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Template-directed Intramolecular *C*-Glycosidation. Cation-mediated Synthesis of Ketooxetanes from Thioglycosides

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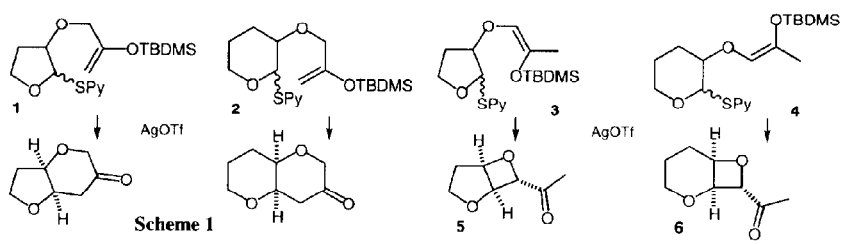
Abstract

Bicyclic ketooxetanes may be assembled using cation-mediated cyclisation reactions of thioglycosides possessing silyl enol ether-containing side-chains.

Keywords: *C*-Glycoside, cyclisation, ketooxetane, stereoselective

1. INTRODUCTION

We have been looking at cation-mediated cyclisation reactions of thioglycosides as a way of assembling *C*-glycosides. During the course of this programme we have shown that bicyclo[4.4.0] and -[4.3.0] ring-systems are formed readily on silver(I) triflate treatment of thiopyridyl glycosides **1** and **2** possessing nucleophilic side-chains (Scheme 1).[1] We observed also that upon treatment with the same thiophilic metal reagent silyl enol ethers **3** and **4** underwent cyclisation to give respectively the bicyclic ketooxetanes **5** and **6**.



Scheme 1

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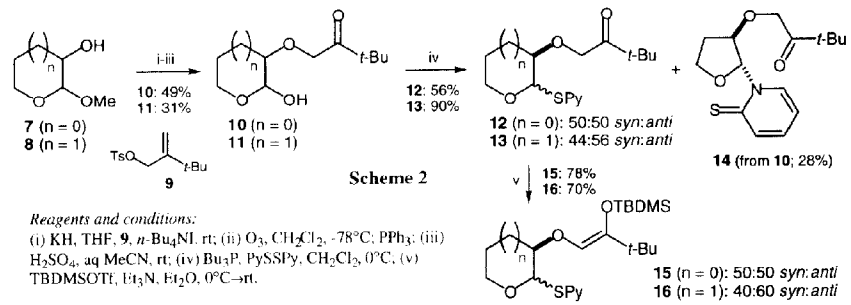
Substrates **3** and **4** had been formed as minor regioisomers during the preparation of **1** and **2**, and we became interested in developing this unusual ring-forming chemistry so that compounds such as **5** and **6** were the major products of the sequence. This paper reports on our investigations in full.[2]

2. RESULTS AND DISCUSSION

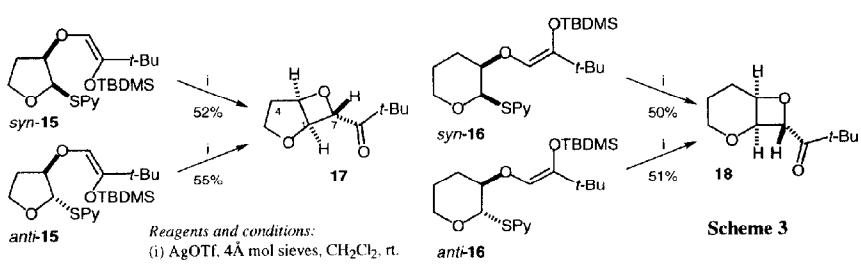
In light of our previous studies on six-membered ring-formation from thioglycosides having nucleophilic enol ether side-chains we focused initially on analogous substrates made from precursors in which the regiochemical sense of enol ether formation was unambiguous. *t*-Butyl ketones had proved to be amenable to synthetic manipulation post-cyclisation in tetrahydrofuran-forming cation-mediated reactions,[3] and accordingly substrates **15** and **16** were chosen as the initial synthetic targets. Our first approach to substrates of this type began with the simple model methyl glycosides **7** and **8**.[4] The ketonic side-chain was introduced using a two-step procedure involving firstly allylation with the tosylate **9** derived from 2-*t*-butyl-2-propenol, which was made by copper(I)-catalysed addition of *t*-BuMgCl to propargyl alcohol.[5] The volatility of 2-*t*-butyl-2-propenol was such that it was used directly in tosylation reactions as a mixture with unreacted propargyl alcohol (see Experimental section). Ozonolysis of the product alkenes followed by hydrolysis gave ketoalcohols **10** and **11**, which were converted into the thioglycosidic ketones using the standard procedure.[6]



Scheme 2

Reagents and conditions:
(i) KH, THF, **9**, *n*-Bu_4NI, rt; (ii) O_3, CH_2Cl_2, -78°C; PPh_3; (iii) H_2SO_4, aq MeCN, rt; (iv) Bu_3P, PySSPy, CH_2Cl_2, 0°C; (v) TBDMSOTf, Et_3N, Et_2O, 0°C→rt.

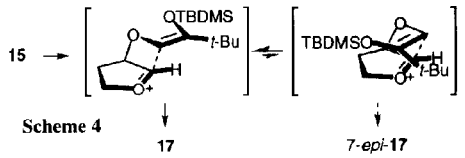
The behaviour of the homologous compounds **10** and **11** differed from each other in one important respect: whilst **11** gave only *S*-glycosides **13** in the *n*-Bu_3P–PySSPy reaction, the lower homologue **10** consistently gave a single diastereomeric *anti*- *N*-glycoside **14** in addition to the expected thioethers **12**.[7] Treatment of **12** and **13** with *t*-butyldimethylsilyl triflate and triethylamine in the usual way gave single enol ether geometric isomers as mixtures of anomers which could be separated by chromatography in readiness for cyclisation studies (Scheme 2). It was found most straightforward to effect the separation of *S*- from *N*-glycosides at the silyl enol ether stage in the lower homologous series. Cyclisation reactions were carried out on diastereomerically pure substrates in order to provide mechanistic insights into the cyclisation reactions, since



Scheme 3

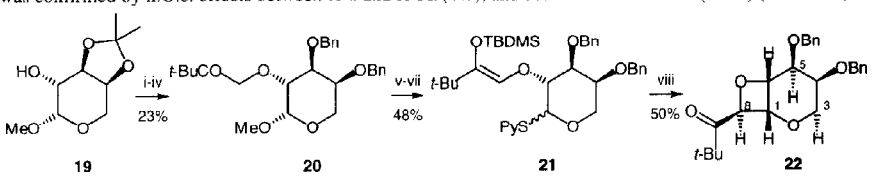
Reagents and conditions:
(i) AgOTf, 4Å mol sieves, CH_2Cl_2, rt.

truly dissociative processes proceeding via cationic intermediates would give the same products independently of the stereochemical relationship between the anomeric leaving group and the nucleophilic side-chain. Reactions were carried out as for the six- and five-membered ring-forming processes studied earlier,[2,3] by adding dichloromethane solutions of substrate to suspensions of silver(I) triflate in the same solvent, causing off-white precipitates to appear almost immediately. Single diastereomers of bicyclic ketooxetanes **17** and **18** were formed, irrespective of the *syn*- or *anti*- nature of the substrates. The cyclisation reactions of **15** and **16** are summarised in Scheme 3. The stereochemistry of the cyclisation products was assigned at this stage by consideration of a simple pictorial model in which the incipient oxetane ketone substituent is positioned *exo*- on the bicyclic nucleus (Scheme 4). The silyl enol ether derived from *N*-glycoside **14** was inert to the cyclisation conditions, despite the fact that ionisation prior to cyclisation would involve loss of the same leaving group.



Scheme 4

Having demonstrated the viability of oxetane-forming reactions on simple model systems it was considered important to assess whether these processes were equally facile on substrates derived from sugars, since it was considered that in more highly oxygenated systems the stability/lifetime of the intermediate anomeric cations might be compromised. (*tert*-Butyl)allylation of methyl 3,4-*O*-isopropylidene-β-L-arabino-pyranoside **19**[8] using the now standard conditions followed by replacement of the acetonide protecting group with benzyl ethers and ozonolysis gave ketone **20**. This was subjected to acid-catalysed hydrolysis, thioglycosidation and finally silyl enol etherification to yield the cyclisation substrate **21** as a mixture of anomers. Treatment with silver(I) triflate gave in moderate yield the ketooxetane **22**, whose stereochemistry was confirmed by n.O.e. effects between H-8 and H-3α (4%), and between H-8 and H-5 (2.9%) (Scheme 5).[9]

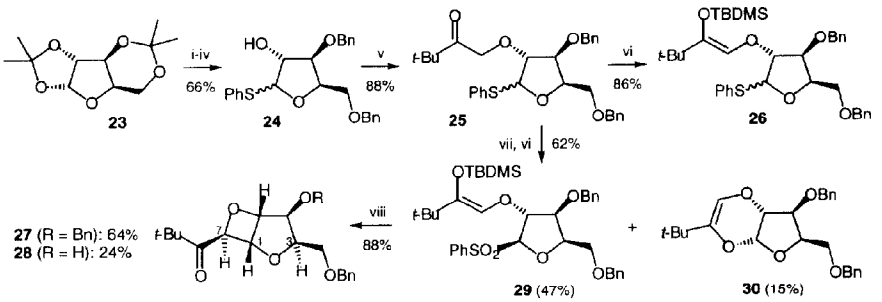


Reagents and conditions: (i) KH, **9**, Bu_4NI, THF, rt; (ii) TFA, aq THF, rt; (iii) KH, BnBr, Bu_4NI, THF, 0°C→rt; (iv) O_3, CH_2Cl_2, -78°C; PPh_3; (v) H_2SO_4, aq MeCN, 40°C; (vi) PySSPy, Bu_3P, CH_2Cl_2, 0°C→rt; (vii) TBDMSOTf, Et_3N, Et_2O, rt; (viii) AgOTf, 4Å mol sieves, CH_2Cl_2, rt.

Scheme 5

All of the work carried out so far had entailed ketonic side-chain incorporation using a two-step sequence prior to introduction of the anomeric leaving group. In order to streamline our strategy for cyclisation substrate assembly methods were sought for direct attachment of the side-chain to a precursor already functionalised at the anomeric position. We were keen also to assess the viability of cyclisation reactions of substrates possessing thio*phenyl* rather than thiopyridyl leaving groups in an attempt to obviate the use of silver(I) triflate as the activator. In light of the successful cyclisation of **21** it was decided to look at fully-oxygenated substrates directly, in both the five- and six-membered template ring cases. Our starting point in the lower homologous series was the commercially available[10] pentose derivative 1,2:3,5-di-*O*-isopropylidene-α-D-xylofuranose **23**. This was converted by sequential selective hydrolysis–benzylation[11(i)]–hydrolysis into a partially-protected intermediate,[11(ii)] which was subjected to modified thioglycosidation conditions to provide **24** as a mixture of thioglycoside anomers. The stage was now set for attempted direct incorporation of the *t*-butyl ketone-containing side-chain. A search of the literature revealed a paucity of available methods with which to effect etherification of hard alkoxide nucleophiles by S_N2 reaction with α-haloketones. This is presumably because of competing attack at the

carbonyl carbon atom, although it was felt that the steric bulk of the *t*-butyl group would attenuate this unwanted reactivity. In the event, **24** underwent high-yielding alkylation with 1-bromopinacolone under phase-transfer conditions[12] to give anomers **25**, which were converted as before into the corresponding silyl enol ethers **26**. A range of thiophilic reagents[13] was screened for the cyclisation reactions. Optimum results were attained with mercury(II) triflate:*N*,*N*-dimethylaniline complex in MeCN,[14] which had been effective in the cyclisation reaction of the thiophenyl analogue of **16**; treatment of **26** with this reagent gave **27** in 18% yield. The stereochemical assignment followed from the observation of a 13.8% n.O.e. enhancement of H-3 upon irradiation of H-7,[9] which served also to confirm the stereochemistry assigned in the simple analogue **15**. It occurred to us at this stage that the deployment of a *sulfone* leaving group might give better results, especially given the ample precedent from the work of Ley[15] on intermolecular *C*-glycosidation reactions. Therefore, sulfide was subjected to oxidation followed by enol etherification to give a modified cyclisation substrate **29** as a single diastereomer; the moderate yield was due partly to competing formation of dioxinone **30** during the silylation step. After evaluation of a series of oxaphilic Lewis acids, the best conditions for the cyclisation of **29** were found to involve use of tin(IV) chloride in cold, dilute dichloromethane solutions containing molecular sieves for the interception of adventitious moisture. Oxetane **27** was formed in 64% yield, together with 24% of the debenzylated product **28** (Scheme 6).

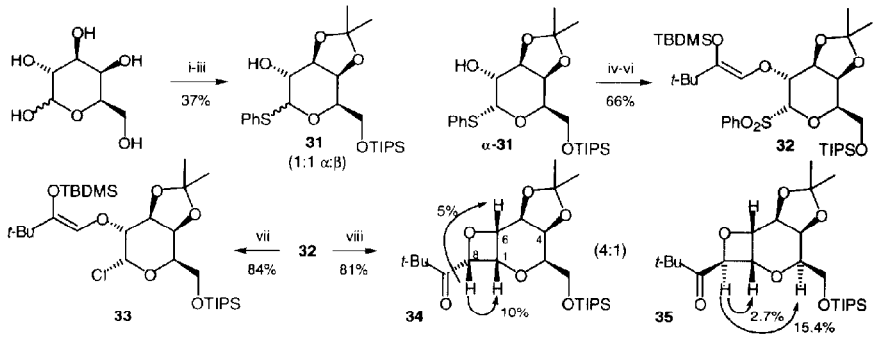


Reagents and conditions: (i) aq AcOH, rt; (ii) BnCl, KOH, 50°C, then 80°C; (iii) H_2SO_4, aq MeCN, 35°C; (iv) PhSSPh, Bu_3P, CH_2Cl_2, 0°C→rt; (v) 50% aq NaOH–CH_2Cl_2, Aliquat® 336, 2-bromopinacolone, rt; (vi) TBDMSOTf, Et_3N, CH_2Cl_2, 0°C→rt; (vii) CH_3CO_3H, NaOAc, CH_2Cl_2–H_2O, 0°C→rt; (viii) $SnCl_4$, CH_2Cl_2, 4Å mol sieves, -40°C.

