Product Analysis in the Iodine(III)-Promoted Oxidation of Carbohydrate-Derived Cyclic Enol Ethers: A Mechanistic Study

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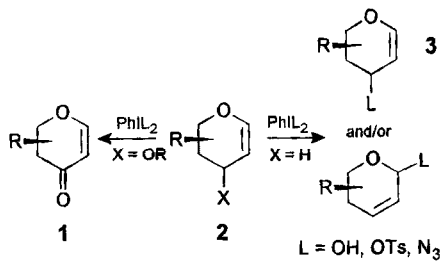
A study on the mechanism of the well-documented hypervalent iodine-mediated allylic oxidation of glycals leading to 2,3-dihydro-4*H*-pyran-4-ones is presented. Notable features are the isolation of ring-contracted by-products **6** and **7**, which are produced upon oxidation of per-*O*-benzylated glycal **4**, as well as the characterization of carbohydrate-derived tetrahydrofurfurals **12a** and **13a**, which are formed by the conformation-dependent oxidation of glycals **9a** and **10b**. In addition, the iodine(III)-mediated oxidation process has been studied by in situ NMR spectroscopy of *lyxo*-configured glycals **14a,b**. Intermediate alkylphenyliodonium species **19b,d** and 2-enopyranosides **16a** and **20a** have been characterized by their NMR signals. These data support a plausible mechanism that is initiated by electrophilic attack of the iodine(III) reagent on the electron-rich enol ether double bond of the glycal. This is followed by the breaking of a bond β,γ-positioned in relation to the carbohydrate-bound iodine and subsequent reductive elimination of iodobenzene. Thus, depending on the glycals employed, a number of diverse oxidation products may be formed.

The versatility of hypervalent iodine(III) reagents in organic synthesis is well recognized[1]. Recently, we reported on the use of these reagents for the synthesis of 2,3-dihydro-4*H*-pyran-4-ones **1** (L = OH/OTs)[2] and 3-azidoglycals **3** (L = N_3)[3] from carbohydrate-derived enol ethers **2** (Scheme 1). Along with the iodine(III)-promoted oxidation of triisopropylsilyl enol ethers described by Magnus and coworkers[4], this type of allylic oxidation reveals a unique reactivity pattern of polycoordinated iodine compounds. Although a mechanistic rationale has been proposed by ourselves[2b][5] and others[4], this allylic oxidation is still open to discussion. For example, doubt prevails as to whether this kind of iodine(III) chemistry proceeds via ionic or radical pathways. Unfortunately, intermediates of this oxidation process have hitherto eluded trapping. Accordingly, we have investigated the mechanism of iodine(III)-mediated oxidation of glycals by the isolation of by-products and intermediates that were detected by studying the reaction in the NMR tube.

Scheme 1



Tetrahydrofurans by Ring-Contraction of Glycals

The oxidative 3-*O*-deblocking of benzylated glycals by PhI(OH)OTs is currently the only practical method available for the synthesis of *O*-benzylated 2,3-dihydro-4*H*-pyran-4-ones such as **5**. These have proven useful as enantiomerically pure building blocks since they are ideally set up for carbanion chemistry[6]. To optimize this transformation and to gain further insight into the mechanism, we conducted a careful search for by-products. As described previously[2], treatment of *lyxo*-configured per-*O*-benzylated glycal **4** with PhI(OH)OTs furnished enone **5** as the main product (58%)[7]. To our surprise, we also isolated two diastereomeric tetrahydrofurans **6** and **7** (16%), which must have been formed via an unprecedented pathway (Scheme 2). The ring-contraction proceeded in a highly stereoselective manner as the configuration of the newly formed stereogenic center at C-3 was found to be identical in **6** and **7**.

In an attempt to verify the assumption that the two isomeric tetrahydrofurans differ only in the configuration at C-2, the benzylacetal groups in **6** and **7** were independently treated with hydrochloric acid. However, aromatization is strongly favoured after selective hydrolysis at C-2 and only furan **8** could be isolated. The configurations of the ring-contracted products **6** and **7** were particularly difficult to determine by NMR spectroscopy, as 2-H and 3′-H show similar chemical shifts in the ^{1}H-NMR spectra and couple to the same neighbouring protons 3-H. Therefore, hetero-multiple-bond correlation (HMBC) experiments were car-

