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A Chemoenzymatic Synthesis of Differentially Protected D-Talose Derivatives

Martin G. Banwell,[A,B] *Alison J. Edwards*,[A] *John N. Lambert*,[C]
Xing Hua Ma[A] *and Keith G. Watson*[C]

[A] Research School of Chemistry, Institute of Advanced Studies, The Australian National University, Canberra, ACT 0200, Australia.
[B] Author to whom correspondence should be addressed (e-mail: mgb@rsc.anu.edu.au).
[C] Biota Chemistry Laboratory, Chemistry Department, Monash University, Clayton, Vic. 3168, Australia.

The synthesis of the D-talose derivatives (10)–(14) from the readily available and enantiomerically pure *cis*-1,2-dihydrocatechol (2) is described. The structures of compounds (7) and (13) have been established by single-crystal X-ray analyses.

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Introduction

D-Talose [D-*talo*-hexose, (1)], one of the rarer D-aldohexoses, as well as certain deoxy-derivatives, represent key residues associated with a range of biologically significant entities. The first reported occurrence of this hexose was by Hesse who, in 1902, described the isolation of a hydrate as a hydrolysis product of cocacitrin.[1] More recently, D-talose has been identified[2] as the central motif associated with the aminoglycoside hygromycin B (produced by *S. hygroscopicus*) which acts as a broad spectrum antibiotic and is used in veterinary medicine as an anthelmintic, especially against acarids.[3] 6-Deoxy-D-talose (D-talomethylose) is obtained by hydrolysis of the capsular polysaccharide of Gram-negative bacteria.[4] It has also been identified in an extracellular polysaccharide produced by the ruminal bacterium *Butyrivibrio fibrisolvens* X6C61[5] and in the serotype c polysaccharide antigen from *Actinbacillus actinomycetemcomitans*.[6] An *O*-acetylated homopolysaccharide of 6-deoxy-D-talose (6-deoxy-α-D-talan polymer) has recently been isolated from *Burkholderia* (*Pseudomonas*) *plantarii* DSM 65357 while 3-*O*-methyl-6-deoxy-D-talose has been identified in lipopolysaccharides of *Rhodopseudomonas palustris*.[8] D-Talose has found use as a bulking and/or browning agent in food preparation.[9] Further, since it also has the same natural taste as sucrose, D-talose can be used as a low-calorie sweetening agent.[9] The 'all-*cis*' arrangement of the non-anomeric hydroxy groups in the pyranose form of compound (1) has a number of useful implications in molecular recognition processes[10] and may be responsible for the capacity of this sugar to reduce molybdenum inhibition of the growth of the yeast *Saccharomyces cerevisiae*.[11]

Given the foregoing it is not surprising that some effort has been directed to the preparation of the title compound and various derivatives. The most common and perhaps obvious route to D-talose has been by C2 epimerization of the more abundant D-galactose, a conversion that can be achieved directly through the agency of various molybdenum species,[12] or by multi-step sequences.[13] A practical and recently reported synthesis of D-talose involves a stannylene acetal-mediated epimerization process.[14] The dihydroxylation of D-galactal provides another route to target (1).[15] Paulsen has also reported[16] a simple synthesis of D-talose by acetoxonium rearrangement of D-galactose. In related work, 1,6-anhydro-β-D-talopyranose has been prepared from the C2 epimeric 1,6-anhydro-β-D-galactopyranose by an oxidation/reduction sequence.[17]

A concise syntheses of D-talose has recently been developed by O'Doherty[18] and involves the asymmetric dihydroxylation of furfural.* The synthesis of differentially protected talose derivatives has also been the subject of some effort with the work just described providing access to such species on route to the final target, i.e. (1). Not surprisingly, the selective manipulation of D-talose itself has also provided methods for accessing useful derivatives,[21] while regimes involving manipulations (including inversion at C2) of a

* The concise synthesis of L-talose from non-carbohydrate sources was achieved using asymmetric epoxidation methodology (see reference 19 and references therein). More recent syntheses have been reported by Vogel, Marshall, and Ogasawara (see reference 20).

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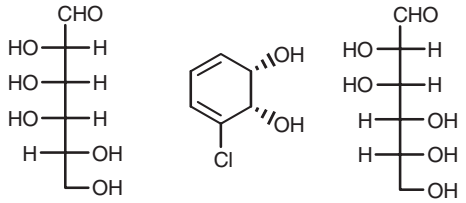
galactose derivative have also been reported.[22] Chain-extension approaches employing the Henry reaction of D-lyxose and its derivatives have provided efficient syntheses of various amino-deoxy-D-talose derivatives.[23]



(1) (2) (3)

For sometime now, we have been engaged in a program directed toward the synthesis of novel and/or rare carbohydrates from non-carbohydrate precursors. Two types of precursors have been exploited in this work, namely ring-fused *gem*-dibromocyclopropanes[24] and 3-halo-*cis*-1,2-dihydrocatechols (2).[25]* Both types of compound are available in either enantiomeric form, the first by resolution of the racemate, and the second through whole-cell biotransformation of the corresponding aromatic. A key chemical step in the elaboration of each of these precursors to the target carbohydrate is the ozonolytic cleavage of the appropriate halocycloalkene followed by reductive workup, a strategy pioneered by Hudlicky and coworkers in their seminal studies on the conversion of 3-halo-*cis*-*1,2*-dihydrocatechols (2) into various aldohexoses, particularly derivatives of D-mannose (3).[26,27]† As part of our efforts in this general area we now report on the preparation of a range of previously unreported and differentially protected D-talose derivatives from compound (2) (X = Cl). The relative ease of access to such compounds afforded by the present work should assist in general investigations into the chemical and biological properties of this rare type of D-aldohexose. Further, since ^{2}H, ^{13}C and/or ^{17}O-labelled *cis*-1,2-dihydrocatechols are rather easily produced, the correspondingly labelled D-talose derivatives will also be readily available by the pathway described here.‡