Scheme 6

The final phase of our project was directed towards application of the anomeric sulfone methodology to the synthesis of bicyclo[4.2.0] systems derived from pyranose sugar derivatives. As for the five-membered substrate **26**, we followed a route which allowed ketone side-chain incorporation into an intermediate already possessing the anomeric sulfur moiety. Thus, the primary alcohol group of D-galactose was protected as the TIPS ether and then subjected to *S*-glycosidation using Bu_3P–PhSSPh, giving anomeric mixtures of thioglycosides which were protected as the isopropylidene derivatives **31**. The stereoselectivity of the *S*-glycosidation step was found to be profoundly affected by the solvent medium: in CH_2Cl_2, the ratio of α:β anomers was 2:1,[16] whereas in CH_2Cl_2–pyridine mixtures the α-selectivity was virtually complete, although yields were generally inferior. The importance of this finding lay in the subsequent observation that the β-anomer of **31** underwent alkylation under the phase-transfer conditions at a considerably reduced rate than the α-isomer, and the ultimate choice of solvent for the thioglycosidation reaction represented a compromise between high yield and efficiency of the later alkylation reaction. Alkylation of the α-anomer of **31** proceeded efficiently; the product was subjected to *S*-oxidation and enol etherification to provide cyclisation substrate **32** in good overall yield. In contrast with the lower homologous substrate derived from D-xylose, aluminium-based reagents were found to be the most effective. Brief treatment of **32** with dichloroethylaluminium in dilute toluene solution in the presence of molecular sieves at ambient temperature gave in good yield a

mixture of oxetane **34** and the C-8 epimer **35**. Interestingly, similar treatment of **32** with chlorodiethylaluminium gave in similar yield the chloride **33**. Structural assignments followed again from n.O.e. experiments; no enhancement of the H-3 signal was observed upon irradiation of H-8 in **34**, and similarly no effect was seen for H-6 in **35** upon irradiation of H-8.[9] The synthesis and cyclisation reactions of **32** are depicted in Scheme 7.

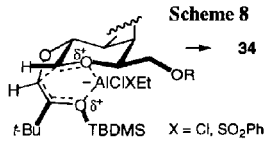


Reagents and conditions: (i) TIPSCl, imidazole, DMAP, DMF, rt; (ii) PhSSPh, Bu_3P, CH_2Cl_2, 0°C→rt; (iii) $Me_2C(OMe)_2$, pyH$^+$TsO$^-$, CH_2Cl_2, rt; (iv) 50% aq NaOH–CH_2Cl_2, Aliquat® 336, 2-bromopinacolone, rt; (v) CH_3CO_3H, NaOAc, CH_2Cl_2–H_2O, 0°C→rt; (vi) TBDMSOTf, Et_3N, CH_2Cl_2, 0°C→rt; (vii) Et_2AlCl, 4Å mol sieves, PhMe, -78°C→rt; (viii) $EtAlCl_2$, PhMe, rt.

Scheme 7

The selectivity for oxetane **34** was unexpected, since all of our previous cyclisation reactions had given exclusively products with the ostensibly thermodynamically more stable *exo*-oriented ketone substituents. Particularly noteworthy was the contrast in cyclisation stereochemistry of **32** with that of thiopyridyl glycoside **21** derived from L-arabinose, which was structurally most similar. We tentatively ascribe the preferred formation of the *endo*- product **34** to a chelating interaction of the aluminium reagent with the Lewis basic ketone and pyran oxygen atoms during formation of the product (Scheme 8). Further evidence to support the assignment of structures **34** and **35** came from subsequent chemical transformations of the oxetanes. Treatment of both isomers with TBAF gave the same crystalline alcohol **36** (Figure), which was different from

Scheme 8



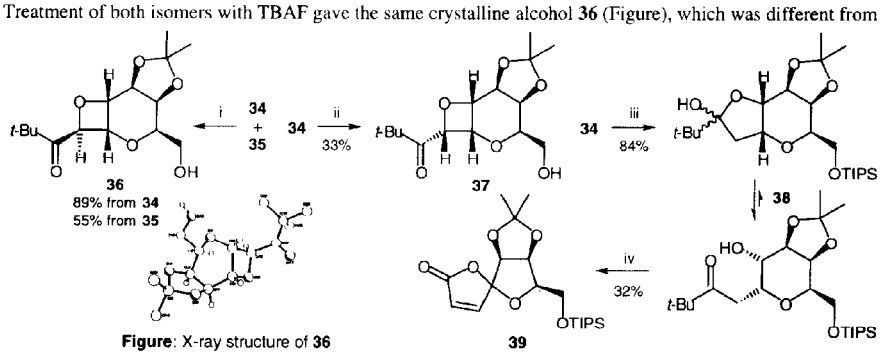


Figure: X-ray structure of **36**

Reagents and conditions: (i) TBAF, THF, rt; (ii) TFA, aq THF, rt; (iii) SmI_2, THF–MeOH, -78°C → 40°C; (iv) CF_3CO_3H, Na_2HPO_4, CH_2Cl_2, -10°C→rt.

Scheme 9

the alcohol **37** formed on acid-catalysed removal of the TIPS group from the major isomer **34**. The oxetane ring in **34** could be cleaved reductively by treatment with samarium(II) iodide, giving the product **38** as a mixture of hydroxyketone and ketol forms. Exposure of this mixture to buffered trifluoroperacetic acid[17] gave the spiro-butenolide **39** as a single diastereomer;[18] presumably this arises by oxidation of the secondary alcohol in the hydroxyketone form of **38**, elimination with concomitant ring-opening, ketol formation with ring-contraction, and finally ring-closure of the ketol OH onto the carboxyl group generated by Baeyer–Villiger oxidation of the ketone. The derivatisation reactions of **34** and **35** are shown in Scheme 9.

3. CONCLUSIONS

The results presented herein show that relatively strained four-membered oxygen heterocycles may efficiently be assembled by cation-mediated cyclisation reactions. In many cases the processes are completely stereoselective, and this may be explained in terms of a minimisation of steric crowding in the bicyclic transition-state. In the case where stereoselectivity is reversed, a model has been put forward based on metal chelation of the incipient product to explain the anomalous result.

4. EXPERIMENTAL

General Procedures

^{1}H Nmr and ^{13}C nmr spectra were recorded in $CDCl_3$ on either Jeol GX-270Q, Bruker DRX-300, Bruker DRX-400 or Bruker AM-500 spectrometers, using residual isotopic solvent ($CHCl_3$, δ_H = 7.26 ppm; $CDCl_3$, δ_C = 77.0 ppm) as internal reference. Infrared spectra were recorded on Perkin-Elmer 881 and Mattson 5000 FTIR spectrophotometers. Mass spectra were recorded using VG-7070B, VG707E, VG Autospec Q or Jeol SX-102 instruments. Elemental combustion analyses were performed in the microanalytical laboratories of Imperial College. Melting points were measured on a Reichert hot stage apparatus and are uncorrected. Column chromatography was performed on Merck Kieselgel 60 (230-400 mesh) or Matrex Silica 60 (35-70 micron) under pressure. Analytical thin layer chromatography was performed using pre-coated glass-backed plates (Merck Kieselgel 60 F_{254}) and visualised with ultraviolet light and iodine, acidic ammonium molybdate (IV), vanillin or potassium permanganate solutions as appropriate. Standard solvents were distilled under dried nitrogen; diethyl ether and tetrahydrofuran from sodium-benzophenone ketyl, CH_2Cl_2 from phosphorus pentoxide, acetonitrile from calcium hydride and toluene from sodium. Petrol refers to petroleum ether bp 40-60°C which was distilled prior to use. Other solvents and reagents were purified before use according to standard procedures.[19]

2-*tert*-Butyl-2-propen-1-ol *p*-toluenesulfonate (9).

Copper(I) iodide (3.38 g, 17.8 mmol, 0.1 equiv) was added to a three-necked round bottom flask containing Et_2O (180 ml). Propargyl alcohol (10 g, 178 mmol, 1.0 equiv) was added at -10°C under Ar. *t*-Butylmagnesium chloride (223 ml of a 2M solution in Et_2O, 445 mmol, 2.5 equiv) was added to the mixture *via* a cannula maintaining the temperature at -10°C. The solution was stirred for 30 min at -10°C, brought to rt and then stirred for a further period of 20 h during which time it acquired a black colour. Excess magnesium reagent was destroyed by adding saturated aqueous NH_4Cl at 0°C. The solution was filtered and the solid grey mass was washed with ether and water. The ether layer was washed with water and the water layer was extracted twice with ether. The combined ether layers were dried and evaporated to give a mobile yellow oil containing 2-*tert*-butyl-2-propen-1-ol and propargyl alcohol (9.3 g, 1:1 molar ratio, 2:1 weight ratio, 43%). Distillation under reduced pressure gave a product having a 2-*tert*-butyl-2-propen-1-ol:propargyl alcohol ratio of 92:8. The alcohol mixture (containing 3.496 g 2-*tert*-butyl-2-propen-1-ol, 30.67 mmol, 1.0 equiv) and an indicator crystal were dissolved in THF (90 ml). *n*-BuLi (12.9 ml of a 2.5M solution in hexanes, 32.20 mmol, 1.05 equiv) was added to the mixture at -20°C. The solution underwent a colour change from pale yellow

through yellow to brown. Tosyl chloride (5.55 g, 29.14 mmol, 0.95 equiv) in THF (10 ml) was added at -20°C and the mixture was stirred for 30 min. The mixture was allowed to attain rt and stirred for 1.5 h. The THF was evaporated to give a whitish syrupy solid which was dissolved in ether. The precipitated LiCl was filtered and the ether layer was washed with water, dried and evaporated to give a yellow oil which was purified by chromatography to yield **9** (5.57 g, 68%) as a colourless oil; R_f 0.53 (25% ether–petrol); ν_{max} (film) 2964, 2874, 1639, 1579, 1493, 1443, 1361, 1293, 1180, 1176, 1098, 986, 927, 861, 838, 720 cm^{-1}; δ (270 MHz) [7.81-7.78 (2H, m), 7.36-7.32 (2H, m), aromatics], [5.08 (1H, s), 5.04 (1H, d, J 1 Hz), $=CH_2$], 4.55 (2H, d J 1 Hz, CH_2OTs), 2.45 (3H, s, $C_6H_4CH_3$), 1.03 (9H, s, CMe_3); *m/z* (EI) 268 $[M]^+$, 253, 213, 212, 173, 172, 155, 139, 113, 97, 96, 91, 83, 81, 79, 65, 55, 41, 39, 29, 27 (Found: $[M]^+$, 268.1129. $C_{14}H_{20}O_3S$ requires $[M]^+$, 268.1133).

2-Methoxytetrahydrofuran-3-ol (7).

To a stirred solution of dihydrofuran (20.0 g, 285.7 mmol, 1.0 equiv) in MeOH (300 ml) was added dropwise a solution of peracetic acid (42.73 ml of a 36 wt % solution in dilute acetic acid, 228.6 mmol, 0.8 equiv) over 40 min, maintaining the temperature below 0°C. The solution was allowed to warm to rt and stirred for 30 min. Aqueous NaOH (2M) was added and the resulting solution was vigorously stirred overnight. The turbid solution was filtered and the MeOH evaporated under reduced pressure. The aqueous layer was extracted with EtOAc (6 x 75 ml), dried ($MgSO_4$) and concentrated under reduced pressure to give a mixture of the *trans*- and *cis*- alcohols **7** (92:8 by ^1H nmr; 14.4 g, 53%, 92:8) as a pale yellow oil. A small portion of the mixture was purified by chromatography (60% ether–petrol) to give the *trans*- alcohol as a colourless oil, R_f 0.35 (70% ether–petrol); ν_{max} (film) 3435, 2931, 1727, 1447, 1364, 1284, 1193, 1106, 1039, 973, 861, 778 cm^{-1}; δ_H (500 MHz) 4.80 (1H, s, H-2), 4.20 (1H, dd, J 5.5, 1.5 Hz, H-3), 4.07 (1H, q, J 8 Hz, H-5), 3.93 (1H, dt, J 9, 4.5 Hz, H-5), 3.31 (3H, s, OMe), 2.33-2.27 (1H, broad s, OH), [2.23 (1H, m) and 1.81 (1H, m), H-4]; *m/z* (EI) 119 $[M+H]^+$, 117, 115, 112, 110, 103, 101, 87, 85, 75, 71, 69, 61, 58, 57, 41, 33, 31, 29, 27 (Found: $[M-OMe]^+$, 87.0445. $C_5H_{10}O_3$ requires $[M-OMe]^+$, 87.0446).

2-Methoxytetrahydro-2*H*-pyran-3-ol (8).

To a stirred solution of 3,4-dihydro-2*H*-pyran (13.15 g, 156.7 mmol, 1.3 equiv) in MeOH (200 ml) was added a solution of peracetic acid (25.4 ml of a 32 wt % solution in dilute AcOH, 120.57 mmol, 1.0 equiv) dropwise over 40 min. The temperature of the solution was maintained below 0°C during the addition. The solution was allowed to warm to rt and stirred for 30 min. NaOH solution (2M) was added and the resulting solution was vigorously stirred overnight. The turbid solution was filtered and the MeOH evaporated under reduced pressure. The aqueous layer was extracted with EtOAc (6 x 75 ml), dried ($MgSO_4$) and concentrated under reduced pressure to give a pale yellow oil. This was purified by chromatography (60% ether–petrol) to give **8** (11.13 g, 70%) as a colourless oil; R_f 0.5 (ether); ν_{max} (film) 3441, 2948, 1123, 1080, 1043, 993, 96 cm^{-1}; δ_H (250 MHz) 4.30 (1H, br s, OH), 4.18 (1H, d, J 5.0 Hz, H-2) 3.95-3.81 (1H, m, H-3), 3.49 (3H, s, OMe), 3.45-3.30 (2H, m, H-6), 2.0-1.35 (4H, m, H-3, H-4); *m/z* (EI) 132 $[M]^+$, 117, 104, 101, 100, 84, 61, 57, 49, 44.

3-(2-*tert*-Butyl-2-propenyloxy)-2-methoxytetrahydrofuran.

To petrol-washed KH (2.83 g of a 3 5% suspension in mineral oil, 24.23 mmol, 1.1 equiv) in dry DMF (75 ml) was added a solution of **7** (2.60 g, 22.03 mmol, 1.0 equiv) in DMF (10 ml) dropwise. The flask was cooled to 0°C and the mixture stirred at rt for 20 min. Tosylate **9** (6.6 g, 24.62 mmol, 1.12 equiv) and Bu_4NI (5 mole%) was added to the reaction flask and the mixture was stirred at rt during 14 h. The reaction was quenched by the addition of MeOH, the mixture filtered and the filtrate diluted with H_2O and extracted twice with EtOAc. The dried ($MgSO_4$) organic layer was evaporated to give a yellow oil which was purified by chromatography (7% ether–petrol) to yield [2*R**,3*R**]-3-(2-*tert*-butyl-2-propenyloxy)-2-methoxytetrahydrofuran (3.59 g, 81%) as a colourless oil; R_f 0.65 (25% ether–petrol); ν_{max} (film) 2957, 2873,

1635, 1463, 1361, 1300, 1192, 1145, 1126, 1081, 1044, 963, 905 cm^{-1}; δ (500 MHz) [5.06 (1H, d, J 1.3 Hz), 5.00 (1H, s,), $=CH_2$], 4.92 (1H, s, H-2), 4.07-3.90 (5H, m, H-3, 5, 5', $OCH_2C=C$), 3.33 (3H, s, OMe), 2.17-2.11 (1H, m, H-4), 1.94-1.88 (1H, m, H-4'), 1.08 (9H, s, CMe_3); *m/z* (EI) 214 $[M]^+$, 199, 184, 183, 169, 167, 154, 139, 121, 97, 83, 69, 57, 55, 41, 29, 27 (Found: $[M-OMe]^+$, 183.1384. $C_{12}H_{22}O_3$ requires $[M-OMe]^+$, 183.1385), followed by [*2R*,3S**]-3-(2-*tert*-butyl-2-propenyloxy)-2-methoxytetrahydrofuran (0.36 g, 8%) as a colourless oil; R_f 0.44 (25% ether–petrol); ν_{max} (film) 2957, 1636, 1589, 1462, 1361, 1300, 1270, 1190, 1147, 1121, 1081, 1049, 910, 860, 776, 729 cm^{-1}; δ (500 MHz) [5.09 (1H, d, J 1.0 Hz), 5.03 (1H, s), $=CH_2$], 4.84 (1H, d, J 4.0 Hz, H-2), 4.13, 4.05 (2H, AB q, J 13.0 Hz, $OCH_2C=C$), 4.04-4.0 (1H, m, H-5), 3.96 (1H, dt, J 8.5, 4.0 Hz, H-3), 3.84 (1H, m, H-5), 3.42 (3H, s, OMe), 2.18 (1H, m, H-4), 2.04-1.98 (1H, m, H-4), 1.09 (9H, s, CMe_3); *m/z* (EI) 214 $[M]^+$, 199, 184, 183, 167, 154, 149, 139, 127, 125, 121, 97, 83, 70, 69, 57, 55, 41, 29, 27 (Found: $[M]^+$, 214.1572. $C_{12}H_{22}O_3$ requires $[M]^+$, 214.1568).