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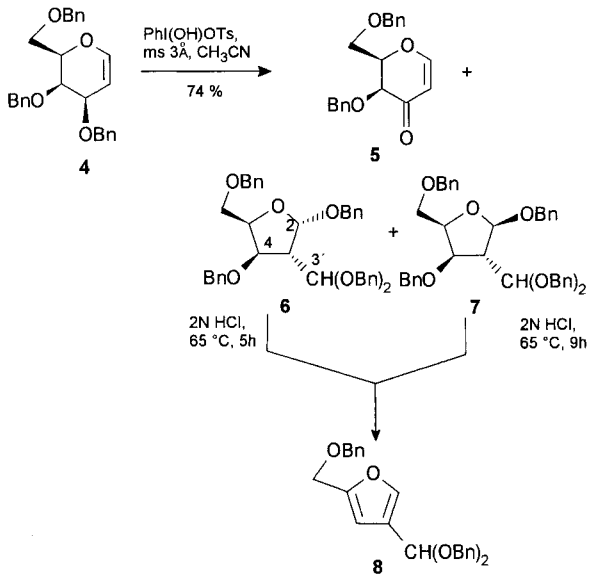
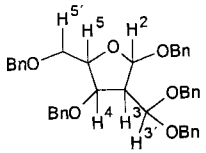
Scheme 2



ried out, which showed 2-H and 3′-H to be correlated to the corresponding adjacent two and four benzyl protons, respectively. Additionally, these experiments clearly revealed correlation between C-4 and both 2-H and 3′-H, while C-5 only gave a cross-peak with 2-H. From nuclear Overhauser effect (NOE) experiments, the configurations of **6** and **7** were unequivocally proven (Table 1). In **6**, a large NOE is observed for the neighbouring protons at 2-H and 3-H, as well as for 4-H and 5-H, indicating a 2,3-*cis*-substitution. In contrast to this observation, the effect is much smaller for the couple 3-H/4-H. Together with the strong NOE between the side-chain protons 3′-H and 4-H, these results clearly demonstrate that 3-H and 4-H must be *trans*-oriented in **6**. Compound **7** also exhibited the expected large NOE correlation between 4-H and 5-H. However, the small observed effect between 3-H and 4-H, as well as 2-H and 3-H, reveal an all *trans* orientation between 2-H, 3-H and 4-H. Further support for the configuration of **7** was gained from the observation of NOEs between 2-H and 3′-H, as well as 4-H and 3′-H.

Table 1. NOE correlations in tetrahydrofurans **6** and **7**



Furan	Relative Nuclear Overhauser Effects in %[a]					
	2-H/3-H	2-H/3′-H	3-H/4-H	3′-H/4-H	4-H/5-H	5′-H/3-H
6	11.7 (11.3)	n.d.[b]	1.8 (2.2)	5.0 (5.0)	13.0 (–)[c]	n.d.[b]
7	3.0 (2.7)	6.0 (–)[c]	2.1 (2.0)	–[c] (≈4.0)	≈8.0 (–)[c]	0.9 (0.7)

[a] Values in brackets refer to the reversed nuclear Overhauser experiment. – [b] NOE not detected. – [c] Not determined due to overlapping signals.

Glycals bearing bulky protective groups such as *tert*-butyldimethylsilyl or *tert*-butyldiphenylsilyl groups, as well as C-1 alkylated glycals, exhibit a different behaviour and provide further insight into the mechanism of the iodine(III)-promoted oxidation of cyclic enol ethers. The large protective groups in **9a** and **10a** cause a change in conformation from the half-chair to an inverted half-chair or twist-boat type, thus reducing steric strain as indicated by the coupling constants J in the ^{1}H-NMR spectra [**9a** (**10a**): $J_{2,3}$ = 2.0 (2.0) Hz, $J_{2,4}$ = 1.6 (1.0) Hz, $J_{3,4}$ = 4.0 (5.2) Hz, $J_{3,5}$ = 1.6 (2.0) Hz, $J_{4,5}$ = 2.0 (2.0) Hz]. In the crystal, the methyl- and the two *tert*-butyldiphenylsilyl groups of **9a** are pseudoaxially oriented, as was concluded from X-ray structural investigations (Figure 1). Clearly, these conformational conditions strongly favour ring-contraction (Scheme 3)[5]. Thus, glycal **9a** gave tetrahydrofurfural **12a** (31%) as a single isomer when treated with PhI(OH)-OTs[8],[9]. Unexpectedly, 2,3-dihydro-4*H*-pyran-4-ones could not be detected at all. In contrast to this observation, **9b** afforded enone **11a** (71%) along with *vic*-bis(tosyloxy)-pyran **11b** (7%). Alkylated glycal **10b**, which was previously prepared from the corresponding glycal **9b**[10], shows a similar chemical behaviour to **9a** in that it stereoselectively gives tetrahydrofuran **13a** (26%) along with minor amounts of aldehyde **13b** (6%)[11]. The iodine(III)-mediated oxidation of alkylated glycal **10a**, however, afforded diol **12b** (10%), which may have been formed by a route similar to that by which **11b** was produced (see below). Aldehyde **13b** may be derived from the corresponding diol with an analogous structure to **12b** by the known iodine(III)-promoted oxidative glycol cleavage[12].

