. Wei, Y. Kishi, *J. Org. Chem.* **1994**, *59*, 88−96.

[25] O. R. Martin, W. Lai, *J. Org. Chem.* **1993**, *58*, 176−185.

[26] B. Patro, R. R. Schmidt, *Synthesis* **1998**, 1731−1734.

[27] P. J. Garegg, B. Samuelsson, *J. Chem. Soc., Perkin Trans. 1* **1980**, 2866−2869.

[28] C. Y. Meyers, A. M. Malte, W. S. Matthews, *J. Am. Chem. Soc.* **1969**, *91*, 7510−7512.

[29] This observation is consistent with a more general trend for enol ethers listed in: E. Pretsch. P. Bühlmann, C. Affolter, *Structure Determination of Organic Compounds*, third completely revised and enlarged English edition, Springer Verlag, Berlin, **2000**, p. 172.

[30] Alcohol **27b** was synthesised from **26** according to: P. Allevi, M. Anastasia, P. Ciuffreda, A. Fiecchi, A. Scala, *J. Chem. Soc., Perkin Trans. 1* **1989**, 1275−1280.

[31] H. Ohrui, G. H. Jones, J. G. Moffat, M. L. Maddox, A. T. Christiensen, S. K. Byram, *J. Am. Chem. Soc.* **1975**, *97*, 4602−4613 and references therein.

[32] D. Rouzaud, P. Sinaÿ, *J. Chem. Soc., Chem. Commun.* **1983**, 1353−1354.

[33] B. Bernet, A. Vasella, *Helv. Chim. Acta* **1979**, 1990−2016.

[34] P. G. Goekjian, T.-C. Wu, H.-Y. Kang, Y. Kishi, *J. Org. Chem.* **1991**, *56*, 6422−6434.

[35] A. Dondoni, H. M. Zuurmond, A. Boscarato, *J. Org. Chem.* **1997**, *62*, 8114−8124.

[36] For a review of structure, see: H. Paulsen, *Angew. Chem. Int. Ed. Engl.* **1990**, *29*, 823−839; for a review of function, see: R. A. Dwek, *Chem. Rev.* **1996**, *96*, 683−720; for a review of biosynthesis, see: R. T. Schwartz, R. Datema, *Adv. Carbohydr. Chem. Biochem.* **1982**, *40*, 287−379.

[37] For a review of the glycosidic linkage in glycoproteins, see: C. M. Taylor, *Tetrahedron* **1998**, *54*, 11317−11361.

[38] [38a] A. Dondoni, A. Marra, A. Massi, *J. Org. Chem.* **1999**, *64*, 933−944. [38b] R. N. Ben, A. Orellana, P. Arya, *J. Org. Chem.* **1998**, *63*, 4817−4820. [38c] D. Urban, T. Skrydstrup, J.-M. Beau, *Chem. Commun.* **1998**, 955−956. [38d] T. Fuchss, R. R. Schmidt, *Synthesis* **1998**, 753−758. [38e] F. Burkhart, M. Hoffmann, H. Kessler, *Angew. Chem. Int. Ed. Engl.* **1997**, *36*, 1191−1192.

[39] A. Dondoni, A. Marra, *Chem. Rev.* **2000**, *100*, 4395−4421.

[40] [40a] P. Garner, J.-M. Park, *J. Org. Chem.* **1987**, *52*, 2361−2364. [40b] for an improved synthesis of this useful chiral building block, see: A. D. Campbell, T. M. Raynham, R. J. K. Taylor, *Synthesis* **1998**, 1707−1709.

[41] A. Dondoni, A. Marra, A. Massi, *Tetrahedron* **1998**, *54*, 2827−2832.

[42] A. Dondoni, D. Perrone, *Synthesis* **1997**, 527−529.

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