[*2R*,3R]-3-(3,3-Dimethyl-2-oxobutoxy)-2-methoxytetrahydrofuran**.

Through a solution of [*2R*,3R**]-3-(2-*tert*-butyl-2-propenyloxy)-2-methoxytetrahydrofuran (2.53 g, 11.82 mmol, 1.0 equiv) in CH_2Cl_2 (200 ml) in a two-necked flask fitted with a guard tube containing $CaCl_2$ at -78°C was bubbled O_3 (200V, 35 l h^{-1}). At the first appearance of a faint blue tinge the passage of O_3 was stopped and He was bubbled into the solution to remove excess O_3. The colourless solution was cooled to 0°C and Ph_3P (3.3 g, 11.82 mmol, 1.0 equiv) added. The mixture was stirred for 0.5 h and allowed to warm to rt overnight. The mixture was concentrated under reduced pressure to give a yellow oil which solidified on addition of Et_2O. The mixture was filtered and the filtrate was concentrated under reduced pressure to give an oil which on the addition of Et_2O yielded further white solid. This procedure was repeated and the resulting oil was purified by chromatography (35% ether–petrol) to yield [*2R*,3R**]-3-(3,3-dimethyl-2-oxobutoxy)-2-methoxytetrahydro-furan (1.65 g, 65%) as a colourless oil; R_f 0.49 (40% ether–petrol); ν_{max} (film) 2960, 2831, 1721, 1478, 1443, 1394, 1360, 1278, 1192, 1145, 1105, 1055, 1000, 965, 942 cm^{-1}; δ_H (500 MHz) 4.93 (1H, s, H-2), 4.35, 4.30 (2H, AB q, J 17.0 Hz, $OCH_2C=O$), 4.04 (1H, dd, J 15.0, 7.5 Hz, H-5), 3.89 (1H, dt, J 8.5, 5.5 Hz, H-3), 3.84 (1H, dd, J 6.0, 3.5 Hz, H-5), 3.30 (3H, s, OMe), 2.16 (1H, m, H-4), 1.95 (1H, m, H-4), 1.13 (9H, s, CMe_3); *m/z* (EI) 215 $[M-H]^+$, 185, 156, 141, 127, 101, 85, 71, 57, 41, 29 (Found: $[M-OMe]^+$, 185.1181. $C_{11}H_{20}O_4$ requires $[M-OMe]^+$, 185.1178).

3-(3,3-Dimethyl-2-oxobutoxy)tetrahydrofuran-2-ol (10).

To a solution of [*2R*,3R**]-3-(3,3-dimethyl-2-oxobutoxy)-2-methoxytetrahydrofuran (1.22 g, 5.64 mmol, 1.0 equiv) in 40% aqueous MeCN (40 ml) was added concentrated H_2SO_4 (80 drops) and the mixture stirred at 35°C for 4 h. The solution was neutralised and the MeCN was evaporated under reduced pressure. EtOAc and H_2O were added and the aqueous layer was repeatedly extracted with EtOAc. The combined organic layers were dried ($MgSO_4$) and evaporated to give **10** (35:65 *cis*-:*trans*- by ^1H nmr; 1.06 g, 93%) as a pale yellow oil; R_f 0.35 (80% ether–petrol); ν_{max} (film) 3424, 2962, 1721, 1481, 1367, 1145, 1059, 861 cm^{-1}; δ_H (500 MHz) 5.38 (0.65H, s, H-2 *trans*), 5.21 (0.35H, s, J 4.0 Hz, H-2 *cis*), 4.49 and 4.33 (both 0.65H, AB q, J 17.5 Hz, OCH_2CO), 4.35, 4.30 (2 x 0.35H, AB q, J 17.5 Hz, OCH_2CO), 4.05-3.95, 3.85-3.79, 3.77-3.70 (3H, m, H-3, 5), 3.50-3.20 (broad s, OH), 2.25-2.12, 2.11-1.90 (2H, m, H-3), 1.10 (9 x 0.35H, s, CMe_3 *cis*), 1.09 (9 x 0.65H, s, CMe_3 *trans*); *m/z* (EI) 202 $[M]^+$, 184, 173, 172, 169, 158, 149, 145, 129, 127, 117, 103, 100, 87, 86, 69, 57, 43, 41, 31, 29, 27 (Found: $[M]^+$, 202.1207. $C_{10}H_{18}O_4$ requires $[M]^+$, 202.1205).

3-(2-*tert*-Butyl-2-propenyloxy)-2-methoxytetrahydro-2*H*-pyran.

This was prepared analogously to 3-(2-*tert*-butyl-2-propenyloxy)-2-methoxytetrahydrofuran on a 7.58 mmol scale to give 3-(2-*tert*-butyl-2-propenyloxy)-2-methoxytetrahydro-2*H*-pyran (1.07 g, 62%) as a colourless oil; R_f 0.67 (25% ether–petrol); ν_{max} (film) 2957, 2873, 1636, 1464, 1386, 1361, 1191, 1146, 1126, 1081, 1045, 962, 904, 879, 849, 819 cm^{-1}; δ_H (500 MHz) [5.10 (1H, d, J 1.0 Hz), 5.00 (1H, s), $=CH_2$], 4.40

(1H, d, J 4.0 Hz, H-2), 4.12 (2H, ABq, J 13.0 Hz, OCH_2), 3.81 (1H, ddd, J 11.4, 8.3, 3.5 Hz, H-3), 3.53-3.46 (1H, m, H-6), 3.44 (3H, s, OMe), 3.25-3.19 (1H, m, H-6), [1.90-1.85 (1H, m), 1.84-1.78 (1H, m), 1.71-1.63 (1H, m), 1.48-1.39 (1H, m), H-4, H-4]; *m/z* (EI) 228 $[M]^+$, 171, 140, 130, 125, 115, 111, 97, 84, 69, 55, 43, 41, 29 (Found: $[M]^+$, 228.1722. $C_{13}H_{24}O_3$ requires $[M]^+$, 228.1725).

[2*R,3*R**]-3-(3,3-Dimethyl-2-oxobutoxy)-2-methoxytetrahydro-2*H*-pyran**.

This was prepared analogously to [2*R**,3*R**]-3-(3,3-dimethyl-2-oxobutoxy)-2-methoxytetrahydrofuran on a 3.31 mmol scale to give[2*R**,3*R**]-3-(3,3-dimethyl-2-oxobutoxy)-2-methoxytetrahydro-2*H*-pyran (0.495 g, 65%) as a colourless oil; R_f 0.37 (40% ether–petrol); ν_{max} (film) 2958, 1720, 1478, 1392, 1366, 1273, 1192, 1143, 1116, 1080, 1044, 1003, 961, 900, 878, 821, 782, 724 cm^{-1}; δ_H (270 MHz) 4.50 (2H, s, $OCH_2C{=}O$), 4.34 (1H, d, J 5.0 Hz, H-2), [3.90-3.78 (1H, m), 3.50-3.32 (1H, m), 3.17-3.00 (1H, m), H-3, H-6], 3.43 (3H, s, OMe), [2.18-1.95 (1H, m), 1.85-1.70 (1H, m), 1.69-1.58 (1H, m), 1.54-1.40 (1H, m), H-4, H-5], 1.12 (9H, s, CMe_3); *m/z* (EI) 230 $[M]^+$, 199, 170, 1145, 142, 127, 115, 114, 100, 99, 85, 71, 57, 45 (Found: $[M]^+$, 230.1516. $C_{12}H_{22}O_4$ requires $[M]^+$, 230.1518).

3-(3,3-Dimethyl-2-oxobutoxy)tetrahydro-2*H*-pyran-2-ol (11).

This was prepared analogously to 3-(3,3-dimethyl-2-oxobutoxy)tetrahydrofuran-2-ol on a 0.830 mmol scale to give **11** (0.137 g, 77%) as a pale yellow oil; R_f 0.34 (Et_2O); ν_{max} (film) 3410, 2958, 2929, 2860, 1721, 1462, 1367, 1275, 1146, 1080, 1031, 862, 74 cm^{-1}; δ_H (500 MHz) 4.62 (1H, s, J 7.0 Hz, H-2), [4.60 (1H, d, J 18.0 Hz), 4.46 (1H, d, J 18.0 Hz), $OCH_2C{=}O$], 4.20-3.20 (3H, m, H-3, H-6), 2.0-1.50 (4H, m, H-4, H-5), 1.15 (9H, s, CMe_3); *m/z* (EI) 216 $[M\text{-}OH]^+$, 199, 185, 113, 101, 100, 91, 85, 71, 57, 41, 29. *m/z* (CI) 234 $[M+NH_4]^+$, 217, 199, 181, 164, 120, 101, 60, 44, 39 (Found: $[M+NH_4]^+$, 234.1705. $C_{11}H_{20}O_4$ requires $[M+NH_4]^+$, 234.1705).

(*Z*)-3-[3,3-Dimethyl-2-(*tert*-butyldimethylsilyloxy)-1-butenyloxy]-2-(2-pyridylthio)tetrahydro-furan-2-ol (15).

To a solution of alcohols **10** (1.0 g, 4.95 mmol, 1.0 equiv) and 2-Aldrithiol® (1.09 g, 4.95 mmol, 1.05 equiv) in dry CH_2Cl_2 (17 ml) at 0°C was added Bu_3P (1.0 ml, 4.95 mmol, 1.0 equiv) dropwise, giving a deep yellow-coloured solution. The reaction mixture was stirred at 0°C for 15 min and then at rt overnight. The solution was evaporated to give a gum which was purified by chromatography (40% ether–petrol) to give a mixture of *syn*- and *anti*-**12** and **14** (1.25 g, 85%, 1:1:1). A small portion of the mixture was subjected to further chromatography to give a pure sample of *syn*-**12** as a pale yellow oil; R_f 0.21 (65% ether–petrol); ν_{max} (film) 2961, 1722, 1577, 1532, 1452, 1419, 1367, 1282, 1145, 1054, 861, 763 cm^{-1}; δ_H (250 MHz) [8.47-8.45 (1H, m),7.523-7.27 (2H, m), 7.04-6.98 (1H, m) aromatics], 6.44 (1H, d, J 5.0 Hz, H-2), 4.57, 4.40 (2H, AB q, J 17.5 Hz, OCH_2CO), 4.34-4.26 (1H, m, H-3), 4.19-4.09 (1H, m, H-5), 4.0-3.92 (1H, m, H-5), 2.28-2.20 (2H, m, H-4), 1.15 (9H, s, CMe_3); *m/z* (CI) 296 $[M+H]^+$, 185, 184, 112, 70, 57 (Found: $[M+H]^+$, 296.1320. $C_{15}H_{21}NO_3S$ requires $[M+H]^+$, 296.1320). To a solution of the mixture of ketones (1.0 g, 3.39 mmol, 1.0 equiv) in dry Et_2O (3.5 ml) at 0°C was added Et_3N (0.945 ml, 6.78 mmol, 2.0 equiv) and the mixture stirred for 15 min. TBDMSOTf (1.17 ml, 5.08 mmol, 1.5 equiv) was added dropwise and the reaction stirred for 1 h at 0°C and then overnight at rt. The reaction was diluted with Et_2O and the ether layer washed with aqueous $NaHCO_3$, H_2O, dried ($MgSO_4$) and concentrated under reduced pressure to give a crude product which was purified by chromatography (40% ether–petrol) to give a mixture of *syn*- and *anti*- **15** together with the silyl enol ether derived from **14** (1:1:1 by ^1H nmr; 1.064 g, 78%) as a pale yellow oil. The three silyl enol ethers were separated by further chromatography; *syn*-**15**: R_f 0.32 (30% ether–petrol); ν_{max} (film) 2955, 2858, 1679, 1577, 1453, 1417, 1381, 1339, 1250, 1223, 1127, 1057, 964, 833, 780, 723 cm^{-1}; δ_H (500 MHz) [8.48-8.46 (1H, m), 7.50 (1H, dt, J 8.0, 2.0 Hz), 7.30-7.28 (1H, m), 7.00 (1H, ddd, J 6.0, 5.0, 1.0 Hz), aromatics], 6.42 (1H, d, J 5.0 Hz, H-2), 5.51 (1H, s, =CH), 4.48 (1H, dd, J 10.0, 5.0 Hz, H-3), 4.17 (1H, dd, J 16.0, 8.0 Hz, H-

5), 3.99 (1H, m, H-5), 2.24-2.20 (2H, m, H-4), 1.03 (9H, s, $=CMe_3$), 0.97 (9H, s, $SiCMe_3$), 0.27, 0.25 (6H, 2 x s, $SiMe_2$); *m/z* (EI) 409 $[M]^+$, 352, 283, 238, 180, 168, 112, 84, 73, 57, 41 (Found: $[M]^+$, 409.2113. $C_{21}H_{35}NO_3SSi$ requires $[M]^+$, 409.2107); *anti*-**15**: R_f 0.76 (30% ether–petrol); ν_{max} (film) 2957, 2857, 1680, 1579, 1556, 1454, 1416, 1389, 1356, 1254, 1224, 1159, 1122, 1072, 987, 913, 837, 781, 723 cm^{-1}; δ_H (500 MHz) [8.45-8.43 (1H, m), 7.51 (1H, dt, J 7.5, 2.0 Hz), 7.25 (1H, d, J 8.0 Hz), 7.02 (1H, ddd, J 6.0, 5.0, 1.0 Hz), aromatics], 6.22 (1H, s, J 5.0 Hz, H-2), 5.80 (1H, s, =CH), 4.47 (1H, dd, J 6.0, 1.0 Hz H-3), 4.19-4.09 (2H, m, H-5), 2.40-2.31(1H, m, H-4), 2.20-2.10 (1H, m, H-4), 1.06 (9H, s, $=CMe_3$), 0.92 (9H, s, $SiCMe_3$), 0.18 (6H, s, $SiMe_2$); *m/z* (EI) 409 $[M]^+$, 352, 298, 294, 241, 238, 208, 199, 180, 94, 73, 57, 41, 29 (Found: $[M]^+$, 409.2113. $C_{21}H_{35}NO_3SSi$ requires $[M]^+$, 409.2107).