Tracking, Isolation and Characterization of Possible Intermediates

Among the wide range of glycals tested, the galactals **14a** and **14b** were the only substrates to provide access to possible intermediates of the oxidation process. When tri-*O*-acetyl-D-galactal (**14a**) was treated with 1.2 equivs. of PhI(OH)OTs in the presence of 3 Å molecular sieves in CH_3CN, rapid formation of a new compound was observed by TLC. After prolonged reaction times, this intermediate slowly disappeared leaving 2,3-dihydro-4*H*-pyran-4-one **15a** as essentially a single, main product (Scheme 4). This primary spot was not detectable by UV absorption, but upon treatment with a spray of 5% H_2SO_4 in ethanol it was converted into a new material, presumably **15a**, which showed a strong UV absorption. At this stage, attempts to isolate and characterize the intermediate were unsuccessful. We were only able to obtain enone **15a** (58%) and the 1,2,3-orthoacetate **17** (2.4%)[13]. However, when we employed as little as 0.6 equiv. of Koser's reagent [PhI(OH)OTs], the starting material **14a** (11%) and enone **15a** could be isolated after rapid work-up and flash chromatography, along with small amounts of **17** and the novel α-2-enopyranose **16a** (Scheme 2). The isolation of **16a** was particularly surprising, since the corresponding *O*-benzyl and *O,O′*-benzylidene derivatives had previously been deemed too unstable to be isolated[14]. The 2,3-unsaturated pyranose **16a** showed the same R_f-value and chemical behaviour as the intermediate spot that had been detected by TLC (*vide supra*). The ^{1}H-NMR spectrum featured two resonances at δ = 5.68