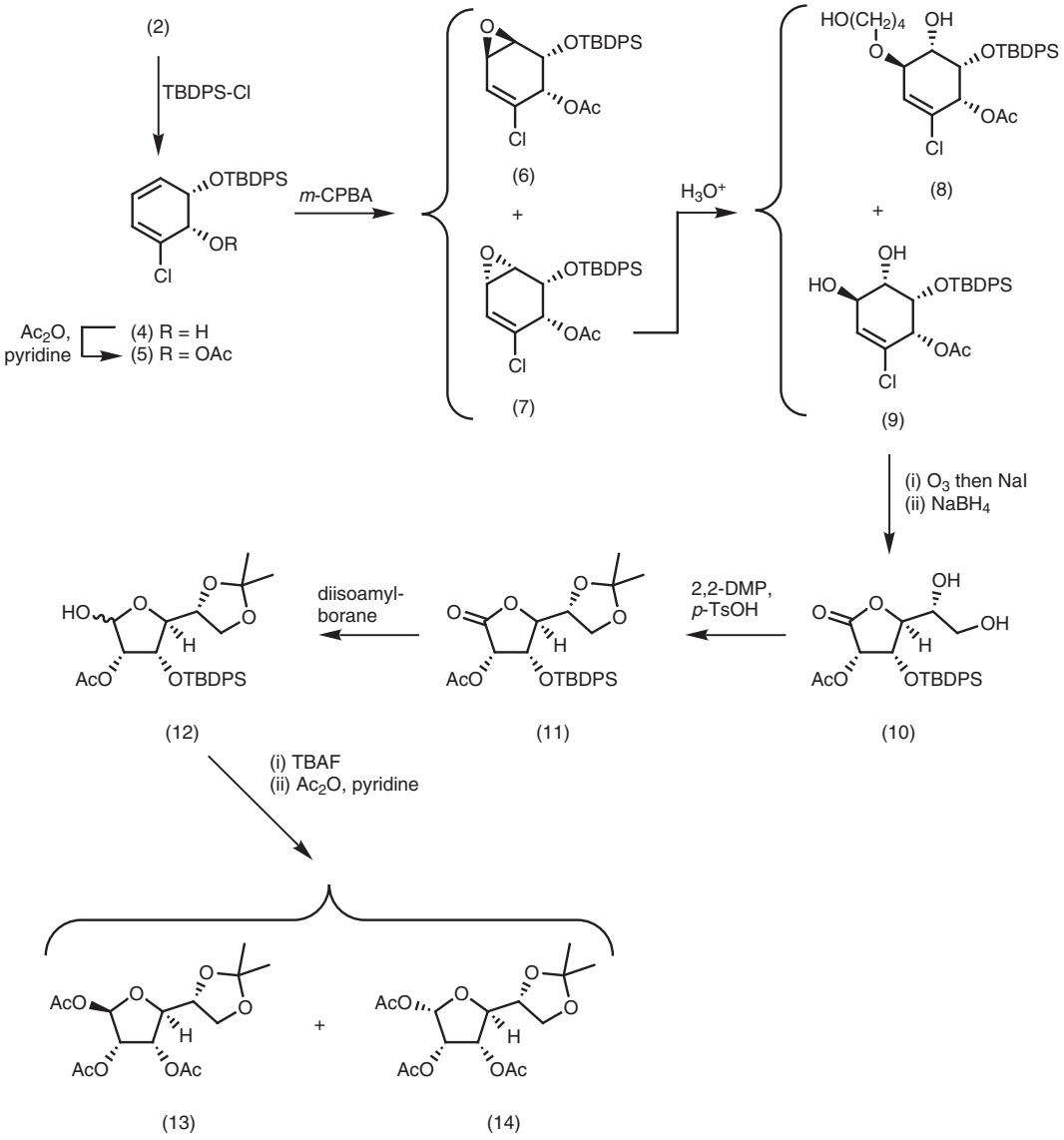
Results and Discussion

The elaboration of the *cis*-1,2-dihydrocatechol (2) into various D-talose derivatives is shown in Scheme 1. In keeping with earlier work[25*d*] on its iodo-congener, chlorodiol (2) was selectively mono-protected at the less sterically hindered hydroxy group using *tert*-butyldiphenylsilyl chloride (TBDPS-Cl) so as to give the mono-ol (4) together with small amounts of its regio-isomer. This unstable mixture was immediately *O*-acetylated under standard conditions to afford the differentially protected *cis*-1,2-dihydrocatechol (5) [78% from (2)] which could be readily separated from its co-produced regioisomer [16% from (2)]. Since, like precursor (4), compound (5) was particularly prone to elimination processes (leading to aromatic products) it was immediately subject to the next step of the reaction sequence, namely selective epoxidation of the non-chlorinated double-bond using *m*-chloroperbenzoic acid (*m*-CPBA). In this manner, the diastereoisomeric and chromatographically separable epoxides (6) (58%) and (7) (18%) were obtained, with the predominance of the former product being determined by the steric demands of the TBDPS and (to a lesser extent) acetyl moieties that direct epoxidation to the less congested β-face of the non-chlorinated double-bond with compound (5). The appearance of three additional signals [relative to the 18 seen in isomer (6)] in the low-field region of the ^{13}C NMR spectrum of the minor isomer (7) is attributed to the restricted rotation of the aromatic rings associated with the TBDPS group in this highly congested 'all-*cis*' substituted cyclohexene. Confirmation of the structure of products (6) and (7) follows from a single-crystal X-ray analysis of the latter (see Fig. 1, Tables 1, 2 and Experimental Section).

In keeping with earlier observations,[28] reaction of epoxide (7) with aqueous acid results in the opening of the three-membered ring by a pathway involving nucleophilic attack at the allylic carbon, so as to form the required conduritol derivative (9). However, the choice of acid catalyst for this conversion was critical. Thus, when HCl in aqueous tetrahydrofuran (THF) was employed only minor amounts (12%) of the required compound, (9), were obtained, with the corresponding chlorohydrin (see Experimental) being the predominant product (55%). In contrast, when phosphoric acid was employed as catalyst then target (9) predominated (71%), although significant amounts (20%) of a product, (8), incorporating the elements of THF, were obtained. Compound (9) embodies the necessary stereochemical array of hydroxy residues for elaboration to D-talose derivatives. To this end, the alkenyl halide residue within substrate (9) was subjected to reaction with ozone at –78°C and the intermediate hydroperoxy species[25*e*] reduced by workup with sodium borohydride. In this way the D-talonic acid γ-lactone (10) was obtained, albeit in a modest yield of 54%. Compound (10) was readily converted by standard methods into the corresponding and more easily handled acetonide (11) (82%), which was subject to full analytical and spectroscopic characterization.

The elaboration of compound (11) to protected forms of D-talose was straightforward and involved reduction of the lactone carbonyl. This could be achieved using diisoamylborane[29] and in this manner lactol (12) (83%) was obtained as a ca. 2 : 3 mixture of the α- and β-anomers. Reaction of this mixture with tetra-*n*-butylammonium fluoride (TBAF) resulted in removal of the TBDPS group and the ensuing material was immediately subjected to exhaustive acetylation under standard conditions. The resulting triacetates (13) (40%) and (14) (47%) could be

* For an excellent overview on the production and synthetic utility of *cis*-1,2-dihydrocatechols see reference 26.
† For a very useful review on the synthesis of monosaccharides from non-carbohydrate sources see reference 27*b*.
‡ For useful discussions on the value of carbohydrates incorporating such labels see reference 25*d*.



Scheme 1

separated by flash chromatography on silica, and the structure of the former was confirmed by single-crystal X-ray analysis (see Fig. 2, Tables 3, 4 and Experimental Section).

Efforts were made to chemically correlate triacetates (13) and (14) with known derivatives of D-talose. Thus, a mixture of these compounds was subjected to reaction with aqueous trifluoroacetic acid so as to effect global deprotection and thereby generate D-talose itself (Scheme 2). The crude product obtained by this means was then exhaustively acetylated with acetic anhydride in the presence of pyridine. Thin-layer chromatography (TLC) analysis of the resulting material revealed the presence of at least three fractions with two able to be isolated by flash chromatographic techniques. One fraction (the less mobile) contained a ca. 2 : 1 mixture of two penta-*O*-acetates (53% combined yield), whilst the other provided a single compound (22%) of the same composition. Two of these three compounds were presumed to correspond to the α-forms of penta-*O*-acetyl-D-talopyranose, (15) and (16), respectively, while the remaining material was thought to be the isomeric β-penta-*O*-acetyl-D-talofuranose based on, amongst other things, the ^{1}H nuclear magnetic resonance (NMR) chemical shift (δ 6.42) and coupling (d, *J* 4.5 Hz) observed for the anomeric proton in this material. Support for these conclusions came from the preparation of authentic samples of compounds (15) and (16) from D-talose itself. Thus, such studies established that the two-component fraction contained a ca. 2 : 1 mixture of the penta-*O*-acetyl-β-D-talofuranose and compound (15) whilst the more mobile fraction contained pure samples of compound (16).

Conclusions

The concise and chemoenzymatic nature of the routes to the D-talose derivatives described above offer a rather flexible

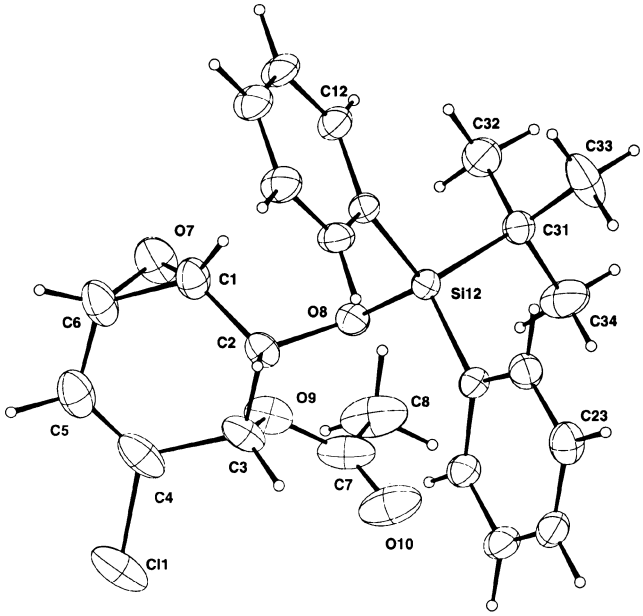


Fig. 1. ADEP (with 50% probability ellipsoids) of compound (7) derived from X-ray crystallographic data.

entry into this rare class of carbohydrate that should facilitate further studies in the appropriate areas of glycobiology and molecular recognition.