(*Z*)-3-[3,3-Dimethyl-2-(*tert*-butyldimethylsilyloxy)-1-butenyloxy]-2-(2-pyridylthio)tetra-hydro-2*H*-pyran (16).

This was prepared analogously to **15** on a 0. 615 mmol scale to give a mixture of *syn*- and *anti*- silyl enol ethers **16** (40:60 by ^1H nmr; 0.140 g, 63% from **11**) as a pale yellow oil; R_f 0.45 (40% ether–petrol); ν_{max} (film) 2957, 2932, 2858, 1678, 1578, 1556, 1453, 1415, 1386, 1354, 1281, 1249, 1225, 1159, 1125, 1076, 1056, 1007, 984, 913, 830, 782, 760, 724 cm^{-1}; δ_H (500 MHz) [8.44-8.43, 7.52-7.49, 7.28-7.23, 7.03-6.99 (4H, m, aromatics)], 6.42 (0.6H, d, J 3.5 Hz, H-2 *trans*), 6.12 (0.4H, d, J 2.5 Hz, H-2 *cis*), 5.62 (0.4H, s, =CH *cis*), 5.54 (0.6H, s, =CH *trans*), 4.05-3.90, 3.83-3.63 (3H, several multiplets, H-3, H-6), [2.10-1.90, 1.89-1.77, 1.75-1.60, 1.55-1.45 (4H, several multiplets, H-4, H-5)], 1.05 (0.4H x 9, s, $=CCMe_3$ *cis*), 0.98 (0.6H x 9, s, $=CCMe_3$ *trans*), 0.95 (0.4H x 9, s, $SiCMe_3$ *cis*), 0.94 (0.6H x 9, s, $SiCMe_3$ *trans*), 0.23, 0.22 (0.4H x 6, s x 2, $SiMe_2$ *cis*), 0.218, 0.203 (0.6H x 6, s x 2, $SiMe_2$ *trans*); *m/z* (EI) 425, 424, 423 $[M]^+$, 378, 377, 376, 254, 253, 252, 196, 195, 194, 166, 112, 94, 73, 57, 41, 29 (Found: $[M]^+$, 423.2260. $C_{22}H_{37}NO_3SSi$ requires $[M]^+$, 423.2260).

[1*R,5*S**,7*R**]-7-(2,2-Dimethyl-1-oxopropyl)-2,6-dioxabicyclo[3.2.0]heptane (17).**

To a stirred suspension of activated 4A° powdered molecular sieves (0.5 g) and AgOTf (0.066g, 0.257 mmol, 1.05 equiv) in dry CH_2Cl_2 (6 ml) previously stirred under argon during 5 min was added a solution of *anti*-**15** (0.10 g, 0.245 mmol, 1.0 equiv) in CH_2Cl_2 (2 ml) at rt. After 80 min solid $NaHCO_3$ was added and the mixture filtered. The filtrate was concentrated under reduced pressure to yield a pale yellow oil which was purified by chromatography (30% ether–petrol) to yield the oxetane **17** (0.024 g, 55%) as an oil; R_f 0.37 (40% ether–petrol); ν_{max} (film) 2966, 1712, 1478, 1367, 1170, 1087, 971, 931, 895 cm^{-1}; δ_H (500 MHz.) 5.41 (1H, t, J 4.2 Hz, H-5), 5.25 (1H, d, J 2.6 Hz, H-7), 4.73 (1H, dd, J 4.0, 3.0 Hz, H-1), [4.35 (1H, t, J 9.0 Hz), 4.25 (1H, ddd, J 11.5, 9.0, 5.0 Hz,) H-3, ABXY system], 2.16 (1H, dd, J 14.0, 5.0 Hz, H-4), 1.72 (1H, dddd, obscured by residual H_2O, H-4), 1.18 (9H, s, CMe_3); δ_C (125.8 MHz, $CDCl_3$) 211.0 (C=O), 86.5 (C-7, C-5), 80.2 (C-1), 67.6 (C-3), 43.1 (*C*Me_3), 33.2 (C-4), 26.0 (Me); δ_C (125.8 MHz, C_6D_6) 210.2 (C=O), 86.9 (C-7), 86.2 (C-5), 80.5 (C-1), 67.3 (C-3), 43.2 (*C*Me_3), 33.3 (C-4), 25.8 (Me); *m/z* (CI, NH_3) 202 $[M+NH_4]^+$, 185 $[M+H]^+$, 167, 139, 127, 115, 99, 71, 58, 39 (Found: $[M+H]^+$, 185.1178. $C_{10}H_{16}O_3$ requires $[M+H]^+$, 185.1178).

[1*R,6*S**,8*R**]-8-(2,2-Dimethyl-1-oxopropyl)-2,7-dioxabicyclo[4.2.0]octane (18).**

This was prepared analogously to **17** from *syn*-**16** on a 0.248 mmol scale to yield **18** (0.023 g, 50%) as an oil; R_f 0.31 (40% ether–petrol); ν_{max} (film) 2926, 2855, 1728, 1486, 1463, 1364, 1281, 1144, 1073, 861, 775 cm^{-1}; δ_H (500 MHz) 5.40 (1H, d, J 3.5 Hz, H-8), 4.92 (1H, m, H-6), 4.46 (1H, dd, J 6.0, 4.0 Hz, H-1), 4.03 (1H, m, H-3), 3.60 (1H, ddd, J 12.5, 8.5, 4.0 Hz, H-3), 2.15-1.95 (2H, m, H-5), 1.88-1.75 (2H, m, H-4), 1.25 (9H, s, CMe_3); δ_H (500 MHz, C_6D_6), 5.28 (1H, dd, J 3.5, 1.0 Hz, H-8), 4.62 (1H, m, H-6), 4.29 (1H, dd, J 5.5, 3.5 Hz, H-1), 3.64 (1H, m, H-3), 3.08 (1H, ddd, J 12.5, 9.0, 3.5 Hz, H-3), 1.78-1.63 (2H, m, H-5), 1.28-1.18 (2H, m, H-4, 1.01 (9H, s, CMe_3); δ_C (125.8 MHz, C_6D_6), 210.5 (C=O), 85.9 (C-8), 76.8 (C-6), 72.5 (C-1), 62.8 (C-3), 43.1 (*C*Me_3), 26.1 (C-5), 25.9 (Me), 20.1 (C-4); *m/z* (EI) 198 $[M]^+$, 183, 181, 150, 127, 113, 94, 84, 71, 57, 55, 41, 29 (Found: $[M]^+$, 198.1250. $C_{11}H_{18}O_3$ requires $[M]^+$, 198.1256).

Methyl 2-*O*-(2-*tert*-butyl-2-propenyl)-3,4-*O*-isopropylidene-β-L-arabinopyranoside.

This was prepared analogously to 3-(2-*tert*-butyl-2-propenyloxy)-2-methoxytetrahydrofuran starting from methyl 3,4-*O*-isopropylidene-β-L-arabinopyranoside[8] on a 15.54 mmol scale to yield methyl 2-*O*-(2-*tert*-butyl-2-propenyl)-3,4-*O*-isopropylidene-β-L-arabinopyranoside (1.71 g, 50%) as a colourless oil; R_f 0.66 (40% ether–petrol); $[\alpha]_D^{24}$ +5.4 (*c* 0.02, $CHCl_3$); ν_{max} (film) 2960, 1637, 1461, 1380, 1218, 1061, 905, 852, 807 cm^{-1}; δ_H (500 MHz) [5.09 (1H, d, J 1.5 Hz), 4.99 (1H, s), $=CH_2$], 4.75 (1H, d, J 3.5 Hz, H-1), 4.30-4.22 (3H, m, H-3, $OCH_2C=C$), 4.21-4.18 (1H, m, H-4), 3.92 (1H, dd, J 13.4, 1.2 Hz, H-5), 3.88 (1H, dd, J 13.3, 2.6 Hz, H-5), 3.49 (1H, dd, J 7.5, 3.5 Hz, H-2), 3.39 (3H, s, OMe), 1.50, 1.33 (6H, 2 x s, CMe_2), 1.06 (9H, s, CMe_3); *m/z* (EI) 300 $[M]^+$, 285, 187, 156, 149, 143, 141, 129, 100, 97, 85, 59, 55, 43, 41 (Found: $[M]^+$, 300.1940. $C_{16}H_{28}O_5$ requires $[M]^+$, 300.1936).

Methyl 2-*O*-(2-*tert*-butyl-2-propenyl)-β-L-arabinopyranoside.

To a solution of methyl 2-*O*-(2-*tert*-butyl-2-propenyl) 3,4-*O*-isopropylidene-β-L-arabinopyranoside (1.367 g, 4.56 mmol, 1.0 equiv) in THF–H_2O (4:1; 13 ml) was added TFA in portions of 0.2 ml/30 min (total of 1.5 ml). After 7 h the solution was neutralised, the THF was evaporated and the water was removed by azeotropic distillation with C_6H_6 under reduced pressure. The resulting syrup was purified by chromatography (20% EtOAc–ether) to give methyl 2-*O*-(2-*tert*-butyl-2-propenyl)-β-L-arabinopyranoside (1.0 g, 85%) as a colourless oil; R_f 0.43 (EtOAc); $[\alpha]_D^{29}$ +85.1 (*c* 1.9, EtOAc); ν_{max} (film) 3431, 2959, 1675, 1639, 1462, 1360, 1195, 1095, 1000, 914, 887, 861, 778 cm^{-1}; δ_H (500 MHz) [5.12 (1H, d, J 1.0 Hz), 5.05 (1H, s), , $=CH_2$], 4.90 (1H, d, J 3.5 Hz, H-1), [4.23 (1H, d, J 12.5 Hz), 4.08 (1H, d, J 12.5 Hz), $OCH_2C=C$], 4.02-3.99 (2H, m, H-3, H-4), 3.79 (1H, dd, J 12.5, 1.0 Hz, H-5), 3.71 (1H, dd, J 12.5, 1.5 Hz, H-5), 3.69-3.66 (1H, m, H-2), 3.41 (3H, s, OMe), 2.50-2.20 (broad s, OH), 1.09 (9H, s, CMe_3); *m/z* (EI) 260 $[M]^+$, 245, 213, 203, 185, 169, 103, 97, 73, 69, 55, 45, 43, 41, 29, 27 (Found: $[M]^+$, 260.1620. $C_{13}H_{24}O_5$ requires $[M]^+$, 260.1623).

Methyl 3,4-di-*O*-benzyl-2-*O*-(2-*tert*-butyl-2-propenyl)- β-L-arabinopyranoside.

To a suspension of petrol-washed KH (1.16 g of a 35% suspension in mineral oil, 10.18 mmol, 3.0 equiv) in dry DMF (8 ml) was added a solution of methyl 2-*O*-(2-*tert*-butyl-2-propenyl)-β-L-arabinopyranoside (0.883 g, 3.396 mmol, 1.0 equiv) in DMF (2 ml) at 0°C with stirring. The mixture was stirred rt for 20 min. Benzyl bromide (1.02 ml, 8.49 mmol, 2.5 equiv) and Bu_4NI (5 mole%) in DMF (2 ml) was and the mixture stirred at rt overnight. Methanol was added, the mixture was filtered, the filtrate was partitioned between EtOAc and H_2O and the aqueous layer extracted with EtOAc (2 x). The dried ($MgSO_4$) EtOAc layer was concentrated under reduced pressure to give a yellow oil which was purified by chromatography (15% ether–petrol) to yield methyl 2-*O*-(2-*tert*-butyl-2-propenyl)-3,4-di-*O*-benzyl-β-L-arabinopyranoside (1.07 g, 72%) as a colourless oil; R_f 0.64 (40% ether–petrol); $[\alpha]_D^{29}$ +58.9 (*c* 1.8, $CHCl_3$); ν_{max} (film) 3031, 2927, 1638, 1590, 1456, 1354, 1196, 1057, 991, 907, 860, 776, 736, 698 cm^{-1}; **δ** (500 MHz) 7.38-7.27 (10H, m, aromatics), [5.16 (1H, d, J 1.5 Hz), 5.01 (1H, s), $=CH_2$], 4.87 (1H, d, J 3.5 Hz, H-1), 4.73 (2H, s, $OCH_2C=C$), 4.72, 4.62 (2H, AB q, J 12.0 Hz, CH_2Ph), 4.35, 4.24 (2H, AB q, J 13.0 Hz, CH_2Ph), 3.95 (1H, dd, J 9.5, 3.5 Hz, H-2), 3.87 (1H, dd, J 10.0 , 3.0 Hz, H-3), 3.75 (1H, broad s, H-4), 3.67 (1H, dd, J 12.5, 2.5 Hz, H-5), 3.61 (1H, dd, J 12.5, 1.0 Hz, H-5'), 3.41 (3H, s, OMe), 1.07 (9H, s, CMe_3); *m/z* (EI) 440 $[M]^+$, 408, 349, 317, 277, 259, 149, 94, 91, 69., 55, 41, 29, 28 (Found: $[M]^+$, 440.2560. $C_{27}H_{36}O_5$ requires $[M]^+$, 440.2562).

Methyl 3,4-di-*O*-benzyl-2-*O*-(3,3-dimethyl-2-oxobutyl)-β-L-arabinopyranoside (20).

This was prepared analogously to [2*R**,3*R**]-3-(3,3-dimethyl-2-oxobutoxy)-2-methoxytetrahydrofuran on a 1.75 mmol scale to give **20** (0.580 g, 75%) as a colourless oil; R_f 0.39 (60% ether–petrol); $[\alpha]_D^{29}$ +42.5 (*c* 2.4, $CHCl_3$); ν_{max} (film) 2948, 1723, 1488, 1453, 1356, 1202, 1122, 1076, 1038, 964, 740, 700 cm^{-1}; δ_H (500 MHz) 7.37-7.27 (10H, m, aromatics), 5.13 (1H, d, J 3.5 Hz, H-1), 4.72, 4.64 (2H, AB q, J 18.0 Hz, CH_2Ph),

4.71, 4.67 (2H, AB q, J 12.5 Hz, CH_2Ph), 4.63 (2H, s, OCH_2CO), 3.92 (1H, dd, J 9.5, 3.5 Hz, H-3), 3.76-3.73 (2H, m, H-2, 4), 3.68 (1H, dd, J 12.5, 2.5 Hz, H-5), 3.59 (1H, d, J 12.3 Hz, H-5); *m/z* (EI) **442** $[M]^+$, 410, 319, 303, 277, 262, 261, 231, 213, 205, 181, 169, 149, 132, 126, 117, 105, 99, 94, 92, 83, 69, 57, 45, 41, 27 (Found: $[M]^+$, 442.2355. $C_{26}H_{34}O_6$ requires $[M]^+$, 442.2355).

1-Deoxy-3,4-di-*O*-benzyl-2-*O*-(3,3-dimethyl-2-oxobutyl)-1-pyridylthio-L-arabinopyranose.