Scheme 3

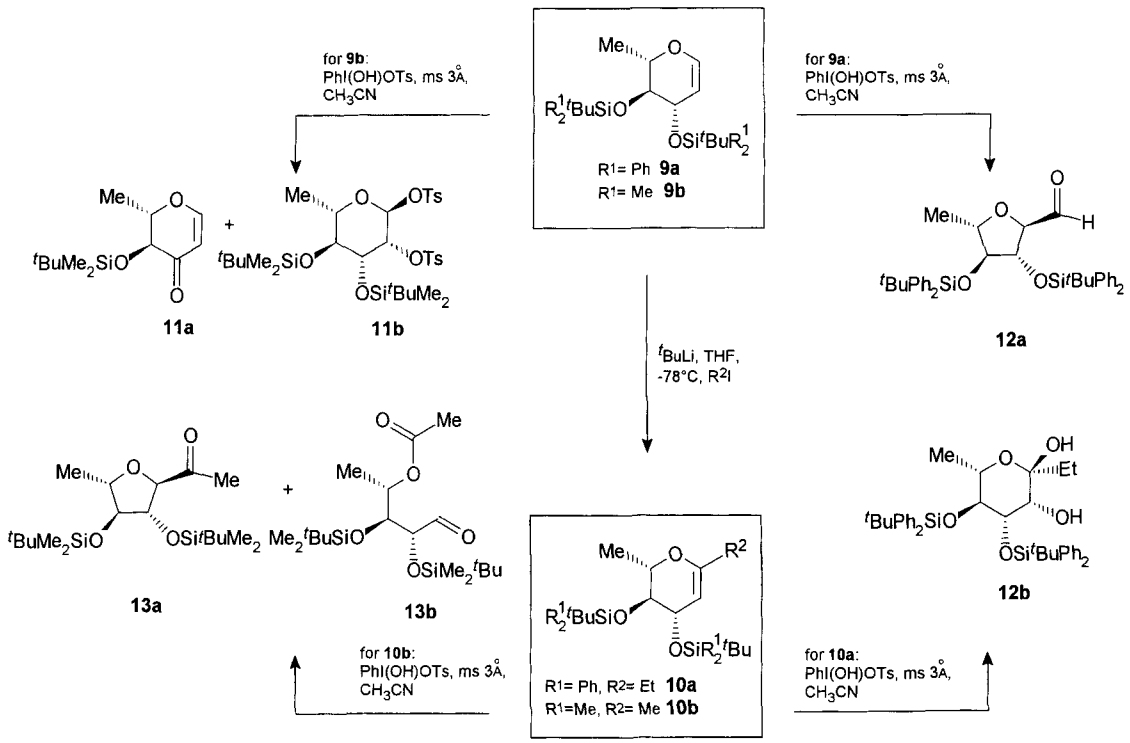


Figure 1. ORTEP representation of **9a**

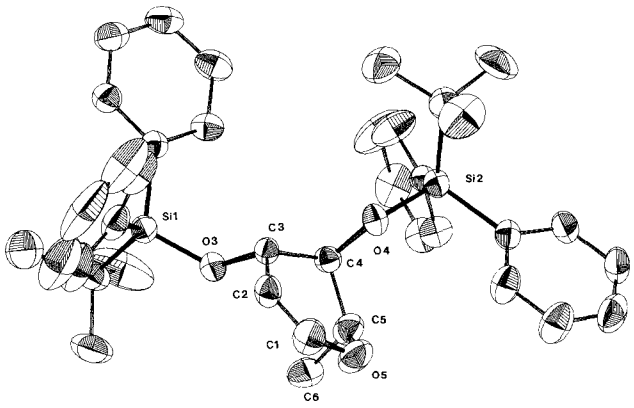


Table 2. Significant interatomic bond distances and angles in **9a**

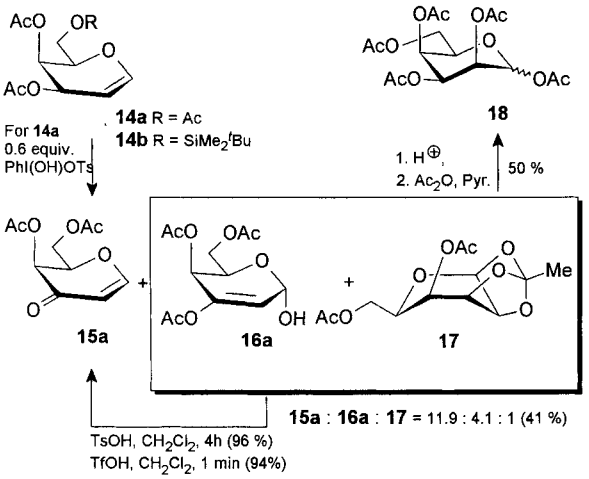
Bond lengths [pm]			
O5 – C1	1.375(6)	C5 – C6	1.527(6)
C1 – C2	1.294(6)	C3 – O3	1.441(4)
C2 – C3	1.488(5)	O3 – Si1	1.641(3)
C3 – C4	1.516(5)	C4 – O4	1.430(4)
C4 – C5	1.507(5)	O4 – Si2	1.643(3)
C5 – O5	1.428(5)		
Torsion angles [°]			
C2 – C3 – C4 – C5	41.3		
C3 – C4 – C5 – O5	–54.9		
O3 – C3 – C4 – O4	157.1		
O4 – C4 – C5 – C6	–171.5		

and 5.77 for 1-H and 2-H ($J_{1,2}$ = 3.6 Hz), which were found to be connected to two signals at δ = 116.8 (C-2) and 90.8 (C-1) in the ^{13}C-NMR spectrum. The quaternary carbon at δ = 146.8 was ascribed to C-3. The molecular peak at *m/z* = 287 (M^+ – 1) in the mass spectrum (CI) further supported the proposed constitution of **16a**.