Experimental

Melting points were recorded with a Kofler hot stage apparatus and are uncorrected. Proton (^{1}H) and carbon (^{13}C) NMR spectra were recorded with a Varian Unity 300 or Varian Gemini 300 spectrometer operating at 300 MHz for proton and 75 MHz for carbon. All such spectra were recorded in deuteriochloroform ($CDCl_3$) solution at 22°C. The degree of protonation of each carbon atom observed in the ^{13}C NMR spectra was determined by attached proton test (APT) experiments. Infrared (IR) spectra (ν_{max}) were recorded with either a Perkin–Elmer 983G infrared spectrophotometer or a Perkin–Elmer 1800 Series FTIR instrument. Samples were analysed either as thin films on sodium chloride plates (for liquids) or as potassium bromide disks (for solids). Low-resolution electron-impact mass spectra (LREI-MS) (*m/z*) were recorded at 70 eV on either a VG Micromass 7070F mass spectrometer or a JEOL AX-505H mass spectrometer. High-resolution mass spectra were recorded with a VG Micromass 7070F instrument. Optical rotations were measured at 20°C with a Perkin–Elmer 241 polarimeter at the sodium D-line (589 nm) using spectroscopic grade chloroform (Merck) and at the concentration (*c*) (g/100 mL) indicated. The measurements were carried out in a cell with a path length of 1 dm. Specific rotations ($[\alpha]_D^{20}$) were calculated using the equation $[\alpha]_D = (100.\alpha)/(c.1)$ and are given in units of 10^{-1}.deg.cm^2.g^{-1}. THF was distilled, under nitrogen, from sodium benzophenone ketyl. Dichloromethane was distilled from calcium hydride and methanol from magnesium methoxide.

Table 1. Bond lengths (Å) for (7), $C_{24}H_{27}ClO_4Si$

Atom	Atom	Distance	Atom	Atom	Distance
Cl1	C4	1.733(6)	C7	C8	1.526(9)
Si12	O8	1.651(3)	C11	C12	1.398(6)
Si12	C11	1.881(4)	C11	C16	1.386(6)
Si12	C21	1.881(4)	C12	C13	1.381(6)
Si12	C31	1.889(4)	C13	C14	1.401(7)
O7	C1	1.416(6)	C14	C15	1.357(7)
O7	C6	1.414(7)	C15	C16	1.391(6)
O8	C2	1.435(5)	C21	C22	1.382(6)
O9	C3	1.455(6)	C21	C26	1.398(6)
O9	C7	1.333(9)	C22	C23	1.395(7)
O10	C7	1.182(8)	C23	C24	1.374(8)
C1	C2	1.476(7)	C24	C25	1.355(7)
C1	C6	1.448(7)	C25	C26	1.381(7)
C2	C3	1.539(6)	C31	C32	1.534(7)
C3	C4	1.532(8)	C31	C33	1.536(8)
C4	C5	1.346(9)	C31	C34	1.516(7)
C5	C6	1.404(9)			

Table 2. Bond angles (degrees) for (7), $C_{24}H_{27}ClO_4Si$

Atom	Atom	Atom	Angle	Atom	Atom	Atom	Angle
O8	Si12	C11	108.17(16)	O9	C7	O10	126.2(6)
O8	Si12	C21	110.33(17)	O9	C7	C8	111.2(6)
C11	Si12	C21	109.43(18)	O10	C7	C8	122.6(8)
O8	Si12	C31	104.46(19)	Si12	C11	C12	120.1(3)
C11	Si12	C31	114.93(19)	Si12	C11	C16	122.0(3)
C21	Si12	C31	109.38(19)	C12	C11	C16	117.4(4)
C1	O7	C6	61.5(3)	C11	C12	C13	121.3(4)
Si12	O8	C2	123.6(2)	C12	C13	C14	119.7(4)
C3	O9	C7	115.4(5)	C13	C14	C15	119.7(4)
O7	C1	C2	118.8(5)	C14	C15	C16	120.4(5)
O7	C1	C6	59.2(3)	C11	C16	C15	121.5(4)
C2	C1	C6	119.5(5)	Si12	C21	C22	121.5(3)
O8	C2	C1	113.1(4)	Si12	C21	C26	121.5(3)
O8	C2	C3	107.9(4)	C22	C21	C26	116.9(4)
C1	C2	C3	114.3(4)	C21	C22	C23	121.9(5)
O9	C3	C2	108.3(3)	C22	C23	C24	119.3(5)
O9	C3	C4	106.2(4)	C23	C24	C25	120.0(4)
C2	C3	C4	110.6(5)	C24	C25	C26	120.9(5)
Cl1	C4	C3	112.4(6)	C21	C26	C25	121.0(5)
Cl1	C4	C5	124.3(5)	Si12	C31	C32	112.4(3)
C3	C4	C5	123.3(5)	Si12	C31	C33	109.7(4)
C4	C5	C6	120.4(5)	C32	C31	C33	108.2(5)
O7	C6	C1	59.3(3)	Si12	C31	C34	108.3(3)
O7	C6	C5	118.7(6)	C32	C31	C34	106.1(5)
C1	C6	C5	120.2(6)	C33	C31	C34	112.3(6)

*(1*S*,6*S*)-2-Chloro-6-{[(1,1-dimethylethyl)diphenylsilyl]oxy}-2,4-cyclohexadien-1-ol (4) and (1*S*,2*S*)-3-Chloro-2-{[(1,1-dimethylethyl)diphenylsilyl]oxy}-3,5-cyclohexadien-1-ol*

A magnetically stirred solution of compound (2) (17.0 g, 116.0 mmol) and imidazole (21.0 g, 308.5 mmol) in dichloromethane (100 mL) maintained at 18°C under a nitrogen atmosphere was treated, dropwise over a period of 0.5 h, with TBDPS-Cl (Aldrich, 32.5 mL, 124.2 mmol). The ensuing mixture was stirred for a further 1.0 h then diluted with water (500 mL) and extracted with dichloromethane (3 × 150 mL). The combined organic phases were washed with brine (2 × 150 mL) then dried ($MgSO_4$), filtered and concentrated under reduced pressure to give a ca. 4 : 1 mixture (as judged by ^{1}H NMR analysis) of the *title compounds* as a clear colourless oil. Since this material was exceptionally prone to decomposition it was used immediately in the next step of the reaction sequence.

*(1*S*,6*S*)-2-Chloro-6-{[(1,1-dimethylethyl)diphenylsilyl]oxy}-2,4-cyclohexadien-1-ol Acetate (5) and (1*S*,6*S*)-5-Chloro-6-{[(1,1-dimethylethyl)diphenylsilyl]oxy}-2,4-cyclohexadien-1-ol Acetate*

The 4 : 1 mixture of compound (4) and its regio-isomer (44.65 g, 116.0 mmol), obtained as described immediately above, was dissolved in pyridine (30 mL) and the resulting solution treated with acetic anhydride (22 mL, 233.2 mmol) and 4-dimethylaminopyridine (DMAP) (1.40 g, 11.6 mmol) while being stirred magnetically and

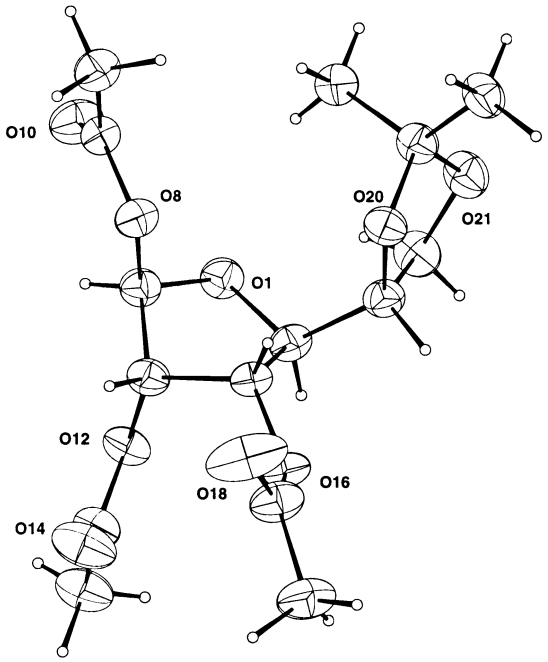


Fig. 2. ADEP (with 50% probability ellipsoids) of compound (13) derived from X-ray crystallographic data.