This was prepared analogously to **12** on a 0.105 mmol scale to give 2-thiopyridyl 2-*O*-(3,3-dimethyl-2-oxobutyl)-3,4-di-*O*-benzyl-L-arabinopyranoside (*anti-*:*syn-* 65:35 by ^1H nmr; 0.048 g, 62% over 2 steps from **20**), *trans*:*cis* 65:35) as a pale yellow oil; R_f 0.37, 0.33 (70% ether–petrol); ν_{max} (film) 2928, 1723, 1576, 1452, 1418, 1364, 1276, 1117, 862, 760, 698 cm^{-1}; δ_H (500 MHz) 8.47-8.46, 7.60-7.20, 7.12-6.97 (14H, aromatics), 6.48-6.38 (0.65H, broad signal, H-1 *anti-*), 6.10-6.00 (0.35H, broad signal, H-1 *syn-*), 4.80-4.40 (6H, m, 2 x CH_2Ph, OCH_2CO), 4.04-3.45 (5H, m, H-2, H-3, H-4, H-5), 0.96 (9H, s, CMe_3); *m/z* (EI) 410 $[M\text{-}PySH]^+$, 391, 368, 320, 293, 279, 261, 220, 205, 187, 167, 149, 129 (Found: $[M\text{-}PySH]^+$, 410.2090. $C_{30}H_{35}NO_5S$ requires $[M\text{-}PySH]^+$, 410.2090).

(*Z*)-1-Deoxy-2-*O*-(2-*tert*-butyldimethylsilyloxy-3,3-dimethylbutenyl)-3,4-di-*O*-benzyl-1-pyridylthio-L-arabinopyranose (21).

This was prepared analogously to **15** on a 0.123 mmol scale to give **21** as a mixture of diastereomers (*syn-*:*anti-* 45:55 by ^1H nmr; 0.060 g, 77%) as a pale yellow oil; R_f 0.37, 0.25 (10% ether–petrol); ν_{max} (film) 2957, 1680, 1578, 1455, 1416, 1355, 1251, 112, 960, 832, 781, 699 cm^{-1}; δ_H (500 MHz) 8.46-8.43, 7.51-7.23, 7.03-6.99 (14H, m, aromatics), 6.21 (0.55H, d, J 3.0 Hz, H-1 *anti*), 6.15 (0.45H, d, J 3.0 Hz, H-1 *cis*), 5.47 (0.45H, s, =CH *syn*), 5.39 (0.55H, s, =CH *anti*), [4.76-4.56 (4H, several overlapping signals, 2 x CH_2 Ph for *syn* and *anti*, these were partially analysed as 4.75, 4.67 (AB q, J 12.0 Hz), 4.62, 4.57 (AB q, J 12.5 Hz)], 4.26-3.59 (5H, H-2, H-3, H-4, H-5), 1.01, 0.99, 0.94, 0.92 (9H, 4 x s, $=CMe_3$); *m/z* (EI) 635 $[M]^+$, 580, 579, 407, 406, 299, 298, 270, 269, 254, 253, 233, 221, 220, 219, 208, 205, 202, 173, 168, 157, 149, 115, 112, 110, 105, 94, 92, 91, 82, 75, 73, 67, 59, 57, 55, 43, 41, 39, 28 (Found: $[M]^+$, 635.3101. $C_{36}H_{49}NO_5SSi$ requires $[M]^+$, 635.3101).

[1*S*,4*S*,5*S*,6*R*,8*S*]-3,4-Bis(benzyloxy)-8-(2,2-dimethyl-1-oxopropyl)-2,7-dioxabicyclo[4.2.0]octane (22).

This was prepared analogously to **17** on a 0.167 mmol sale to give the oxetane **128** (0.034 g,.50%) as an oil; R_f 0.38 (50% ether–petrol); ν_{max} (film) 2961, 1712, 1455, 1364, 1261, 1207, 1098, 780, 737, 698 cm^{-1}; δ_H (500 MHz) 7.38-7.28 (10H, m, aromatics), 5.49 (1H, dd, J 5.5, 0.5 Hz, H-8), 5.03 (1H, m, H-6), 4.77 and 4.62 (2H, AB quartet, J 12.0 Hz, CH_2Ph), 4.75 (1H, dd, J 6.5, 5.5 Hz, H-1), 4.71-4.68 (2H, AB quartet, J 12.0 Hz, CH_2Ph),4.07 (1H, dd, J 5.0, 2.5 Hz, H-5), [4.01 (1H, dd, J 12.5, 4.0 Hz), 3.94 (1H, dd, J 12.5, 2.5 Hz) H-3 ABX system], 3.95 (1H, m, H-4), 1.18 (9H, s, CMe_3); δ_C (125.8 MHz), 210.7 (C=O), 138.1, 138.0, 128.4, 127.7, 127.6, 127.5 (2 x Ph), 85.7 (C-8), 83.0 (C-6), 79.2 (C-5), 72.6 (C-1), 72.2 (C-4), 71.9, 71.2 (2 x CH_2Ph), 65.7 (C-3), 42.9 (CMe_3), 26.1 (Me); *m/z* (EI), 410 $[M]^+$, 319, 302, 272, 253, 181, 161, 149, 127, 107, 105, 100, 91, 57, 41, 28 (Found: $[M]^+$, 410.2093. $C_{25}H_{30}O_5$ requires $[M]^+$, 410.2093).

3,5-Di-*O*-benzyl-1,2-*O*-isopropylidene-α-D-xylofuranose.[10,11]

A solution of 1,2:3,5-di-*O*-isopropylidene-D-xylofuranose **23** (12.50 g, 54.3 mmol, 1 equiv) in 75% (w/v) aqueous acetic acid (268 ml) was stirred at rt during 72 h. The resulting colourless solution was concentrated under reduced pressure to give a cloudy pale yellow syrup which was azeotropically dried with 50% butanol–toluene (3 x 100 ml) to give crude 1,2-*O*-isopropylidene-D-xylofuranose (10.33 g, 100%) as a pale yellow oil. This was dissolved in benzyl chloride (45.7 ml, 393.43 mmol, 7.25 equiv) and the golden-yellow solution heated to 50°C . Potassium hydroxide pellets (16.75 g, 298.46 mmol, 5.5 equiv) were added portionwise over 30 min and the reaction mixture heated to 80°C during 4.5 h. The cooled reaction mixture

was partitioned between water (150 ml) and ether (150 ml) and the aqueous phase extracted with ether (2 x 100 ml). The combined ethereal layers were dried (Na_2SO_4) and concentrated under reduced pressure. Chromatography (petrol→25% ether–petrol) gave 3,5-di-*O*-benzyl-1,2-*O*-isopropylidene-α-D-xylofuranose (17.73 g, 88% over two steps), as a golden yellow oil; R_f 0.29 (25% ether–petrol); $[\alpha]_D^{32}$ -44.8 (*c* 1.0, $CHCl_3$), Lit[21] $[\alpha]_D^{20}$ -48.4 (*c* 1.00, $CHCl_3$); ν_{max} (film) 3069, 3034, 2986, 2938, 2861, 1501, 1454, 1381, 1374, 1253, 1214, 1165, 1092, 1076, 1017, 888, 859, 737, 698, 640, 606 cm^{-1}; δ_H (250 MHz) 7.37-7.23 (10H, m, aromatic protons of 2 x CH_2Ph), 5.94 (1H, d, J 4.0 Hz, H-1), 4.60 (1H, d, J 4.0 Hz, H-2), 4.58 (2 x 2H, 2 x AB q, J 13.0, 12.0 Hz, 2 x CH_2Ph), 4.41 (1H, td, J 6.5, 3.0 Hz, H-4), 3.98 (1H, d, J 4.0 Hz, H-3), 3.78 (2H, dd, J 10.0, 6.5 Hz, H-5), [1.48 (3H, s), and 1.31 (3H, s), 2 x Me of isopropylidene]; δ_C (62.9 MHz) [138.1 and 137.6 (*ipso*-C of 2 x $PhCH_2$], [128.4, 128.4, 127.9, 127.8, 127.6 and 127.6 (*ortho*-C, *meta*-C and *para*-C of 2 x $PhCH_2$)], 111.67 (Me_2C of isopropylidene), 105.1 (C-1), [82.4, 81.8 and 79.3 (C-2, C-3 and C-4)], [73.6 and 72.0 (2 x $PhCH_2$)], 67.6 (C-5), [28.8 and 26.3 (2 x *Me* of isopropylidene)]; *m/z* (CI) 388 $[M+NH_4]^+$, 371 $[MH]^+$, 313 $[MH-Me_2CO]^+$, 295 $[MH-Me_2CO-H_2O]^+$, 272, 230, 205 $[MH-Me_2CO-PhCH_2OH]^+$, 163, 121 (Found: C, 71.22; H, 6.99. $C_{11}H_{14}O_4S$ requires C, 71.33; H, 7.07%).

1-Deoxy-3,5-di-*O*-benzyl-1-phenylsulfenyl-D-xylofuranose (24).

A solution of 3,5 di-*O*-benzyl-1,2-*O*-isopropylidene α-D-xylofuranose (1.22 g, 3.30 mmol, 1 equiv) in water (10 ml) and acetonitrile (14 ml) was heated at 35°C and concentrated sulfuric acid (600 μl) was added dropwise. Additional concentrated sulfuric acid (600 μl portions) was added dropwise at 1 h 15 min, 2 h and 2 h 30 min. After 4 h, the reaction mixture was allowed to cool to rt, and after 19.5 h was neutralised with aqueous sodium hydroxide (2M; 65 ml). The acetonitrile was removed under reduced pressure and the resulting cloudy, yellow solution was partitioned between EtOAc (150 ml) and water (50 ml). The aqueous phase was extracted with EtOAc (3 x 100 ml) and dried ($MgSO_4$). Concentration under reduced pressure gave crude 3,5-di-*O*-benzyl-D-xylofuranose (1.08 g) as a pale yellow oil. To this was added a solution of phenyl disulfide (865 mg, 3.918 mmol, 1.2 equiv) in CH_2Cl_2 (16.3 ml). The pale yellow solution was cooled to 0°C and tri-*n*-butylphosphine (1.27 ml, 4.90 mmol, 1.5 equiv) was added dropwise. After 15 min, the reaction mixture was allowed to warm to rt After 15.5 h, the reaction mixture was diluted with EtOAc (300 ml) and washed with aqueous NaOH (2 x 100 ml) and dried (Na_2SO_4). Concentration and chromatography (25% EtOAc–petrol) gave **24** (6:1 anomeric mixture by ^1H nmr; 1.049 g, 76% over two steps) as a pale yellow oil; R_f 0.27 (25% EtOAc–petrol); ν_{max} (film) 3421, 3062, 3030, 2924, 2867, 1584, 1497, 1481, 1454, 1440, 1396, 1369, 1346, 1307, 1255, 1207, 1177, 1092, 1027, 949, 911, 815, 735, 697, 606 cm^{-1}; major isomer: δ_H (270 MHz) [7.54-7.49 (2H, m), and 7.42-7.20 (8H, m), aromatic protons of 2 x CH_2Ph], 5.17 (1H, d, J 4.5 Hz, H-1), 4.69-4.51 (4H, m, 2 x CH_2Ph), 4.42 (1H, coalesced dt, J 6.0, 5.0 Hz, H-4), 4.34 (1H, coalesced dt, J 4.0, 3.5 Hz, H-2), 4.03 (1H, dd, J 5.5, 3.5 Hz, H-3), 3.81 (1H, dd, J 10.5, 5.0 Hz, H-5), 3.74 (1H, dd, J 10.5, 6.5 Hz, H-5), 4.21 (1H, d, J 4.0 Hz, OH); *m/z* (CI) 440 $[M+NH_4]^+$, 423 $[MH]^+$, 405 $[MH-H_2O]^+$, 330 $[M+NH_4-PhSH]^+$, 314 $[MH-CH_2Ph-H_2O]^+$, 219, 168 (Found $[M+NH_4]^+$, 440.1908. $C_{25}H_{26}O_4S$ requires $[M+NH_4]^+$, 440.1896).

1-Deoxy-3,5-di-*O*-benzyl-2-*O*-(3,3-dimethyl-2-oxobutyl)-1-phenylsulfenyl-D-xylofuranose (25).

To a solution of Aliquat® 336 (348 mg, 861 μmol, 0.1 equiv) and 1-deoxy-3,5-di-*O*-benzyl-1-phenylsulfenyl-D-xylofuranose **24** (3.64 g, 8.61 mmol, 1 equiv) in CH_2Cl_2 (43 ml) at rt was added 1-bromopinacolone (3.58 ml, 25.84 mmol, 3 equiv). Aqueous sodium hydroxide (50% w/w, 43 ml) was added and the reaction mixture stirred vigorously at rt during 1 h. Reaction mixture was partitioned between water (150 ml) and CH_2Cl_2 (150 ml) and the aqueous phase extracted with CH_2Cl_2 (2 x 100 ml). The combined organic extracts were dried (Na_2SO_4) and concentrated under reduced pressure. Chromatography (15%-25% EtOAc–petrol) **25** (12:5 anomeric mixture by ^1H nmr; 3.96 g, 88%) as a pale yellow oil; R_f 0.22 (major), 0.33 (minor) (15% EtOAc–petrol); ν_{max} (film) 3088, 3062, 3031, 3005, 2966, 2931, 2870, 1720, 1584, 1497, 1478, 1454, 1423, 1395, 1368, 1308, 1289, 1260, 1140, 1094, 1062, 1027, 1009, 911, 839, 781, 739, 698 cm^{-1}; major: δ_H (500 MHz) [7.53-7.50 (2H, m), and 7.35-7.23 (13H, m), aromatic protons of 2 x CH_2Ph and SPh],

5.33 (1H, d, J 3.5 Hz, H-1), 4.63 (2H, AB q, J 12.0 Hz, CH_2Ph), 4.58 (2H, AB q, J 12.0 Hz, CH_2Ph), 4.38 (1H, m, H-4), 4.37 (2H, AB q, J 17.5 Hz, OCH_2CO), 4.15 (1H, dd, J 5.0, 2.5 Hz, H-3), 4.06 (1H, dd, J 3.0, 2.5 Hz, H-2), 3.83 (1H, dd, J 10.5, 5.0 Hz, H-5), 3.79 (1H, dd, J 10.5, 6.5 Hz, H-5'), 1.13 (9H, s, CMe_3); minor: δ_H (500 MHz) [7.54-7.52 (2H, m), and 7.34-7.21 (13H, m), aromatic protons of 2 x CH_2Ph and SPh], 5.77 (1H, d, J 5.0 Hz, H-1), 4.69 (2H, AB q, J 12.0 Hz, CH_2Ph), 4.58 (1H, m, H-4), 4.57 (2H, AB q, J 12.0 Hz, CH_2Ph), 4.50 (2H, AB q, J 17.5 Hz, OCH_2CO), 4.32 (1H, dd, J 4.5, 2.0 Hz, H-3), 4.13 (1H, dd, J 5.0, 2.0 Hz, H-2), 3.81 (1H, dd, J 10.0, 6.0 Hz, H-5), 3.73 (1H, dd, J 10.0, 6.0 Hz, H-5), 1.17 (9H, s, CMe_3); δ_C (major) (62.9 MHz) 211.2 (C=O), [138.3 and 138.0 (*ipso*-C of 2 x $PhCH_2$)], 135.4 (*ipso*-C of SPh), [131.0, 128.8, 128.4, 128.3, 127.8, 127.8, 127.7, 127.5 and 126.7 (*ortho*-C, *meta*-C and *para*-C of 2 x $PhCH_2$ and SPh)], 89.0 (C-1), [85.5, 82.4 and 78.4 (C-2, C-3 and C-4)], 73.3 (OCH_2CO), [72.3 and 72.1 (2 x $PhCH_2$)], 67.9 (C-5), 42.8 (C-3'), 26.3 (C-4'); *m/z* (CI) 538 $[M+NH_4]^+$, 495, 448 $[M+NH_4\text{-}H\text{-}PhCH_2)$, 411 $[MH\text{-}PhSH]^+$, 391, 320, 303 $[MH\text{-}PhSH\text{-}PhCH_2OH]^+$, 273, 230, 195 $[MH\text{-}PhSH\text{-}2PhCH_2OH]^+$, 111, 106 (Found: C, 71.11; H, 7.05; S, 5.98. $C_{31}H_{36}O_5S$ requires C, 71.51; H, 6.97; S, 6.16%).