Determination of the structure of **17** proved to be troublesome. All coupling constant values in the ^{1}H-NMR spectrum ($J_{1,2}$ = 5.0 Hz, $J_{2,3}$ = 3.6 Hz, $J_{3,4}$ = 0.8 Hz, $J_{4,5}$ = 3.6 Hz) were assigned by analysis of the ^{1}H-^{1}H- and ^{1}H-^{13}C-COSY spectra. These data and the long-range couplings ($J_{2,4}$ = 2.2 Hz, $J_{3,5} \approx$ 1.0 Hz) pointed to a bridged framework with little flexibility. Furthermore, these spectra revealed the presence of three methyl groups, which are attached to two carbonyl carbons. No additional keto group, as in 2,3-dihydro-4*H*-pyran-4-one **15a**, could be detected. Instead, the ^{13}C-NMR spectrum showed a quaternary carbon at δ = 117.5, which is a typical value for the carbon atom of ortho esters. From the IR spectrum, it was concluded that no hydroxy groups were present in the molecule. In addition, mass spectrometry (CI) gave the expected molecular peak [*m/z* = 289 (M^+ + 1)]. All these data support the bridged nature of **17**. To further conclusively confirm the constitution, **17** was hydrolyzed under acidic conditions. The reaction yielded a complex mixture of partially acetylated pyranoses. Therefore, the crude product was directly acetylated, giving a separable mixture of per-*O*-acetylated α,β-D-taloses **18** (α:β ≈ 3:1).

Under acidic conditions (CH_2Cl_2, TFA), pyranose **16a** was instantaneously transformed to enone **15a** in high yield (94%). However, when TsOH in acetonitrile was employed, which constitutes late-stage oxidation conditions, transformation of **16a** into **15a** proceeded only very sluggishly (Scheme 4). Furthermore, **16a** was found to be stable for

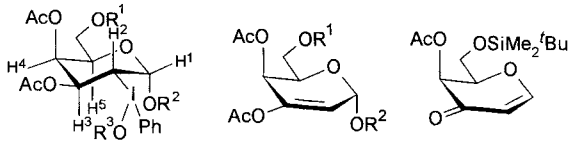
Scheme 4



several days in an aqueous bicarbonate solution, which we commonly use for terminating the oxidation process.

The observation that (diacetoxy)iodobenzene does not react with glycals at room temp. allowed the oxidation to be carried out using an in situ procedure. Thus, generation of Koser's reagent by slow addition of anhydrous *p*-toluenesulfonic acid to a mixture of (diacetoxy)iodobenzene [PhI(OH)OTs] and glycal **14a** gave enone **15a** in yields of around 60%. If **16a** is an intermediate of the main pathway, a catalytic amount of TsOH (10 mol%) and one equivalent of $PhI(OAc)_2$ should be sufficient for quantitative transformation. However, under these conditions **15a** was only formed in low yield (< 10%). Therefore, it is reasonable to conclude that the tosylate group is incorporated into the sugar framework in the course of oxidation and that **16a** is not an intermediate on the main route, but is formed in the course of a side reaction.

Table 3. ^{1}H-NMR of intermediates **19b,d** in CD_3CN: chemical shifts δ values and coupling constants *J* (Hz)[a]



19a R^1 = Ac, R^2 = H, R^3 = Ts
19b R^1 = Ac, R^2 = Ts, R^3 = H
19c R^1 = $SiMe_2{}^tBu$, R^2 = H, R^3 = Ts
19d R^1 = $SiMe_2{}^tBu$, R^2 = Ts, R^3 = H

16b R^1 = Ac, R^2 = Ts
20a R^1 = $SiMe_2{}^tBu$, R^2 = H
20b R^1 = $SiMe_2{}^tBu$, R^2 = Ts

15b

Intermediates	1-H	2-H	3-H	4-H	5-H	6-H	6'-H
19b[b]	6.65	5.69	4.59	5.28	–[c]	3.75	3.55
19d[b]	6.64	5.71	4.56	5.31	3.69	3.23	2.79

$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5}$	$J_{5,6}$	$J_{5,6'}$	$J_{6,6'}$
2.8	12.0	3.0	<1.0	6.8	6.0	11.4
2.8	12.0	2.8	≈0.8	9.2	5.6	9.2

[a] For details see Experimental Section. – [b] ^{1}H- and ^{13}C-resonances for the silyl and acetyl groups could not be resolved. – [c] not detected.