Table 3. Bond lengths (Å) for (13), $C_{15}H_{22}O_9$

Atom	Atom	Distance	Atom	Atom	Distance
O1	C2	1.415(4)	O21	C7	1.430(4)
O1	C5	1.451(4)	O21	C22	1.423(4)
O8	C2	1.439(4)	C2	C3	1.503(4)
O8	C9	1.373(4)	C3	C4	1.518(5)
O10	C9	1.195(4)	C4	C5	1.519(5)
O12	C3	1.447(4)	C5	C6	1.515(4)
O12	C13	1.343(4)	C6	C7	1.525(5)
O14	C13	1.193(5)	C9	C11	1.491(5)
O16	C4	1.442(4)	C13	C15	1.495(5)
O16	C17	1.356(4)	C17	C19	1.492(5)
O18	C17	1.191(5)	C22	C23	1.516(4)
O20	C6	1.428(4)	C22	C24	1.502(5)
O20	C22	1.449(4)			

Table 4. Bond angles (degrees) for (13), $C_{15}H_{22}O_9$

Atom	Atom	Atom	Angle	Atom	Atom	Atom	Angle
C2	O1	C5	110.0(2)	O20	C6	C7	104.3(2)
C2	O8	C9	115.4(3)	C5	C6	C7	114.5(3)
C3	O12	C13	118.2(3)	O21	C7	C6	103.5(3)
C4	O16	C17	115.8(3)	O8	C9	O10	122.5(3)
C6	O20	C22	108.8(2)	O8	C9	C11	111.0(3)
C7	O21	C22	105.7(3)	O10	C9	C11	126.5(3)
O1	C2	O8	110.2(2)	O12	C13	O14	123.7(4)
O1	C2	C3	106.2(3)	O12	C13	C15	109.7(3)
O8	C2	C3	106.3(3)	O14	C13	C15	126.6(3)
O12	C3	C2	105.1(3)	O16	C17	O18	123.4(3)
O12	C3	C4	108.7(3)	O16	C17	C19	111.9(3)
C2	C3	C4	100.5(3)	O18	C17	C19	124.7(4)
O16	C4	C3	113.7(2)	O20	C22	O21	104.5(3)
O16	C4	C5	109.2(3)	O20	C22	C23	110.0(3)
C3	C4	C5	101.9(3)	O21	C22	C23	111.5(3)
O1	C5	C4	103.9(3)	O20	C22	C24	108.7(3)
O1	C5	C6	110.7(2)	O21	C22	C24	109.1(3)
C4	C5	C6	115.5(3)	C23	C22	C24	112.7(3)
O20	C6	C5	112.0(3)				

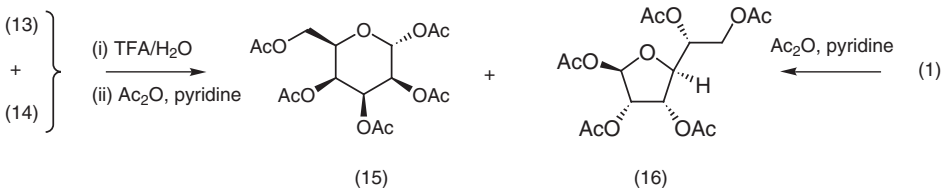
maintained at 18°C under a nitrogen atmosphere. After 2 h the reaction mixture was concentrated under reduced pressure and the residue subjected to flash chromatography (silica gel, gradient elution using 1.25 to 1.5% v/v hexane/ethyl acetate) thereby affording two fractions, A and B.

Concentration of fraction A (R_F 0.5) afforded *compound (5)* (38.54 g, 78%) as a clear colourless oil, $[\alpha]_D$ –107.4 (*c*, 1.75) (Found: $M^{+\bullet}$, 426.1421. $C_{24}H_{27}{}^{35}ClO_3Si$ requires $M^{+\bullet}$, 426.1418). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.75–7.70, complex m, 4H; 7.50–7.38, complex m, 6H; 6.17, d, *J* 5.9 Hz, 1H; 5.75, ddd, *J* 9.0, 5.9 and 2.4 Hz, 1H; 5.61, dd, *J* 9.0 and 2.4 Hz, 1H; 5.56, d, *J* 6.6 Hz, 1H; 4.72, dt, *J* 6.6 and 2.4 Hz, 1H; 2.15, s, 3H; 1.09, s, 9H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 170.2, 136.0, 135.9, 133.7, 132.8, 130.7, 130.4, 130.1, 130.1, 127.9(1), 127.8(7), 125.3, 121.9, 71.1, 70.5, 26.9, 21.0, 19.2. ν_{max} (KBr) 2958, 2932, 2858, 1747, 1427, 1226, 112, 868, 821, 702 cm^{-1}. EI MS *m/z* (70 eV) 428 and 426 ($M^{+\bullet}$, both < 1%), 384 (< 1) and 386 (< 1), 368 (< 1) and 366 (2), 84 (100).

Concentration of fraction B (R_F 0.4) afforded *(1*S*,6*S*)-5-chloro-6-{[(1,1-dimethylethyl)diphenylsilyl]oxy}-2,4-cyclohexadien-1-ol acetate* (7.90 g, 16%) as a clear colourless oil, $[\alpha]_D$ +5.3 (*c*, 1.03) (Found: $M^{+\bullet}$, 426.1417. $C_{24}H_{27}{}^{35}ClO_3Si$ requires $M^{+\bullet}$, 426.1418). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.77–7.70, complex m, 4H; 7.45–7.37, complex m, 6H; 6.18, d, *J* 5.2 Hz, 1H; 5.95, ddd, *J* 9.7, 5.7 and 3.1 Hz, 1H; 5.81, ddm, *J* 9.7 and 3.1 Hz, 1H; 5.28, m, 1H; 4.26, d, *J* 5.7 Hz, 1H; 1.77, s, 3H; 1.08, s, 9H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 170.2, 136.2, 136.2, 135.3, 133.6, 132.7, 130.0, 129.8, 127.7, 127.5, 126.1, 124.0, 123.3, 72.5, 71.4, 26.9, 20.9, 19.9. ν_{max} (KBr) 2931, 2857, 1738, 1427, 1369, 1233, 1112, 1049, 702, 505 cm^{-1}. EI-MS *m/z* (70 eV) 428 and 426 ($M^{+\bullet}$, both < 1%), 384 (< 1) and 386 (< 1), 311 (33) and 309 (63), 293 (45) and 291 (80), 241 (87), 199 (100).

*[1*S*-(1α,2α,3α,6α)]-4-Chloro-2-{[(1,1-dimethylethyl)diphenylsilyl]-oxy}-7-oxabicylco[4.1.0]hept-4-en-3-ol Acetate (6) and [1*R*-(1α,2β,-3β,6α)]-4-Chloro-2-{[(1,1-dimethylethyl)diphenylsilyl]oxy}-7-oxa-bicyclo[4.1.0]hept-4-en-3-ol Acetate (7)*

A magnetically stirred solution of compound (5) (2.08 g, 4.87 mmol) in dichloromethane (25 mL) maintained at 0–5°C (ice bath) under a nitrogen atmosphere was treated, in one portion, with *m*-CPBA (technical grade, Aldrich, ca. 70% peracid, 1.26 g, 5.11 mmol peracid).