1-Deoxy-3,5-di-*O*-benzyl-2-*O*-(3,3-dimethyl-2-oxobutyl)-1-phenylsulfonyl-D-xylofuranose.

To a solution of 1-deoxy-3,5-di-*O*-benzyl-2-*O*-(3,3-dimethyl-2-oxo-butyl)-1-phenylsulfenyl-D-xylofuranose (522 mg, 1.00 mmol, 1 equiv) in CH_2Cl_2 (10 ml) at 0°C was added peracetic acid (375 µl of a 36 wt % solution in dilute acetic acid, 2.01 mmol, 2 equiv) and sodium acetate trihydrate (102 mg, 0.752 mmol, 0.75 equiv) in water (1 ml) dropwise with vigorous stirring. The reaction mixture was allowed to warm to rt during 5 h, diluted with water (20 ml) and partitioned between additional water (30 ml) and CH_2Cl_2 (30 ml). The aqueous phase was extracted with CH_2Cl_2 (3 x 40 ml) and the combined organic extracts washed with aqueous sodium hydroxide (2M; 30 ml), brine (30 ml) and dried (Na_2SO_4). Concentration under reduced pressure and chromatography (50% ether–petrol) gave 1-deoxy-3,5-di-*O*-benzyl-2-*O*-(3,3-dimethyl-2-oxobutyl)-1-phenylsulfonyl-D-xylofuranose (19:4 anomeric mixture by ^1H nmr; 438 mg, 79%) as a pale yellow oil; R_f 0.28 (50% ether–petrol); ν_{max} (film) 3063, 3033, 2965, 2923, 2873, 1718, 1593, 1459, 1366, 1315, 1213, 1149, 1069, 1016, 999, 850, 746, 698 cm^{-1}; δ_H (270 MHz) [7.97-7.87 (4H, m), and 7.62-7.24 (26H, m), aromatic protons of 2 x CH_2Ph and SPh, major and minor], 5.01 (1H, d, J 5.0 Hz, H-1 minor), 4.83 (1H, d, J 3.5 Hz, H-1 major), 4.77-4.35 (9H, m, 2 x CH_2Ph major and minor, H-3 major, H-4 major, H-2 minor, H-3 minor, and H-4 minor), 4.22 (1H, dd, J 5.5, 3.0 Hz, H-2 major), 3.82-3.63 (4H, m, H-5 and H-5' major and minor), 1.21 (9H, s, CMe_3 major), 1.18 (9H, s, CMe_3 minor); *m/z* (CI) 570 $[M+NH_4]^+$, 428 $[M+NH_4\text{-}PhSO_2H)$, 338, 320 $[M+NH_4\text{-}PhSO_2H\text{-}PhCH_2OH]^+$, 303, 273, 195, 160 $[PhSO_2H+NH_4]^+$, 108 $[PhCH_2OH]^+$, 91 $[C_7H_7]^+$, 81 $[C_5H_5O]^+$ (Found $[M+NH_4]^+$, 570.2525. $C_{31}H_{36}O_7S$ requires $[M+NH_4]^+$, 570.2526).

(Z)-1-Deoxy-3,5-di-*O*-benzyl-2-*O*-[(2-*tert*-butyldimethylsilyloxy)-3,3-dimethylbutenyl]-1-phenylsulfonyl-β-D-xylofuranose (29).

This was prepared analogously to **15** on a 5.07 mmol scale to give **29** (2.01 g, 59%) as a colourless gum; R_f 0.40 (25% ether–petrol); $[\alpha]_D^{30}$ +38.2 (*c* 0.65, $CHCl_3$); ν_{max} (film) 3089, 3065, 3032, 2956, 2930, 2858, 1680, 1496, 1471, 1450, 1358, 1324, 1249, 1156, 1101, 1077, 1029, 955, 828, 781, 751, 736, 720, 698, 688 cm^{-1}; δ_H (270 MHz) 7.92 (2H, d, J 7.5 Hz, *ortho*-H of $PhSO_2$), 7.57-7.21 (13H, m, aromatic protons of 2 x CH_2Ph, *meta*-H and *para*-H of $PhSO_2$), 5.69 (1H, s, =CH), 4.87 (1H, d, J 3.0 Hz, H-1), 4.75 (1H, coalesced dd, J 2.5, 1.5 Hz, H-2), 4.55 (2H, s, CH_2Ph), 4.47 (2H, AB q, J 12.0 Hz, CH_2Ph), 4.46-4.41 (1H, m, H-4), 4.11 (1H, dd, J 5.0, 1.5 Hz, H-3), 3.76-3.44 (2H, m, H-5), 1.07 (9H, s, $=CMe_3$), 0.94 (9H, s, $SiCMe_3$), 0.11 (6H, s, SiMe); δ_C (125.8 MHz) 144.36 (C-2'), [138.0, 136.9 and 136.6 (*ipso*-C of 2 x CH_2Ph and $PhSO_2$)], 134.0 (C-1'), [129.6, 128.8, 128.4, 128.4, 128.0, 127.8, 127.8, 127.7 and 123.3 (*ortho*-C, *meta*-C and *para*-C of 2 x CH_2Ph and $PhSO_2$)], 97.8 (C-1), [84.2, 83.2 and 81.6 (C-2, C-3 and C-4)], [73.4, 71.9 and 68.2 (2 x CH_2Ph and C-5)], 34.9 (C-3'), 28.2 (C-4'), 26.2 ($SiCMe_3$), 25.7 ($SiCMe_3$), [-3.3 and -3.6 ($SiMe$)]; *m/z* (CI) 684 $[M+NH_4]^+$, 667 $[MH]^+$, 525 $[MH^+\text{-}PhSO_2H)$, 435, 257, 248, 231 $[HOCHC(OTBDMS)CMe_3+H]^+$, 215

$[CH_2C(OTBDMS)CMe_3+H]^+$, 206 $[MH^+-PhSO_2-PhCH_2-OCHC(OTBDMS)CMe_3]^+$, 189 $[M+H^+-PhSO_2-PhCH_2OH-OCHC(OTBDMS)CMe_3]^+$, 173, 143, 108 $(PhCH_2OH]^+$, 98 $[M+H^+-PhSO_2-PhCH_2-OCHC(OTBDMS)CMe_3-PhCH_2OH]^+$, 91 $[C_7H_7]^+$, 81 $[C_4H_5O]^+$ (Found [MH]$^+$, 667.3143. $C_{37}H_{50}O_7SSi$ requires [MH]$^+$, 667.3125) (Found: C, 66.63; H, 7.56. $C_{37}H_{50}O_7SSi$ requires C, 66.40; H, 7.26%).

[1*S*,3*R*,4*S*,5*R*,7*S*]-4-(Benzyloxy)-3-(benzyloxymethyl)-7-(2,2-dimethyl-1-oxopropyl)-2,6-dioxabicyclo[3.2.0]heptane (27) and [1*S*,3*R*,4*S*,5*R*,7*S*]-3-(benzyloxymethyl)-7-(2,2-dimethyl-1-oxopropyl)-4-hydroxy-2,6-dioxabicyclo[3.2.0]heptane (28).

A solution of **29** (52 mg, 77.8 μmol, 1 equiv) in CH_2Cl_2 (1.77 ml) was added to activated 4 Å molecular sieves and cooled to -40°C. Tin(IV) chloride (156 μl of a 1M solution in CH_2Cl_2, 156 μmol, 2 equiv) was added dropwise; the colourless reaction mixture became pale yellow. After 45 min, the reaction mixture was quenched with saturated aqueous sodium bicarbonate solution (10 ml) and was allowed to warm to rt The mixture was partitioned between EtOAc (50 ml) and additional saturated aqueous sodium bicarbonate solution (10 ml). The layers were separated and the aqueous phase extracted with EtOAc (3 x 30 ml). The combined organic extracts were dried (Na_2SO_4) and concentrated. Chromatography (25%-50% ether–petrol) gave **27** (21 mg, 64%) as a pale yellow oil; R_f 0.23 (25% ether–petrol); $[\alpha]_D^{28}$ +16.5 (*c* 0.2, $CHCl_3$); ν_{max} (film) 3033, 2958, 2919, 2855, 1708, 1585, 1490, 1464, 1447, 1337, 1201, 1175, 1073, 1025, 988, 942, 900, 845, 804, 736, 693 cm^{-1}; δ_H (500 MHz) 7.37-7.21 (10H, m, aromatic protons of 2 x CH_2Ph), 5.34 (1H, d, J 2.5 Hz, H-7), 5.27 (1H, d, J 4.0 Hz, H-5), 4.85 (1H, coalesced dd, J 4.0, 2.5 Hz, H-1), 4.74 (1H, overlapping ddd, J 6.5, 5.0, 4.0 Hz, H-3), 4.62 (2H, AB q, J 12.0 Hz, CH_2Ph), 4.51 (2H, AB q, J 12.0 Hz, CH_2Ph), 4.06 (1H, d, J 3.5 Hz, H-4), [3.87 (1H, overlapping dd, J 10.0, 5.0 Hz), and 3.84 (1H, overlapping dd, J 10.0, 6.5 Hz), CH_2OCH_2Ph], 1.18 (9H, s, CMe_3); δ_C (125.8 MHz) 210.4 (C=O), [138.0 and 137.3 (*ipso*-C of 2 x CH_2Ph)], [128.5, 128.4, 128.0, 127.8, 127.7 and 127.7 (*ortho*-C, *meta*-C and *para*-C of CH_2Ph)], 87.3 (C-7), 86.9 (C-1), [81.4, 80.3 and 79.6 (C-3, C-4 and C-5)], [73.7, 72.0 and 68.0 (CH_2OCH_2Ph and 2 x CH_2Ph)], 43.2 (CMe_3), 26.0 (CMe_3); *m/z* (CI) 428 $[M+NH_4]^+$, 411 $[MH]^+$, 391, 319 $[MH^+-CH_2Ph-H)$, 231, 198, 181, 146, 129, 108 $(PhCH_2OH]^+$, 91 $[C_7H_7]^+$ (Found $[M+NH_4]^+$, 428.2442. $C_{25}H_{30}O_5$ requires $[M+NH_4]^+$, 428.2437), followed by **28** (6 mg, 24%) as a pale yellow oil; R_f 0.15 (50% ether–petrol); ν_{max} (film) 3395, 3067, 3026, 2964, 2922, 2851, 1710, 1600, 1456, 1395, 1359, 1256, 1200, 1123, 1072, 1049, 1031, 944, 887, 799, 739, 692 cm^{-1}; δ_H (500 MHz) 7.37-7.26 (5H, m, *ortho*-H, *meta*-H and *para*-H of CH_2Ph), 4.63 (2H, AB q, J 11.5 Hz, CH_2Ph), 4.39 (1H, dd, J 8.0, 6.0 Hz, H-4), 4.35 (1H, d, J 2.5 Hz, H-1), 4.24 (1H, s, H-5 and H-7), [4.07 (1H, d, J 7.5 Hz), and 3.90 (1H, d, J 8.5 Hz), CH_2OCH_2Ph], 4.04 (1H, d, J 6.0 Hz, H-3), 3.08 (1H, d, J 8.0 Hz, OH-4), 1.20 (9H, s, CMe_3); *m/z* (CI) 338 $[M+NH_4]^+$, 321 $[MH]^+$, 252 $[M+NH_4-HOCCMe_3]^+$, 226, 209, 191, 162, 149, 136, 124, 112, 108 $(PhCH_2OH]^+$, 102, 98 $[M+NH_4-H_2O-PhCH_2OH-OHCCOMe_3)$, 84, 69, 59 $[C_3H_7O]^+$, 52, 45 $[C_2H_5O]^+$ (Found $[M+NH_4]^+$, 338.1964. $C_{18}H_{24}O_5$ requires $[M+NH_4]^+$, 338.1967).

6-*O*-Triisopropylsilyl-D-galactopyranose.

TIPSCl (4.00 ml, 18.32 mmol, 1.1 equiv) was added dropwise to a stirred suspension of D-galactose (3.00 g, 16.65 mmol, 1 equiv), imidazole (2.54 g, 36.63 mmol, 2.2 equiv) and DMAP (205 mg, 1.665 mmol, 0.1 equiv) in anhydrous DMF (16.7 ml) at rt. After 29 h, the reaction mixture was diluted with methanol (40 ml) and concentrated under reduced pressure to give a pale yellow syrup. Chromatography (5% MeOH–EtOAc) gave 6-*O*-triisopropylsilyl-D-galactopyranose (5:3 anomeric mixture by ^{1}H nmr; 3.23 g, 58%) as a colourless solid; R_f 0.32 (5% MeOH–EtOAc); ν_{max} (film) 3376, 2943, 2890, 2867, 1658, 1483, 1416, 1385, 1368, 1150, 1102, 1070, 1015, 995, 919, 883, 803, 765, 683, 662 cm^{-1}; δ_H (270 MHz, d_6-DMSO) 6.52 (1H, d, J 6.5 Hz, H-1 major), 6.14 (1H, d, J 4.5 Hz, H-1 minor), 4.94-4.90 (1H, d, J, 4.5 Hz, OH minor), 4.73-4.68 (3H, m, OH major and 2 x OH minor), 4.53 (1H, d, J 5.0 Hz, OH minor), 4.31 (1H, d, J 4 Hz, OH major), 4.26 (1H, d, J 4 Hz, OH major), 4.32-4.22 (1H, m, OH major), 3.87-3.80 (3H, m, H-2, H-3 and H-4 major), 3.75-3.72 (1H, br s, H-2 minor), 3.68-3.52 (3H, m, H-5 major, H-3 and H-4 minor), 3.41-3.35 (2H, m obscured by HOD peak, H-6 major), 3.27-3.23 (3H, m, H-5, H-6 minor), 1.18-1.01 (42H, br m, Me and CH of

TIPS, major and minor); *m/z* (CI) 354 $[M+NH_4]^+$, 337 $[MH]^+$, 336 $[M+NH_4-H_2O]^+$, 319 $[M+NH_4-H_2O-OH]^+$, 294 $[MH-C_3H_7)$, 277 $[MH-C_3H_7-OH]^+$, 264, 247, 234 $[MH-2C_3H_7-OH]^+$, 216 $[MH-2C_3H_7-OH-H_2O]^+$, 173 $[(Me_2CH)_2SiOCHMe_2]^+$, 162 $[M+NH_4-H_2O-TIPSOH]^+$, 148, 120, 91, 74, 57 $[C_4H_9]^+$, 44 $[C_3H_7+H]^+$ (Found: $[MH]^+$, 337.2052. $C_{15}H_{32}O_6Si$ requires $[MH]^+$, 337.2046).

1-Deoxy-1-phenylsulfenyl-6-*O*-triisopropylsilyl-D-galactopyranose.