To obtain more structural evidence on this and other possible intermediates, oxidation of tri-*O*-acetyl-D-galactal (**14a**) was studied in the NMR tube (Table 3). Addition of the required powdered molecular sieves (3 Å) did not create significant resolution problems. ^{1}H-NMR spectra were recorded at intervals of approximately four minutes. **14a** was converted into a primary intermediate within 45 min., which was present at a low equilibrium concentration throughout the experiment, as once formed it rapidly underwent further reaction. After 4 h, enone **15a** was the principal product in the reaction mixture. From the NMR data it was reasoned that the alkylphenyliodonium species **19b** was the primary intermediate. With the exception of traces of **16a**, no other products such as the 2-enopyranoses **16b** or **19a** could be detected. However, the 6-*O*-silylated glycal **14b** exhibited slightly different reactivity towards Koser's reagent. Under identical conditions, **14b** was transformed into the primary intermediate **19d** in the NMR tube within 20 min., which accumulated as further conversions proceeded at a much slower rate. Nevertheless, after 4 h, **19d** was no longer detectable and enone **15b** and small amounts of enopyranose **20a** were present in the NMR tube. Other intermediates such as **19c** or **20b** were not detected at any stage of the experiment.

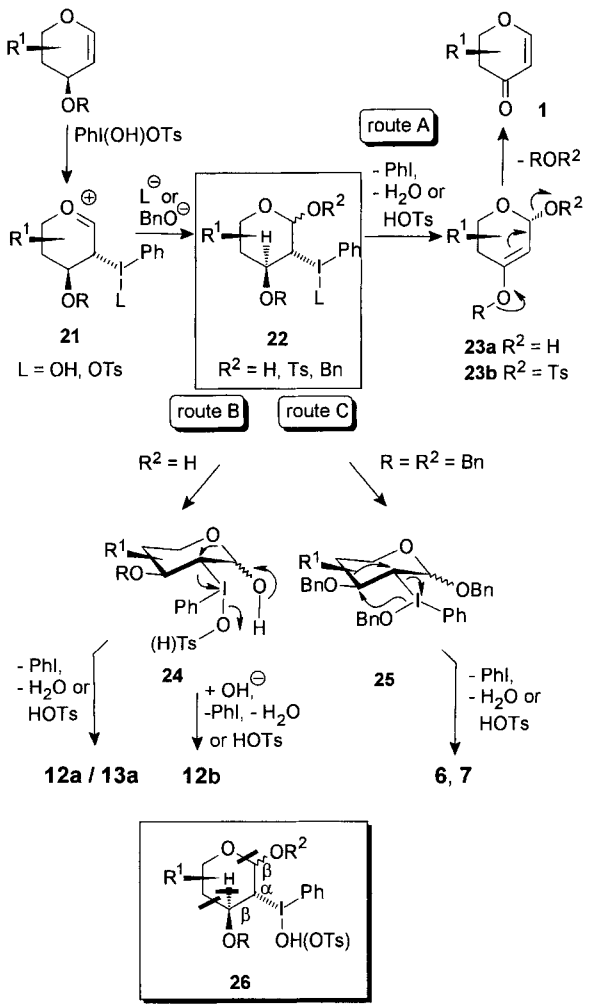
At present, very few NMR data for alkylphenyliodonium species are available[1c][15]. Therefore, the effect of the hypervalent iodine substituent upon the chemical shifts of 2-H and C-2, respectively, can only be estimated. In comparison to iodine, iodine(III) substituents generally cause pronounced downfield shifts (ca. 1–1.5 ppm for α-protons and up to 40 ppm for ^{13}C atoms) in the NMR spectra. Clearly, electron-withdrawing ligands and the electron-deficiency of iodine in the oxidation state +3 overrule the heavy atom effect. All ring protons and the methylene protons at C-6 of the carbohydrate-derived intermediate **19b** and **19d** were clearly identified and all corresponding *J* values were determined (Table 3). For example, the coupling constants for **19d** ($J_{1,2}$ = 2.8 Hz, $J_{2,3}$ = 12.0 Hz, $J_{3,4}$ = 2.8 Hz, $J_{4,5} \approx$ 0.8 Hz) strongly suggest the presence of an α-*galacto*-configured pyranose with an equatorial group at C-2. In contrast to all the other ring protons, the resonances of 1-H (from δ = 6.46 to δ = 6.64) and in particular of 2-H (δ = 4.62 to 5.71) are shifted downfield compared to **14b**, which indicates that strongly electron-withdrawing groups are attached to the sp^3-carbon atoms C-1 and C-2. The pronounced upfield shift for 3-H (from δ = 5.53 to δ = 4.56) and the chemical shifts found for the ring carbons in the ^{13}C-NMR spectrum[16] further confirm that the olefinic double bond has been lost. The low-field resonance of 1-H in **19d** can be ascribed to an anomeric tosyl substituent[2b]. Hence, the 2-enopyranoses **16a** and **20a** are only formed as by-products via the corresponding 2-phenyliodonium pyranoses **19a** and **19c**.