Scheme 2

Stirring was continued overnight during which time the ice bath and reaction mixture were allowed to warm to ca. 18°C. The resulting mixture was then washed with sodium metabisulfite (3 × 60 mL of an 15% w/v aqueous solution), sodium bicarbonate (1 × 60 mL of a saturated aqueous solution) and water (1 × 60 mL) before being dried ($MgSO_4$), filtered and concentrated under reduced pressure. The ensuing light-yellow oil was subjected to flash chromatography (silica gel, gradient elution using 2–3% v/v ethyl acetate/hexane) thereby affording two fractions, A and B.

Concentration of fraction A (R_F 0.5) afforded *compound (6)* (1.25 g, 58%) as a clear colourless oil, $[\alpha]_D$ +34.6 (*c*, 1.1) (Found: $M^{+\bullet}$, 442.1363. $C_{24}H_{27}{}^{35}ClO_4Si$ requires $M^{+\bullet}$, 442.1367). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.75–7.65, complex m, 4H; 7.50–7.40, complex m, 6H; 6.30, dd, *J* 4.1 and 2.2 Hz, 1H; 5.38, m 1H; 4.55, m, 1H; 3.41, m 1H; 3.35, m, 1H; 1.94, s, 3H; 1.11, s, 9H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 170.1, 136.5, 136.3, 135.9, 133.6, 133.3, 130.7, 130.5, 128.4, 128.1, 122.8, 69.4, 68.4, 53.7, 48.6, 27.3, 21.0, 20.0; ν_{max} (KBr) 2957, 2858, 2932, 1751, 1369, 1225, 1112, 703, 506 cm^{-1}. EI-MS *m/z* (70 eV) 444 and 442 ($M^{+\bullet}$, both < 1%), 241 (100), 199 (80).

Concentration of fraction B (R_F 0.3) afforded *compound (7)* (0.38 g, 18%) as a white crystalline solid, melting point (m.p.) 156–158°C, $[\alpha]_D$ –156.9 (*c*, 1.1) (Found: C, 64.8; H, 6.1; Cl, 7.9%; $[M-C_4H_9^{\bullet}]^+$, 385.0663. $C_{24}H_{27}{}^{35}ClO_4Si$ requires C, 65.1, H, 6.1, Cl, 8.0%; $[M-C_4H_9^{\bullet}]^+$, 385.0663). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.81, m, 2H; 7.77, m, 2H; 7.50–7.37, complex m, 6H; 6.25, d, *J* 4.4 Hz, 1H; 5.86, dd, *J* 5.7 and 1.9 Hz, 1H; 4.31, dd, *J* 5.7 and 1.2 Hz, 1H; 3.17, t, *J* 4.2 Hz, 1H; 3.03, m, 1H; 2.24, s, 3H; 1.09, s, 9H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 170.7, 135.9, 135.8, 134.9, 134.7, 133.3, 132.1, 130.3, 130.2, 129.6, 128.1, 128.0, 127.7, 126.7, 70.6, 70.0, 54.9, 47.8, 26.7, 21.2, 19.2. ν_{max} (KBr) 2931, 2858, 1743, 1427, 1370, 1233, 1112, 706, 507 cm^{-1}. EI-MS *m/z* (70 eV) 444 and 442 ($M^{+\bullet}$, both < 1%), 241 (53), 199 (100).

(1S,2S,3S,6R)-4-Chloro-2-{[(1,1-dimethylethyl)diphenylsilyl]oxy}-6-(4′-hydroxybutoxy)-4-cyclohexene-1,3-diol 3-Acetate (8) and (1R,2S,-3S,4S)-5-Chloro-3-{[(1,1-dimethylethyl)diphenylsilyl]oxy}-5-cyclohexene-1,2,4-triol 4-Acetate (9)

A magnetically stirred solution of epoxide (7) (1.08 g, 2.44 mmol) in THF (15 mL) and water (5 mL) was treated with phosphoric acid (0.5 mL of a 93% aqueous solution, M & B) whilst being maintained under a nitrogen atmosphere. The resulting mixture was stirred at 18°C for 40 h then concentrated under reduced pressure and the residue partitioned between ethyl acetate (30 mL) and brine (30 mL). The separated aqueous phase was extracted with ethyl acetate (3 × 30 mL) and the combined organic phases were then dried ($MgSO_4$), filtered and concentrated under reduced pressure. The resulting light-yellow oil was subject to flash chromatography (silica gel, gradient elution using 30 to 50% v/v ethyl acetate/hexane) thereby affording two fractions, A and B.

Concentration of fraction A (R_F 0.5 in 8 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) then afforded *compound (8)* (265 mg, 20%) as a light-yellow oil, $[\alpha]_D$ –87.2 (*c*, 1.0) (Found: $[M-C_4H_9^{\bullet}]^+$, 475.1345. $C_{28}H_{37}{}^{35}ClO_6Si$ requires $[M-C_4H_9^{\bullet}]^+$, 475.1344). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.75–7.70, complex m, 4H; 7.45–7.38, complex m, 6H; 6.07, br d, *J* 4.0 Hz, 1H; 5.61, br d, *J* 4.0 Hz, 1H; 4.28, m, 1H; 4.03, br, t, *J* 4.0 Hz, 1H; 3.64–3.54, complex m, 3H; 3.41, m, 1H; 3.25, m, 1H; 2.43, s, 2H; 1.88, s, 3H; 1.52, m, 4H; 1.08, s, 9H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 169.8, 136.1, 136.0, 132.9, 132.8, 131.7, 130.2, 129.9, 127.9, 127.7, 126.5, 77.4, 70.8, 70.5, 69.9, 62.5, 29.5, 26.9, 26.5, 20.7, 19.5 (one signal obscured or overlapping). ν_{max} (KBr) 3429, 2932, 2858, 1747, 1370, 1228, 1112, 1045, 740, 704, 507 cm^{-1}. EI-MS *m/z* (70 eV) 477 (1%) and 475 (2) $[M-C_4H_9^{\bullet}]^+$, 241 (78), 199 (100), 181 (52), 101 (90).

Concentration of fraction B (R_F 0.7 in 8 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) then afforded *compound (9)* (795 mg, 71%) as a clear, colourless oil, $[\alpha]_D$ –59.1 (*c*, 1.0) (Found: $[M-C_4H_9^{\bullet}]^+$, 403.0763. $C_{24}H_{29}{}^{35}ClO_5Si$ requires $[M-C_4H_9^{\bullet}]^+$, 403.0769). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.75–7.65, complex m, 4H; 7.50–7.38, complex m, 6H; 6.02, m 1H; 5.48, m, 1H; 4.50, m, 1H; 4.30, m, 1H; 3.51, dd, *J* 6.5 and 1.6 Hz, 1H; 2.74, s, 2H; 1.69, s, 3H; 1.08, s, 9H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 170.0, 136.2, 136.1, 132.9, 132.5, 130.9, 130.3, 129.8, 128.5, 128.0, 127.5, 74.4, 72.3, 70.8, 70.4, 27.0, 20.5, 19.8. ν_{max} (KBr) 3429, 2931, 2857, 1747, 1227, 1159, 1112, 1040, 738, 703, 508 cm^{-1}. EI-MS *m/z* (70 eV) 405 (2%) and 403 (7) $[M-C_4H_9^{\bullet}]^+$, 267 (20) and 265 (50), 241 (60), 199 (100), 181 (60).

(1S,2S,3S,6R)-4,6-Dichloro-2-{[(1,1-dimethylethyl)diphenylsilyl]-oxy}-4-cyclohexene-1,3-diol 3-Acetate and (1R,2S,3S,4S)-5-Chloro-3-{[(1,1-dimethylethyl)diphenylsilyl]oxy}-5-cyclohexene-1,2,4-triol 4-Acetate (9)

A solution of compound (7) (457 mg, 1.03 mmol) and water (2 mL) in THF (6 mL) was treated with HCl (1 mL of a 1 M aqueous solution) and the ensuing mixture allowed to stand at 18°C for 24 h and then treated with NaOH (2.5 mL of a 1 M aqueous solution) and dichloromethane (10 mL). The separated aqueous phase was extracted with dichloromethane (3 × 8 mL) and the combined organic phases were washed with brine (1 × 10 mL) then dried ($MgSO_4$), filtered and concentrated under reduced pressure to give a light-yellow oil. Subjection of this material to flash chromatography (silica gel, gradient elution using 3 to 30% v/v ethyl acetate/hexane) afforded three fractions, A–C.