To a solution of phenyl disulfide (2.39 g, 10.82 mmol, 1.2 equiv) and 6-*O*-triisopropylsilyl-D-galactopyranose (3.03 g, 9.02 mmol, 1 equiv) in CH_2Cl_2 (45 ml) at 0°C was added tri-*n*-butylphosphine (3.51 ml, 13.52 mmol, 1.5 equiv) dropwise with stirring. The reaction mixture was allowed to warm to rt and after 15 h diluted with EtOAc (550 ml), washed with aqueous sodium hydroxide (1M; 3 x 100 ml) and dried ($MgSO_4$). Concentration under reduced pressure and chromatography (ether) gave 1-deoxy-1-phenylsulfenyl-6-*O*-triisopropylsilyl-D-galactopyranose (2:1 anomeric mixture by ^1H nmr; 2.89 g, 75%) as a colourless foam; R_f 0.30 and 0.37 (ether); ν_{max} (film) 3399, 3076, 3060, 2942, 2891, 2866, 1585, 1480, 1464, 1439, 1385, 1367, 1289, 1284, 1089, 1070, 1026, 998, 883, 796, 740, 670, 660 cm^{-1}; δ_H (270 MHz) 7.58-7.54 (4H, m, *ortho*-H of Ph, major and minor), 7.34-7.23 (6H, m, *meta*-H and *para*-H of Ph, major and minor), 5.68 (1H, d, J 5.5 Hz, H-1 major), 4.53 (1H, d, J 9.5 Hz, H-1 minor), 4.32-3.94 (6H, complex m, H-2, H-3 and H-4 of major and minor), [3.76-3.38 (4H, complex m) and 3.13-3.07 (2H, m), H-5, H-6 and H-6' of major and minor], 1.28-1.01 (42H, br m, Me and CH of TIPS, major and minor), Hydroxyl resonances not visible; *m/z* (CI) 446 $[M+NH_4]^+$, 429 $[MH]^+$, 402 $[M+NH_4-C_3H_7-H]^+$, 336 $[M+NH_4-PhSH]^+$, 321, 319 $[MH-PhSH]^+$, 294, 271, 219, 190, 174 $(TIPSOH)^+$, 162 $[M+NH_4-PhSH-TIPSOH]^+$, 148, 126, 58 $[C_4H_9]^+$, 44 $[C_3H_7+H]^+$ (Found: $[MH]^+$, 429.2129. $C_{21}H_{36}O_5SSi$ requires $[MH]^+$, 429.2131).

1-Deoxy-3,4-*O*-isopropylidene-1-phenylsulfenyl-6-*O*-triisopropylsilyl-D-galactopyranose (31).

2,2-Dimethoxypropane (1.92 ml, 15.28 mmol, 2.5 equiv) was added to a solution of 1-deoxy-1-phenylsulfenyl-6-*O*-triisopropylsilyl-D-galactopyranose (2.62 g, 6.11 mmol, 1 equiv) in CH_2Cl_2 (26 ml) at rt A solution of pyridinium *p*-toluenesulfonate (154 mg, 0.611 mmol, 0.1 equiv) in CH_2Cl_2 (5 ml) was added dropwise. Additional 2,2-dimethoxypropane (1.92 ml portions) was added after 1 h 50 min, 4 h 15 min, 6 h, 7h, 22 h and 23 h. After 25 h, the colourless reaction mixture was diluted with CH_2Cl_2 (450 ml) and washed with saturated aqueouss $NaHCO_3$ (40 ml), brine (2 x 50 ml) and dried (Na_2SO_4). Concentration under redcued pressure and chromatography (50% ether–petrol) gave **31** (1:1 anomeric mixture by ^1H nmr; 2.41 g, 84%) as a colourless foam; R_f 0.30 and 0.35 (50% ether–petrol); ν_{max} (film) 3420, 3060, 2941, 2983, 2866, 1583, 1481, 1464, 1439, 1381, 1244, 1217, 1163, 1101, 1080, 1051, 1026, 1012, 997, 879, 793, 741, 688, 660 cm^{-1}; δ_H (270 MHz) 7.56 7.51 (4H, m, *ortho*-H of Ph, both anomers), 7.32-7.26 (6H, m, *meta*-H and *para*-H of Ph, both anomers), 5.55 (1H, d, J 5.0 Hz, H-1), 4.57 (1H, td, J 6.5, 2.5 Hz, H-5), 4.46 (1H, d, J 10.5 Hz, H-1), 4.34 (1H, dd, J 5.5, 2.5 Hz, H-4), 4.27 (1H, d, J 2.0 Hz, H-4), 4.17-3.83 (8H, m, H-2, H-3, H-6 and H-6', both anomers), 3.57 (1H, m, H-5), 2.44 (1H, d, J 2.0 Hz, OH-2), 2.35 (1H, d, J 6.5 Hz, OH-2), [1.51 (3H, s), 1.43 (3H, s), 1.35 (3H, s), and 1.33 (3H, s), 2 x Me of isopropylidene, both anomers]; 1.21-1.02 (42H, br m, Me and CH of TIPS, both anomers); *m/z* (CI) 486 $[M+NH_4]^+$, 469 $[MH]^+$, 451 $[MH-Me_2CO]^+$, 376 $[M+NH_4-PhSH]^+$, 359 $[MH-PhSH]^+$, 318 $[M+NH_4-PhSH-Me_2CO]^+$, 300 $[M+NH_4-PhSH-Me_2CO-H_2O]^+$, 283 $[MH-PhSH-Me_2CO-H_2O]^+$, 234, 216, 185 $[MH-PhSH-TIPSOH]^+$, 173 $[(Me_2CH)_2SiOCHMe_2]^+$, 148, 126 $[M+NH_4-PhSH-Me_2CO-H_2O-TIPSOH]^+$, 58 $[Me_2CO]^+$ (Found: $[MH]^+$, 469.2463. $C_{24}H_{40}O_5SSi$ requires $[MH]^+$, 469.2444).

1-Deoxy-2-*O*-(3,3-dimethyl-2-oxobutyl)-3,4-*O*-isopropylidene-1-phenylsulfenyl-6-*O*-triisopropylsilyl-D-galactopyranose.

This was prepared analogously to **25** on a 8.05 mmol scale to give 1-deoxy-2-*O*-(3,3-dimethyl-2-oxobutyl)-3,4-*O*-isopropylidene-1-phenylsulfenyl-6-*O*-triisopropylsilyl-α-D-galactopyranose (3.76 g, 82%) as

a pale yellow oil; R_f 0.35 (25% ether–petrol); $[\alpha]_D^{28}$ +64.8 (*c* 0.52, $CHCl_3$); ν_{max} (film) 3060, 2958, 2943, 2893, 2868, 1720, 1479, 1466, 1441, 1379, 1369, 1244, 1217, 1147, 1105, 1078, 1061, 1026, 1011, 972, 881, 793, 741, 690 cm^{-1}; δ_H (500 MHz) 7.54-7.52 (2H, m, *ortho*-H of Ph), 7.28-7.21 (3H, m, *meta*-H and *patra*-H of Ph), 5.81 (1H, d, J 5.0 Hz, H-1), 4.71 (2H, AB q, J 18.0 Hz, OCH_2CO), 4.55 (1H, td, J 6.5, 2.0 Hz, H-5), 4.40 (1H, m, H-3), 4.33 (1H, dd, J 6.0, 2.5 Hz, H-4), 3.95 (1H, dd J 10.0, 7.0 Hz, H-6), 3.86-3.81 (2H, m, H-2, H-6), 1.47 (3H, s, isopropylidene Me), 1.33 (3H, s, isopropylidene Me), 1.15 (9H, s CMe_3), 1.11-1.00 (21H, m, Me and CH of TIPS); δ_C (100.6 MHz) 211.7 (C=O), 134.7 (*ipso* C of Ph), [131.2 and 128.8 (*ortho*-C and *meta*-C of Ph)], 126.8 (*para*-C of Ph), 109.2 (Me_2C of isopropylidene), 85.9 (C-1), [77.9, 75.9, 73.2 and 69.6 (C-2, C-3, C-4 and C-5)], 71.9 (C-1'), 62.4 (C-6), 42.6 (C-3'), 28.0 (Me of isopropylidene), 26.0 (Me of isopropylidene), 26.3 (C-4'), 17.9 (Me of TIPS), 11.9 (*C*H of TIPS); *m/z* (CI) 584 $[M+NH_4]^+$, 474 $[M+NH_4-PhSH]^+$, 457, 416 $[M+NH_4-PhSH-Me_2CO]^+$, 399, 381, 359 $[M+NH_4-PhSH-Me_2CO-CMe_3]^+$, 300 $[M+NH_4-PhSH-TIPSOH]^+$, 283, 267, 230, 195, 183, 173 $[TIPSO]^+$, 148, 58 (Found $[M+NH_4]^+$, 584.3512. $C_{30}H_{50}O_6SSi$ requires $[M+NH_4]^+$, 584.3441) (Found: C, 63.78; H, 8.76. $C_{30}H_{50}O_6SSi$ requires C, 63.56; H, 8.89%).

1-Deoxy-2-*O*-(3,3-dimethyl-2-oxobutyl)-3,4-*O*-isopropylidene-1-phenylsulfonyl-6-*O*-tri-isopropylsilyl-α-D-galactopyranose.

This was prepared analogously to 1-deoxy-3,5-di-*O*-benzyl-2-*O*-(3,3-dimethyl-2-oxobutyl)-1-phenylsulfonyl-D-xylofuranose on a 1.29 mmol scale to give 1-deoxy-2-*O*-(3,3-dimethyl-2-oxobutyl)-3,4-*O*-isopropylidene-1-phenylsulfonyl-6-*O*-tri-isopropylsilyl-α-D-galactopyranose (725 mg, 94%) as a colourless gum; R_f 0.16 (25% ether–petrol); $[\alpha]_D^{31}$ +52.0 (*c* 0.55, $CHCl_3$); ν_{max} (film) 3063, 2949, 2870, 1721, 1464, 1377, 1315, 1262, 1215, 1154, 1108, 1066, 1002, 883, 789, 736, 687 cm^{-1}; δ_H (270 MHz) 7.98-7.94 (2H, m, *ortho*-H of $PhSO_2$), 7.64-7.60 (1H, m, *para*-H of $PhSO_2$), 7.55-7.49 (2H, m, *meta*-H of $PhSO_2$), 4.99 (1H, dd, J 7.5, 3.0 Hz, H-5), 4.87 (1H, d, J 3.0 Hz, H-1), 4.79 (2H, s, OCH_2CO), 4.49-4.42 (2H, m, H-3 and H-4), 4.26 (1H, t, J 3.5 Hz, H-2), 3.78 (2H, d, J 6.5 Hz, H-6 and H-6'), [1.34 (3H, s), and 1.32 (3H, s), 2 x Me of isopropylidene], 1.17 (9H, s, CMe_3), 1.14-1.05 (21H, br m, Me and CH of TIPS); δ_C (100.6 MHz) 212.6 (C-2'), 138.8 (*ipso*-C of $PhSO_2$), 133.6 (para-C $PhSO_2$), [129.0 and 128.8 (*ortho*-C and *meta*-C $PhSO_2$)], 109.9 (Me_2C of isopropylidene), 88.9 (C-1), [74.4, 73.6, 72.2 and 72.0 (C-2, C-3, C-4 and C-5)], 73.8 (C-1'), 62.3 (C-6), 42.7 (C-3'), [26.3 and 24.4 (2 x *Me* of isopropylidene)], 26.2 (C-4'), 17.9 (*Me* of TIPS), 11.9 (*C*H of TIPS); *m/z* (CI) 616 $[M+NH_4]^+$, 599 $[MH]^+$, 555, 479, 474 $[M+NH_4-PhSO_2H]^+$, 457 $[MH-PhSO_2H]^+$, 413, 381, 355, 283 $[MH-PhSO_2H-TIPSOH]^+$, 255, 241, 225 $[MH-PhSO_2H-TIPSOH-Me_2CO]^+$, 195, 183, 173 $[(Me_2CH)_2SiOCHMe_2]^+$ (Found: $[M+NH_4]^+$, 616.3357. $C_{30}H_{50}O_8SSi$ requires $[M+NH_4]^+$, 616.3339) (Found: C, 60.43; H, 8.53. $C_{30}H_{50}O_8SSi$ requires C, 60.17; H, 8.42%).

(*Z*)-1-Deoxy-2-*O*-[(2-*tert*-Butyldimethylsilyloxy)-3,3-dimethylbutenyl]-3,4-*O*-isopropyl-idene-1-phenylsulfonyl-6-*O*-triisopropylsilyl-α-D-galactopyranose (32).

This was prepared analogously to **29** on a 1.20 mmol scale to give **32** (734 mg, 85%) as a colourless gum; R_f 0.32 (25% ether–petrol); $[\alpha]_D^{32}$ +42.4 (*c* 0.62, $CHCl_3$); ν_{max} (film) 3065, 2944, 2866, 1678, 1464, 1385, 1320, 1256, 1215, 1156, 1115, 1069, 1011, 880, 830, 787, 735, 686 cm^{-1}; δ_H (270 MHz) 7.95-7.92 (2H, m, *ortho*-H of $PhSO_2H$), 7.62-7.56 (1H, m, *para*-H of $PhSO_2H$), 7.49-7.43 (2H, m, *meta*-H of $PhSO_2H$), 5.62 (1H, s, =CH), 4.97 (1H, d, J 3.0 Hz, H-1), 4.47-4.39 (2H, m, H-3 and H-4), 4.34 (1H, t, J 2.5 Hz, H-2), 4.20-4.16 (1H, m, H-5), 3.88-3.77 (2H, m, H-6 and H-6'), [1.42 (3H, s), and 1.30 (3H, s), 2 x Me of isopropylidene], 1.23-1.00 (30H, br m, $=CCMe_3$, Me and CH of TIPS), 0.86 (9H, s, $SiCMe_3$), [0.00 (3H, s), and -0.20 (3H, s), SiMe]; δ_C (100.6 MHz) 142.4 (C-2'), 138.0 (*ipso*-C of $PhSO_2H$), 133.6 (*para*-C of $PhSO_2H$), [129.7 and 128.7 (*ortho*-C and *meta*-C of $PhSO_2H$), 126.6 (C-1'), 109.8 (Me_2C of isopropylidene), 88.8 (C-1), [77.0, 72.5, 71.6 and 70.7 (C-2, C-3, C-4 and C-5)], 61.9 (C-6), 35.0 (C-3'), 28.4 (C-4'), [26.5 and 24.0 (2 x *Me* of isopropylidene)], 26.1 ($SiCMe_3$), 18.9 ($SiCMe_3$), [17.9 and 17.9 (*Me* of TIPS)], 11.8 (*C*H of TIPS), [-4.0 and -4.2 ($SiMe$)]; *m/z* (CI) 730 $[M+NH_4]^+$, 713 $[MH]^+$, 669, 616, 598, 571 $[MH-PhSO_2H]$, 513 $[MH-PhSO_2H-Me_2CO]^+$, 457, 413, 381 $[MH-PhSO_2H-Me_2CO-TBDMSOH]^+$, 371, 341 $[MH-PhSO_2H-$

$HOCHC(OTBDMS)CMe_3]^+$, 267 $[MH-PhSO_2H-TBDMSO-TIPSO]^+$, 257, 241, 231 $[HOCHC(OTBDMS)CMe_3+H]^+$, 215, 199, 173 $[(Me_2CH)_2SiOCHMe_2]^+$, 157, 132 [TBDMSOH]$^+$, 90 (Found: [MH]$^+$, 713.4038. $C_{36}H_{64}O_8SSi_2$ requires [MH]$^+$, 713.3939) (Found: C, 60.90; H, 8.81. $C_{36}H_{64}O_8Si_2S$ requires C, 60.63; H, 9.05%).