Mechanistic Considerations

A mechanism that is consistent with all the collected data, observations and stereochemical results is outlined in Scheme 5. The oxidation is initiated by electrophilic attack

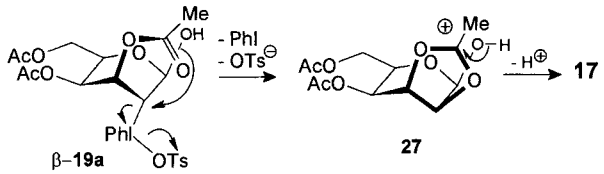
of the iodine(III) reagent at the α-face of the glycal, furnishing oxonium ion **21**. This is trapped by an external nucleophile such as the hydroxy or tosyloxy ligand, or in cases of per-*O*-benzylated glycals, by the benzyloxy group. The 1,2-addition results in the alkylphenyliodonium species **22**, which, for example, corresponds to α-**19**. This highly reactive primary intermediate then undergoes reductive elimination of PhI to give enopyranoses **23**. Compound **22b** (R^2 = Ts) is the main primary intermediate formed. Thus, reductive elimination of PhI affords the labile intermediate **23b**, which has a very short half-life and which is quickly transformed into 2,3-dihydro-4*H*-pyran-4-one **1** by elimination of ROR^2 (route A)[17]. Starting from **22**, this two-step process is believed to proceed spontaneously when the oxidation is terminated by aqueous hydrolysis. However, **23a** (R^2 = H), which corresponds to **16a** or **20a**, is only generated as part of a side reaction.

Scheme 5



In contrast to this main pathway, two alternative routes may operate that lead to tetrahydrofurans **6**, **7** as well as **12a** and **13a**. Under special conformational circumstances described above and when R^2 = H, intermediate **24** undergoes ring-contraction by a stereoselective backside attack of the ring oxygen atom O-5 on the nucleo*fugic* organoiodine substituent at C-2, to afford tetrahydrofurfurals such as **12a** and **13a** (Scheme 5; route B). Likewise, intermolecular nucleophilic attack of, e.g., the hydroxy ligand leads to pyranoses such as **12b**. In contrast, when per-*O*-benzylated glycals are transformed into **1** by oxidative deblocking, benzyl alcohol is liberated, which can efficiently compete for oxonium ion **21** and may also cause a ligand exchange at the central iodine atom to afford the iodine(III) intermediate **25** (Scheme 5; route C). This species undergoes ring-contraction (Scheme 5) by breaking of the C-3/C-4 bond followed by S_N2 attack on C-2, as well as transfer of the benzyloxy group at C-3 with subsequent reductive elimination of PhI. This type of ring-contraction results in tetrahydrofurans such as **6** and **7**.

Scheme 6



In addition, formation of **17** can be readily rationalized by assuming a *trans*-diaxial β-adduct **19a** (corresponding to intermediate **22** in Scheme 5) with a boat configuration. This has the substituents at C-4 and C-5 in a pseudoequatorial orientation and the acetyl group at C-3 in an axial orientation (Scheme 6). Such an intermediate can cyclize to give oxonium cation **27**, which is initially trapped by the anomeric hydroxy group to give the bridged orthoester **17**. In all these cases, reductive elimination of PhI is initiated by the breaking of a bond that is in a β,γ-position with respect to the iodine substituent at C-2 (carbohydrate numbering), as is shown in **26**. Which route is favoured depends on the ring conformation of intermediate **21** or **22**. If the bond to be broken and the carbon-iodine bond are able to adopt an antiperiplanar orientation, then the elimination or substitution reaction will be accelerated.

In summary, we present a detailed mechanistic study on the iodine(III)-mediated oxidation of glycals. Related allylic oxidations of electron-rich olefinic double bonds[3][4] are believed to proceed via analogous intermediates.