Concentration of fraction A (R_F 0.6 in 1 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) afforded starting material (7) (68 mg, 15% recovery), identical, in all respects, with authentic material.

Concentration of fraction B (R_F 0.5 in 1 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) afforded *(1S,2S,3S,6R)-4,6-dichloro-2-{[(1,1-dimethylethyl)diphenylsilyl]oxy}-4-cyclohexene-1,3-diol 3-acetate* (231 mg, 47 at 85% conversion) as a white crystalline solid, m.p. 135.5–137°C, $[\alpha]_D$ –131.4 (*c*, 0.9) (Found: C, 59.6; H, 5.8; Cl, 14.7%; $[M-C_4H_9^{\bullet}]^+$, 421.0427. $C_{24}H_{28}{}^{35}Cl_2O_4Si$ requires C, 60.1; H, 5.9; Cl, 14.8%; $[M-C_4H_9^{\bullet}]^+$, 421.0430). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.75–7.65, complex m, 4H; 7.50–7.38, complex m, 6H; 6.07, d, *J* 4.4 Hz, 1H; 5.70, d, *J* 4.4 Hz, 1H; 4.56, br t, *J* 4.4 Hz, 1H; 4.37, m, 1H; 3.72, m, 1H; 2.70, br s, 1H; 1.98, s, 3H; 1.09, s, 9H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 169.5, 136.1, 136.0, 132.6, 132.5, 130.4, 130.2, 128.1, 127.9, 126.8, 73.4, 70.2, 69.2, 56.6, 27.0, 20.7, 19.5 (one signal obscured or overlapping). ν_{max} (KBr) 2932, 2858, 1751, 1226, 1113, 1048, 736, 702, 508 cm^{-1}. EI-MS *m/z* (70 eV) 425 (< 1%), 423 (2) and 421 (4) $[M-C_4H_9^{\bullet}]^+$, 250 (35) and 248 (78), 241 (88), 199 (100).

Concentration of fraction C (R_F 0.7 in 8 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) afforded *diol (9)* (50 mg, 10 at 85% conversion), identical, in all respects, with material obtained as described immediately above.

3-O-[(1,1-Dimethylethyl)diphenylsilyl]-D-talonic acid γ-Lactone 2-Acetate (10)

A magnetically stirred solution of diol (9) (830 mg, 1.80 mmol) and pyridine (2 mL) in methanol (35 mL) was cooled to –78°C (acetone/dry-ice bath) then treated with a stream of ca. 40% ozone in oxygen (produced by a Wallace & Tiernan ozonator) for 1.0 h, at which point TLC analysis indicated the complete consumption of the starting material. The reaction mixture was purged with nitrogen and then treated with sodium iodide (840 mg, 5.60 mmol). After 3 h the now red-brown reaction mixture was warmed to –66°C and treated with sodium borohydride (1.35 g, 35.69 mmol). The reaction mixture was maintained between –60 and –40°C for 6 h and then treated with sufficient 2 M HCl in methanol so as to reduce the pH to ca. 3.5. The ensuing mixture was concentrated under reduced pressure and the residue partitioned between ethyl acetate (25 mL) and brine (25 mL). The separated aqueous phase was extracted with ethyl acetate (3 × 20 mL) and the combined organic phases were dried ($MgSO_4$), filtered and concentrated under reduced pressure. Subjection of the resulting light-yellow oil to flash chromatography (silica gel, 60% v/v ethyl acetate/hexane elution) and concentration of the appropriate fractions (R_F 0.4) then afforded *lactone (10)* (450 mg, 54%) as a clear, colourless oil, $[\alpha]_D$ +19.1 (*c*, 0.6) (Found: $[M-C_4H_9^{\bullet}]^+$, 401.1041. $C_{24}H_{30}O_7Si$ requires $[M-C_4H_9^{\bullet}]^+$, 401.1057). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.62–7.58, complex m, 4H; 7.50–7.37, complex m, 6H; 5.62, d, *J* 5.6 Hz, 1H; 4.61, d, *J* 5.6 Hz, 1H; 4.13, br s, 1H; 3.42, dd, *J* 11.3 and 8.0 Hz, 1H; 3.31, dd, *J* 11.3 and 4.1 Hz, 1H; 3.15, m, 1H; 2.55, br

s, 2H; 2.10, s, 3H; 1.07, s, 9H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 172.8, 170.2, 135.8, 135.7, 132.9, 132.2, 130.5, 130.5, 128.2, 128.1, 86.3, 71.8, 70.5, 69.2, 63.1, 26.8, 20.6, 19.4. ν_{max} (KBr) 3467, 2930, 2857, 1796, 1753, 1375, 1232, 1113, 1104, 703, 508 cm^{-1}. EI-MS *m/z* (70 eV) 401 [M – $C_4H_9^{\bullet}$]$^+$ (15%), 199 (100).

3-O-*[(1,1-Dimethylethyl)diphenylsilyl]-5,6*-O-*(1-methylethylidene)-D-talonic Acid* γ*-Lactone 2-Acetate (11)*

A solution of compound (10) (100 mg, 0.22 mmol) in 2,2-dimethoxypropane (7 mL) was treated with *p*-toluenesulfonic acid (25 mg, 0.13 mmol) and the resulting mixture stirred at 18°C for 3 h, treated with triethylamine (2 mL) and then concentrated under reduced pressure. Then residue thus obtained was subject to flash chromatography (silica gel, 15% v/v ethyl acetate/hexane elution) and concentration of the appropriate fractions (R_F 0.4) then afforded *compound (11)* (90 mg, 82%) as a white crystalline solid, m.p. 106–107.5°C, $[\alpha]_D$ +16.0 (*c*, 1.0) (Found: C, 63.2; H, 6.5%; [M – $C_4H_9^{\bullet}$]$^+$, 441.1371. $C_{27}H_{34}O_7Si$ requires C, 65.0; H, 6.9%; [M – $C_4H_9^{\bullet}$]$^+$, 441.1370). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.70–7.60, complex m, 4H; 7.55–7.38, complex m, 6H; 5.58, d, *J* 5.5 Hz, 1H; 4.62, d, *J* 5.5 Hz, 1H; 4.06, s, 1H; 3.72, m, 2H; 3.45, t, *J* 7.3 Hz, 1H; 2.15, s, 3H; 1.25, s, 3H; 1.23, s, 3H; 1.07, s, 9H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 172.3, 169.9, 135.9, 135.7, 132.9, 132.1, 130.5, 128.2, 128.1, 110.6, 83.6, 74.2, 71.9, 69.2, 65.2, 26.7, 25.6, 25.5, 20.6, 19.4 (one signal obscured or overlapping). ν_{max} (KBr) 2933, 2859, 1803, 1752, 1373, 1225, 1137, 1113, 1096, 703, 507 cm^{-1}. EI-MS *m/z* (70 eV) 483 [M – $CH_3^{\bullet}$]$^+$, (30%), 441 [M – $C_4H_9^{\bullet}$]$^+$, (33), 383 (100), 341 (50), 241 (80), 199 (94).