[1*S*,3*R*,4*S*,5*R*,6*S*,8*R*]-8-(2,2-Dimethyl-1-oxopropyl)-4,5-(isopropylidenedioxy)-3-(triiso-propylsilyloxymethyl)-2,7-dioxabicyclo[4.2.0]octane (34) and [1*S*,3*R*,4*S*,5*R*,6*S*,8*S*]-8-(2,2-dimethyl-1-oxopropyl)-4,5-(isopropylidenedioxy)-3-(triisopropylsilyloxymethyl)-2,7-dioxabicyclo[4.2.0]octane (35).

To a solution of **32** (25 mg, 35.1 μmol, 1 equiv) in toluene (810 μl) at rt was added ethylaluminium dichloride (70 μl of a 1M solution in hexanes, 70 μmol, 2 equiv). After 10 min, the reaction mixture was quenched with saturated aqueous $NaHCO_3$ (8 ml). The mixture was partitioned between EtOAc (60 ml) and saturated aqueous $NaHCO_3$ (10 ml). The aqueous phase was extracted with EtOAc (2 x 40 ml). The combined organic extracts were dried (Na_2SO_4) and concentrated. Chromatography (25%-50% ether–petrol) allowed the isolation of two epimeric bicyclic ketooxetanes **34** (10 mg, 65%) and **35** (2.5 mg, 16%), both as pale yellow oils; **34**: R_f 0.27 (50% ether–petrol); $[\alpha]_D^{28}$ -12.4 (*c* 0.15, $CHCl_3$); ν_{max} (film) 2935, 2870, 1713, 1467, 1395, 1251, 1212, 1151, 1116, 1068, 1005, 967, 918, 883, 774, 685 cm^{-1}; δ_H (500 MHz) 5.52 (1H, d, J 5.0 Hz, H-8), 4.97 (1H, t, J 5.0 Hz, H-1), 4.83 (1H, d, J 5.0 Hz, H-6), 4.46 (1H, d, J 8.0 Hz, H-4), 4.40 (1H, d, J 7.5 Hz, H-5), 4.31 (1H, dd, J 7.0, 6.0 Hz, H-3), [3.77 (1H, t, J 9.0 Hz), and 3.69 (1H, dd, J 9.0, 6.0 Hz), CH_2OTIPS], [1.39 (3H, s), and 1.32 (3H, s), 2 x Me of isopropylidene), 1.19 (9H, s, CMe_3), 1.12-1.04 (21H, br m, Me and CH of TIPS); δ_C (100.6 MHz) 210.9 (C=O), 108.7 (Me_2C of isopropylidene), 85.7 (C-8), 76.4 (C-1), [74.7, 71.2, 69.8 and 68.1 (C-3, C-4, C-5 and C-6)], 62.2 (CH_2OTIPS), 42.5 (CMe_3), [26.8 and 24.4 (2 x *Me* of isopropylidene)], 26.0 (CMe_3), 17.9 (*Me* of TIPS), 11.9 (*C*H of TIPS); *m/z* (CI) 474 [M+NH$_4$]$^+$, 457 [MH]$^+$, 413, 399 [MH-Me_2CO]$^+$, 279, 255, 234, 190, 174 [TIPSOH]$^+$, 146, 129 [M+NH$_4$-Me_2CO-TIPSO-OHCCOCMe$_3$]$^+$, 58 ([CMe_3H]$^+$ and [Me_2CO]$^+$) (Found: [MH]$^+$, 457.3017. $C_{24}H_{44}O_6Si$ requires [MH]$^+$, 457.2985); **35**: R_f 0.51 (50% ether–petrol); $[\alpha]_D^{28}$ +23.8 (*c* 0.08, $CHCl_3$); ν_{max} (film) 2964, 2923, 2851, 1713, 1554, 1539, 1503, 1451, 1256, 1097, 1067, 1010, 877, 799 cm^{-1}; δ_H (500 MHz) 5.53 (1H, d, J 3.0 Hz, H-8), 4.88 (1H, d, J 6.0 Hz, H-6), 4.64 (1H, dd, J 6.0, 3.0 Hz, H-1), 4.42 (1H, dd, J 8.0, 1.0 Hz, H-4), 4.39 (1H, dd, J 8.0, 1.0 Hz, H-3), 4.35 (1H, t, J 6.0 Hz, H-5), [3.99 (1H, dd, J 10.0, 6.0 Hz), and 3.95 (1H, dd, J 10.0, 6.5 Hz), CH_2OTIPS], [1.38 (3H, s), and 1.32 (3H, s), 2 x Me of isopropylidene], 1.18 (9H, s, CMe_3), 1.09-1.04 (21H, br m, Me and CH of TIPS); *m/z* (CI) 474 [M+NH$_4$]$^+$, 457 [MH]$^+$, 432, 413, 399 [MH-Me_2CO]$^+$, 391, 355, 313, 241, 225 [MH-Me_2CO-TIPSOH]$^+$, 199, 173 [$(Me_2CH)_2SiOCHMe_2$]$^+$, 148, 122, 85 [$COCMe_3$]$^+$, 58 ([CMe_3+H]$^+$ and [Me_2CO]$^+$) (Found: [MH]$^+$, 457.2944. $C_{24}H_{44}O_6Si$ requires [MH]$^+$, 457.2985).

[1*S*,3*R*,4*S*,5*R*,6*S*,8*S*]-8-(2,2-Dimethyl-1-oxopropyl)-3-(hydroxymethyl)-4,5-(isopropylidenedioxy)-2,7-dioxabicyclo[4.2.0]octane (36).

TBAF (45 μl of a 1.1M solution in THF, 49.5 μmol, 2.07 equiv) was added to a solution of **34** (11 mg, 23.9 μmol, 1 equiv) in THF (980 μl) at rt. After 50 min, the reaction mixture was partitioned between EtOAc (50 ml) and brine (15 ml). The aqueous phase was extracted with EtOAc (3 x 20 ml) and the combined organic extracts dried (Na_2SO_4). Chromatography (ether) gave **36** (6.5 mg, 89%) as a colourless solid; R_f 0.32 (ether); ν_{max} (film) 3497, 2954, 2921, 2851, 1713, 1472, 1451, 1369, 1262, 1210, 1159, 1123, 1062, 1005, 980, 959, 939, 897, 795 cm^{-1}; δ_H (500 MHz) 5.49 (1H, d, J 3.0 Hz, H-8), 4.91 (1H, d, J 6.0 Hz, H-6), 4.69 (1H, dd, J 6.0, 3.0 Hz, H-1), 4.42 (1H, dd, J 8.0, 1.5 Hz, H-3), 4.39-4.35 (2H, m, H-5 and H-4), [4.01 (1H, dd, J 12.0, 7.0 Hz), and 3.88 (1H, br d, J 11.5 Hz) CH_2OH], 2.18 (1H, br s, OH), [1.40 (3H, s), and 1.34 (3H, s), 2 x Me of isopropylidene], 1.19 (9H, s, CMe_3); δ_C (100.6 MHz) 210.7 (C=O), 109.2 (Me_2C of isopropylidene), 84.3 (C-8), 76.7 (C-1), [73.6, 72.2, 69.8 and 69.4 (C-3, C-4, C-5 and C-6)], 63.0 (CH_2OH), 43.2 (CMe_3), [26.2 and 24.2 (2 x *Me* of isopropylidene)], 26.1 (CMe_3); *m/z* (CI) 318 [M+NH$_4$]$^+$, 301 [MH]$^+$, 279, 243 [MH-Me_2CO]$^+$, 223, 175, 166, 146 [M+NH$_4$-Me_2CO-OHCCOCMe$_3$]$^+$, 136, 124, 110, 98, 94, 86 [$COCMe_3$+H]$^+$, 72, 58 ([CMe_3+H]$^+$ and [Me_2CO]$^+$), 52, 44 (Found: [MH]$^+$, 301.1651. $C_{15}H_{24}O_6$ requires [MH]$^+$, 301.1651).

1-Deoxy-1-(3,3-dimethyl-2-oxobutyl)-3,4-*O*-isopropylidene-6-*O*-triisopropylsilyl-α-D-galactopyranose (38).

To a solution of **34** (15.5 mg, 33.7 μmol, 1 equiv) in THF (2 ml) and methanol (1 ml) at -78°C was added samarium (II) iodide (675 μl of a 1M solution in THF, 67.5 μmol, 2 equiv) was added dropwise. After 1 h, additional samarium (II) (675 μl) was added dropwise. After 1 h 45 min, the reaction mixture was allowed to warm to -40°C and stirred for 2 h. Saturated aqueous ammonium chloride (5 ml) was added and the mixture warmed to rt and partitioned between EtOAc (40 ml) and saturated aqueous ammonium chloride (15 ml). The aqueous phase was extracted with EtOAc (3 x 20 ml). The combined organic extracts were washed with saturated aqueous sodium thiosulfate (25 ml), water (25 ml), brine (25 ml) and dried ($MgSO_4$). Concentration under reduced pressure and chromatography (25%-50% ether–petrol) gave **38** (10:5:2 mixture of hydroxyketone and two ketols by ^1H nmr; 13.5 mg, 88%) as a pale yellow oil; R_f 0.45 (50% ether–petrol); ν_{max} (film) 3480, 2936, 2868, 1702, 1466, 1375, 1251, 1212, 1153, 1106, 1065, 1004, 885, 798, 757, 680 cm^{-1}; δ_H (500 MHz) *inter alia* for major and minor ketols, 4.44 (1H, dd, J, 7.5, 1.5 Hz, H-3, open form), 4.38 (1H, ddd, J, 8.0, 4.0, 2.5 Hz, H-1), 4.31 (1H, dd, J, 7.5, 2.5 Hz, H-2, open form), 4.23 (1H, dd, J, 7.5, 1.5 Hz, H-4, open form), 4.04 (1H, coalesced ddd, J, 7.5, 5.5, 1.5 Hz, H-5, open form), 3.85-3.64 (6H, complex m, H-6 and H-6' of open form, major and minor ketols), [3.04 (1H, dd, J, 16.0, 8.0 Hz) and 2.75 (1H, dd, J, 16.0, 4.0 Hz), 2 x H-1', open form], [1.49 (3H, s) and 1.32 (3H, s), 2 x Me of isopropylidene, open form], [1.46 (3H, s) and 1.33 (3H, s), 2 x Me of isopropylidene, major ketol], [1.44 (3H, s) and 1.35 (3H, s), 2 x Me of isopropylidene, minor ketol], 1.25 (9H, s, minor ketol), 1.15 (9H, s, CMe_3 open form), 1.12 (9H, s, CMe_3 major ketol), 1.11-1.03 (63H, m, Me and CH of TIPS of open form and ketols); *m/z* (CI) 476 $[M+NH_4]^+$, 459 $[MH]^+$, 441 $[MH-H_2O]^+$, 415, 401 $[MH-Me_2CO]^+$, 391 $[M+NH_4-COCMe_3]$, 383 $[MH-Me_2CO-H_2O]^+$, 365, 339, 285 $[MH-TIPSOH]^+$, 234, 209 $[MH-Me_2CO-H_2O-TIPSOH]^+$, 185, 173 $[(Me_2CH)_2SiOCHMe_2]^+$, 167, 148, 58 ($[CMe_3+H]^+$ and $[Me_2CO]^+$) (Found: $[M+NH_4]^+$, 476.3433. $C_{24}H_{50}NO_6Si$ requires $[M+NH_4]^+$, 476.3407).

[2*R*,3*S*,4*S*,5*S*]-3,4-(isopropylidenedioxy)-8-oxo-2-(triisopropylsilyloxymethyl)-1,9-dioxaspiro[4.4]non-6-ene (39).

To a solution of **38** (11.5 mg, 24.6 μmol, 1 equiv) in CH_2Cl_2 (2 ml) at -10°C was added disodium hydrogenphosphate (9 mg, 616 μmol, 25 equiv) and CF_3CO_3H (240 μl of a 2.1M solution in CH_2Cl_2, 496.8 μmol, 20 equiv). After 1 h, the slurry was warmed to rt. After 17 h the reaction mixture was partitioned between CH_2Cl_2 (50 ml) and water (30 ml). The aqueous phase was extracted with CH_2Cl_2 (4 x 30 ml). The organic extracts were washed with saturated aqueous $Na_2S_2O_3$ (30 ml), saturated aqueous $NaHCO_3$ (30 ml) and dried (Na_2SO_4). Concentration under reduced pressure and chromatography (25%-50% ether–petrol) gave **39** (3 mg, 32%) as a colourless oil; R_f 0.54 (50% ether–petrol); ν_{max} (film) 2941, 2862, 1778, 1462, 1380, 1257, 1210, 1159, 1133, 1091, 1076, 1015, 995, 913, 877, 815, 790, 682 cm^{-1}; δ_H (500 MHz) 7.28 (1H, d, J 6.0 Hz, H-6), 6.25 (1H, d, J 5.5 Hz, H-7), 4.94 (1H, dd, J 6.0, 3.5 Hz, H-3), 4.74 (1H, d, J 5.5 Hz, H-4), 4.34 (1H, td, J 6.0, 3.5 Hz, H-2), [4.05 (1H, dd, J 10.5, 6.0 Hz) and 3.94 (1H, dd, J 10.5, 6.0 Hz) CH_2OTIPS], [1.50 (3H, s), and 1.32 (3H, s), 2 x Me of isopropylidene], 1.15-1.03 (21H, m, Me and CH of TIPS); *m/z* (CI) 416 $[M+NH_4]^+$, 399 $[MH]^+$, 391, 355 $[MH-CO_2]$, 260, 170, 153, 148, 123 $[MH-CO_2-TIPSOH-Me_2CO]^+$, 58 $[Me_2CO]^+$, 52, 44 $[CO_2]^+$ (Found: $[M+NH_4]^+$, 416.2510. $C_{20}H_{34}O_6Si$ requires $[M+NH_4]^+$, 416.2468).

X-Ray crystal data.

Crystal data for **36**: $C_{15}H_{24}O_6$, M = 300.3, monoclinic, space group $C2$ (no. 5), a = 25.396(6), b = 6.289(2), c = 10.787(3) Å, β = 99.38(2)°, V = 1699.7(8) Å^3, Z = 4, D_c = 1.174 g cm^{-3}, μ(Cu-Kα) = 7.50 cm^{-1}, $F(000)$ = 648, T = 293 K; clear plates, 0.60 x 0.25 x 0.03 mm, Siemens P4/PC diffractometer, ω-scans, 1473 independent reflections. The structure was solved by direct methods and the non-hydrogen atoms were refined anisotropically using full matrix least-squares based on F^2 to give R_1 = 0.048, wR_2 = 0.125 for 1229 independent observed reflections [$|F_o| > 4\sigma(|F_o|)$, $2\theta \leq 124°$] and 195 parameters.

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