3-O-*[(1,1-Dimethylethyl)diphenylsilyl]-5,6*-O-*(1-Methylethylidene)-D-talo-furanose 3-Acetate (12)*

A solution of diisoamylborane in THF was prepared by treating BH_3–dimethyl sulfide complex (2 mL of a 2 M solution in THF, 4 mmol, Aldrich) maintained at 0°C under a nitrogen atmosphere with 2-methylbut-2-ene (4 mL of a 2 M solution in THF, 8 mmol). After stirring the ensuing mixture for 3 h at 0°C it was treated with a solution of lactone (11) (231 mg, 0.46 mmol) in THF (5 mL). After 3 days at 18°C, the reaction mixture was quenched with water (1 mL) and sodium bicarbonate (10 mL of a saturated aqueous solution) added. This was followed by the addition of hydrogen peroxide (0.5 mL of a 30% aqueous solution) and the resulting mixture then concentrated under reduced pressure. The residue was partitioned between water (20 mL) and dichloromethane (20 mL) and the separated aqueous phase was then extracted with dichloromethane (3 × 20 mL). The combined organic phases were dried ($MgSO_4$), filtered and concentrated under reduced pressure to afford a light-yellow oil. Subjection of this material to flash chromatography (silica gel, 15% v/v ethyl acetate/hexane) and concentration of the appropriate fractions (R_F 0.3) then afforded a ca. 2 : 3 mixture of the α- and β-forms of *lactol (12)* (192 mg, 83%) as a clear colourless oil, $[\alpha]_D$ –30.2 (*c*, 0.5) (Found: [M – $C_4H_9^{\bullet}$]$^+$, 443.1523. $C_{27}H_{36}O_7Si$ requires [M – $C_4H_9^{\bullet}$]$^+$, 443.1526). ^{13}C NMR ($CDCl_3$, 75 MHz) δ 169.9(9), 169.9(5), 136.0, 135.9, 135.8, 135.7, 133.4, 132.6, 132.4, 131.9, 130.5, 130.3, 130.2, 128.1(3), 128.0(5), 127.9(6), 127.9(2), 109.8, 109.6, 100.0, 96.4, 83.4, 82.0, 77.5, 75.2, 74.3, 74.0, 72.6, 72.4, 66.0, 65.2, 30.1, 27.1, 27.0, 26.1, 25.7, 22.1, 21.3, 21.2, 21.0, 19.3 (one signal overlapping or obscured). ν_{max} (KBr) 3443, 2933, 2859, 1748, 1371, 1235, 1113, 1062, 703, 505 cm^{-1}. EI-MS *m/z* (70 eV) 485 [M – $CH_3^{\bullet}$]$^+$, (23%), 443 [M – $C_4H_9^{\bullet}$]$^+$, (38), 325 (45), 341 (50), 241 (68), 199 (100), 101 (84).

5,6-O-*(1-Methylethylidene)*-α-*D-talofuranose Triacetate (13) and 5,6*-O-*(1-Methylethylidene)*-β-*D-talofuranose Triacetate (14)*

Method A. A magnetically stirred mixture of compound (12) (67 mg, 0.13 mmol) in THF (4 mL) maintained under a nitrogen atmosphere at 18°C was treated with tetra-*n*-butylammonium fluoride (150 μL of a 1 M solution in THF, 0.15 mmol). After 0.5 h the reaction mixture was treated with pyridine (6 mL), acetic anhydride (0.5 mL, 5.30 mmol) and DMAP (13 mg, 0.11 mmol) and then stirring continued at 18°C for 14 h. The resulting light-yellow solution was treated with ammonium chloride (20 mL of a saturated aqueous solution) and ethyl acetate (15 mL). The separated aqueous phase was extracted with ethyl acetate (2 × 10 mL) and the combined organic phases were washed with brine (1 × 15 mL) and then dried ($MgSO_4$), filtered and concentrated under reduced pressure to give a light-yellow oil. Subjection of this material to flash chromatography (silica gel, gradient elution using 20 to 25% v/v ethyl acetate/hexane) afforded two fractions, A and B.

Concentration of fraction A (R_F 0.5 in 4 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) afforded *compound (13)* (18 mg, 40%) as a light-yellow and crystalline solid, m.p. 96–98°C, $[\alpha]_D$ +11.2 (*c*, 0.25) (Found: C, 52.0; H, 6.1%; [M – $CH_3^{\bullet}$]$^+$, 331.1029. $C_{15}H_{22}O_9$ requires C, 52.0; H, 6.4%; [M – $CH_3^{\bullet}$]$^+$, 331.1030). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 6.43, d, *J* 4.5 Hz, 1H; 5.34, dd, *J* 5.9 and 2.1 Hz, 1H; 5.28, m, 1H; 4.30, m, 1H; 4.24, m, 1H; 4.02, t, *J* 6.7 Hz, 1H; 3.91, m, 1H; 2.13, s, 3H; 2.11, s, 3H; 2.07, s, 3H; 1.39, s, 3H; 1.36, s, 3H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 170.3, 169.7, 169.3, 110.1, 94.4, 83.2, 75.3, 71.1, 70.3, 65.2, 26.2, 25.8, 21.3, 21.0, 20.6. ν_{max} (KBr) 2988, 2925, 1750, 1372, 1222, 1111, 1065, 1011, 939 cm^{-1}. EI-MS *m/z* (70 eV) 331 [M – $CH_3^{\bullet}$]$^+$, (80%), 287 (15), 169 (60), 127 (29), 101 (100).

Concentration of fraction B (R_F 0.4 in 4 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) afforded *compound (14)* (22 mg, 47%) as a clear colourless oil, $[\alpha]_D$ –54.0 (*c*, 0.25) (Found: [M – $CH_3^{\bullet}$]$^+$, 331.1029. $C_{15}H_{22}O_9$ requires [M – $CH_3^{\bullet}$]$^+$, 331.1030). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 6.18, d, *J* 1.8 Hz, 1H; 5.44–5.32, complex m, 2H; 4.26–4.14, complex m, 2H; 4.03, m, 1H; 3.84, m, 1H; 2.12, s, 3H; 2.09, s, 3H; 2.08, s, 3H; 1.40, s, 3H; 1.38, s, 3H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 169.7, 169.4, 169.2, 110.0, 98.1, 80.9, 75.3, 74.3, 71.1, 65.2, 26.3, 25.8, 21.3, 20.8, 20.8. ν_{max} (KBr) 2988, 2925, 1752, 1372, 1219, 1062, 970 cm^{-1}. EI-MS *m/z* (70 eV) 331 [M – $CH_3^{\bullet}$]$^+$, (53%), 287 (12), 169 (57), 127 (40), 101 (100).

Method B. A magnetically stirred solution of compound (12) (51 mg, 0.10 mmol) and DMAP (15 mg, 0.12 mmol) in pyridine (2.5 mL) maintained under a nitrogen atmosphere at 18°C was treated with acetic anhydride (0.5 mL). After 3 h the reaction mixture was treated with dichloromethane (8 mL) and ammonium chloride (15 mL of a saturated aqueous solution). The separated organic phase was washed with ammonium chloride (15 mL of a saturated aqueous solution) and brine (1 × 15 mL) and then dried ($MgSO_4$), filtered and concentrated under reduced pressure to give a light-yellow oil. This material was dissolved in THF (2.5 mL) and then treated with tetra-*n*-butylammonium fluoride (90 μL of a 1 M solution in THF, 0.09 mmol). After 0.5 h the reaction mixture was treated with pyridine (4 mL), acetic anhydride (0.5 mL) and DMAP (6 mg, 0.05 mmol), and maintained at 18°C with stirring for 14 h. The resulting light-yellow solution was treated with sodium bicarbonate (15 mL of a saturated aqueous solution) and ethyl acetate (10 mL). The separated aqueous phase was extracted with ethyl acetate (3 × 5 mL) and the combined organic phases were washed with brine (1 × 15 mL) and then dried ($MgSO_4$), filtered and concentrated under reduced pressure to give a light-yellow oil. Subjection of this material to flash chromatography (silica gel, gradient elution using 20 to 25% v/v ethyl acetate/hexane) afforded two fractions, A and B.

Concentration of fraction A (R_F 0.5 in 4 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) afforded compound (13) (22 mg, 63%) identical, in all respects, with the chromatographically more mobile product obtained by Method A as described immediately above.

Concentration of fraction B (R_F 0.4 in 4 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) afforded compound (14) (6 mg, 17%) identical, in all respects, with the chromatographically less mobile product obtained by Method A as described immediately above.

α*-Penta*-O*-acetyl-D-talopyranose (15) a-Penta*-O*-acetyl-D-talofuranose (16)*

Method A. A magnetically stirred solution of authentic D-talose (153 mg, 0.85 mmol) in pyridine (4 mL) was cooled to 0°C (ice-bath) and then treated with acetic anhydride (2 mL). The resulting solution was stirred at 0–18°C for 18 h, and then treated with

$NaHCO_3$ (20 mL of a saturated aqueous solution) and ethyl acetate (20 mL). The separated organic phase was washed with $NaHCO_3$ (1 × 20 mL of a saturated aqueous solution), and NH_4Cl (2 × 20 mL of a saturated aqueous solution), and then dried ($MgSO_4$), filtered and concentrated under reduced pressure to give a light-yellow oil. Subjection of this material to flash chromatography (silica gel, gradient elution using 25 to 35% v/v ethyl acetate/hexane) afforded two fractions, A and B.

Concentration of fraction A (R_F 0.26 in 4 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) afforded compound (15) (259 mg, 78%) as light-yellow crystalline solid, m.p. 104–106°C (lit.[30] 107°C), $[\alpha]_D$ +74.8 (*c*, 0.5) (lit.[30] +70.2 in $CHCl_3$) (Found: C, 49.3; H, 5.3%; $[M-CH_3CO^{\bullet}]^+$, 347.0969. Calc. for $C_{16}H_{22}O_{11}$: C, 49.2; H, 5.7%; $[M-CH_3CO^{\bullet}]^+$, 347.0978). ^1H NMR ($CDCl_3$, 300 MHz) δ 6.08, br s, 1H; 5.3, br s, 1H; 5.25, t, *J* 3.7 Hz, 1H; 5.25, m, 1H; 4.26, br t, *J* 6.9 Hz, 1H; 4.10, m, 2H; 2.10(3), s, 3H; 2.10(1), s, 3H; 2.09, s, 3H; 1.98, s, 3H; 1.95, s, 3H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 170.2, 169.9, 169.5, 169.5, 167.9, 91.4, 68.8, 66.3, 65.3, 65.1, 61.5, 21.0, 20.9, 20.8, 20.7(4), 20.6(6). ν_{max} (KBr) 2974, 1749, 1372, 1226, 1143, 1045, 1002, 732 cm^{-1}. EI-MS *m/z* (70 eV) 347 $[M-CH_3CO^{\bullet}]^+$, (11%), 331 $[M-CH_3CO_2^{\bullet}]^+$, (24), 242 (45), 200 (35), 157 (78), 115 (100), 98 (65).

Concentration of fraction B (R_F 0.32 25:75 v/v ethyl acetate/hexane) afforded compound (16) (40 mg, 12%) as a clear colourless oil, $[\alpha]_D$ +38.6 (*c*, 0.5) (Found: $[M-CH_3CO^{\bullet}]^+$, 347.0969. Calc for $C_{16}H_{22}O_{11}$: $[M-CH3CO^{\bullet}]^+$, 347.0978). ^1H NMR ($CDCl_3$, 300 MHz) δ 6.12, s, 1H; 5.31, m, 2H; 5.18, m, 1H; 4.34, m, 1H; 4.27, dd, *J* 11.9 and 4.5 Hz, 1H; 4.14, dd, *J* 11.9 and 6.6 Hz, 1H; 2.12, s, 3H; 2.11(3), s, 3H; 2.10(9), s, 3H; 2.05, s, 6H. ^{13}C NMR ($CDCl_3$, 75 MHz) δ 170.4, 169.9, 169.5, 169.4, 168.8, 97.7, 79.3, 74.0, 70.0, 69.7, 62.5, 21.2, 21.0, 20.9, 20.7, 20.6. ν_{max} (KBr) 1749, 1372, 1219, 1045, 967, 895, 602 cm^{-1}. EI-MS *m/z* (70 eV) 347 $[M-CH_3CO^{\bullet}]^+$, (2%), 331 $[M-CH_3CO_2^{\bullet}]^+$, (30), 245 (100), 200 (35), 143 (92).

Method B. A magnetically stirred solution of a mixture of compounds (13) and (14) (40 mg, 0.12 mmol, obtained by either one of the two methods described immediately above) in THF/water (4 mL of a 1 : 1 v/v mixture) was treated with trifluoroacetic acid (TFA) (0.4 mL). The resulting mixture was stirred at 0–18°C for 20 h and then concentrated under reduced pressure. The ensuing light-yellow oil was dissolved in pyridine (4 mL), the resulting solution cooled to ca. 0°C (ice-bath) and then treated with acetic anhydride (1 mL) and DMAP (7 mg, 0.06 mmol). The reaction mixture was stirred at 0°C for 1 h and then at 18°C for 23 h before being poured into a mixture of ethyl acetate (10 mL) and ammonium chloride (15 mL of a saturated aqueous solution). The separated organic phase was washed with NH_4Cl (2 × 15 mL of a saturated aqueous solution) then dried ($MgSO_4$), filtered and concentrated under reduced pressure to give a light-yellow oil. Subjection of this material to flash chromatography (silica gel, gradient elution using 25 to 35% v/v ethyl acetate/hexane) afforded two fractions, A and B.

Concentration of fraction A (R_F 0.26 in 4 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) afforded a ca. 2 : 1 mixture of a penta-*O*-acetyl-D-talofuranose and compound (15) (24 mg, 53%) as a light-yellow oil which solidified on standing. Comparison of the ^1H and ^{13}C NMR data derived from this material with those obtained from authentic samples of compound (15) provided a good match. The following additional signals, attributed to the penta-*O*-acetyl-β-D-talofuranose, were observed: ^1H NMR ($CDCl_3$, 300 MHz) δ 6.42, d, *J* 4.5 Hz, 1H; 5.30, m, partially obscured, 1H; 5.23, m, 1H; 5.15, m, 1H; 4.46, t, *J* 2.9 Hz, 1H; 4.31, dd, *J* 11.7 and 4.8 Hz, 1H; 4.16, m, 1H [signals due to acetate methyl groups overlapping with those due to equivalent groups in compound (15)]; ^{13}C NMR ($CDCl_3$, 75 MHz) δ 170.4, 169.9, 169.8, 169.7, 169.3, 93.9, 82.0, 77.4, 69.9, 69.8, 62.1, 29.9, 21.3, 21.1, 20.5 (one signal obscured or overlapping).

Concentration of fraction B (R_F 0.32 in 4 : 2.5 : 5.5 v/v/v ethyl acetate/dichloromethane/hexane) afforded compound (16) (10 mg, 22%) as a clear colourless oil. This material was identical, in all respects, with the material prepared as described above from D-talose.

Crystallography

Crystal Data

Compound (7). $C_{24}H_{27}ClO_4Si$, *M* 443.015, *T* 200 K, orthorhombic, space group *P*212121, *a* 9.7325(7), *b* 9.7726(7), *c* 25.180(2) Å, *V* 2394.9(3) $Å^3$, D_c (*Z* 4) 1.229 g cm^{-3}, *F*(000) 936, μ(Mo Kα) 0.236 Å, 4063 unique data ($2\theta_{max}$ 50.05°), 2935 with $I > 3\sigma(I)$, *R* 0.0611, ω*R* 0.0704, *S* 1.0696.

Compound (13). $C_{15}H_{22}O_9$, *M* 346.332, *T* 200 K, monoclinic, space group *C*2, *a* 16.5808(3), *b* 5.73230(10), *c* 19.0387(5) Å, β 109.5197(9)°, *V* 1705.55(6) $Å^3$, D_c (*Z* 4) 1.349 g cm^{-3}, *F*(000) 736, μ(Mo Kα) 0.112 Å, 2155 unique data ($2\theta_{max}$ 54.96°), 1307 with $I > 2\sigma(I)$, *R* 0.0349, ω*R* 0.0389, *S* 1.0604.

Structure Determination

Intensity data were collected using a Nonius Kappa CCD diffractometer and extracted from diffraction images using the DENZO[31] package. Analytical absorption corrections were applied.[32] Both structures were solved by direct methods[33] and expanded using Fourier techniques.[34] Full matrix least-squares refinement was on *F*, non-hydrogen atoms were refined anisotropically while hydrogen atoms were included at geometrically determined positions and ride on the carbon of attachment. ADEP's of (7) and (13) were generated using *CAMERON* software.[35]

Atomic coordinates, bond lengths and angles, and displacement parameters have been deposited with the Cambridge Crystallographic Data Center (CCDC Nos 185848 and 185849 for compounds (7) and (13), respectively).

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