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Experimental Section

General: All temperatures quoted are uncorrected. – Optical rotations: Perkin-Elmer 141 polarimeter. – IR: PYE Unicam SP3-200. – ^1H NMR, ^{13}C NMR, $^1H,^1H$- and $^1H,^{13}C$-COSY as well as NOESY spectra: Bruker ARX 400-NMR spectrometer. – ^{13}C-NMR multiplicities: DEPT-135 method. – MS: Finnigan MAT 95. – Elemental analyses: Institut für Pharmazeutische Chemie, Technische Universität Braunschweig. – All solvents used were of reagent grade and were further dried. – Reactions were monitored by TLC on silica gel 60 PF^{254} (E. Merck, Darmstadt) and spots

were detected either by UV absorption or by charring with H_2SO_4/4-methoxybenzaldehyde in methanol. – Preparative column chromatography (CC): silica gel 60 (E. Merck, Darmstadt). – PE: petroleum ether, EE: ethyl acetate. – Powdered molecular sieves (3Å) were purchased from Janssen Chem. Co. [Hydroxy(tosyloxy)iodo]benzene [PhI(OH)OTs] was obtained according to Koser's procedure[18]. Glycals **4**, **9b** and **14b** were prepared according to ref.[2b], whereas **14a** is commercially available. Details of the preparations of compounds **5**, **11a**, **15a** and **15b** have been reported previously[2b][19].

(+)-1,5-Anhydro-3,4-bis(O-tert-butyldiphenylsilyl)-2,6-didesoxy-L-arabino-hex-1-enitol (**9a**): Preparation from 3.1 g (23.8 mmol) of the diol 1,5-anhydro-2,6-didesoxy-L-*arabino*-hex-1-enitol under standard silylating conditions[20]; CC with PE/EE (60:1) gave 8.2 g (57%), colorless crystals; m.p. 123°C (ether). – $[\alpha]_D^{24} = +31.4$ (c = 1, $CHCl_3$). – ^1H NMR (C_6D_6): δ = 7.75, 7.63 and 7.18 (3 m, 20 H, arom. H), 6.39 (d, $J_{1,2}$ = 6.0 Hz, 1 H, 1-H), 4.70 (dt, $J_{2,1}$ = 6.0 Hz, $J_{2,3} = J_{2,4}$ = 1.6 Hz, 1 H, 2-H), 4.37 (ddq, $J_{5,Me}$ = 6.4 Hz, $J_{5,4}$ = 2.0 Hz, $J_{5,3}$ = 1.6 Hz, 1 H, 5-H), 4.24 (ddd, $J_{3,4}$ = 4.0 Hz, $J_{3,2}$ = 2.0 Hz, $J_{3,5}$ = 1.6 Hz, 1 H, 3-H), 4.07 (ddd, $J_{4,5}$ = 2.0 Hz, $J_{4,3}$ = 4.0 Hz, $J_{4,2}$ = 1.6 Hz, 1 H, 4-H), 1.38 (d, $J_{Me,5}$ = 6.4 Hz, 3 H, 6-H), 1.05 (s, 18 H, 2 × *t*Bu). – ^{13}C NMR (C_6D_6): δ = 143.4, 136.2, 136.1, 136.0, 134.5 (q), 134.4 (q), 130.0, 129.9, 129.5, 100.2, 74.1, 74.0, 66.4, 30.1, 19.4, 19.3, 16.1. – $C_{38}H_{46}O_3Si_2$ (606.95): calcd. C 75.19, H 7.64; found C 75.20, H 7.68.

X-ray Crystallographic Study of **9a**: Crystal data are given in Table 1. A single crystal of **9a** was investigated on an Enraf-Nonius CAD4 diffractometer using graphite-monochromated Mo-*K*α radiation. The lattice constants were determined by the automatic Search and Indexing routines of the diffractometer. Indexing and refinement of 19 reflections in the range $3° \leq 2\theta \leq 26°$ led to an orthorhombic unit cell with the dimensions a = 965.0(2), b = 1462.1(7) and c = 2565.5(8) pm (V = 3620 Å^3, Z = 4). The space group $P2_12_12_1$ (No. 19)[21] was determined by the reflection conditions. The intensity data of 14128 reflections were measured at room temperature (20°C) in the range $2° \leq 2\theta \leq 64°$. For Lp correction and data processing the program XCAD4[22a] was used. The structure was solved by direct methods using the program SHELXS-86[22b]. The atomic parameters of the molecule were then completed by Fourier difference syntheses and refined (anisotropic displacement parameters for non-H-atoms) by full-matrix least-squares (against F^2) to the attainable R values $R1$ = 0.0813 [for 4152 reflections with $F_o > 4\sigma(F_o)$], w$R2$ = 0.1636 (for all 11507 unique reflections). The hydrogen atoms were refined as a riding model. No split positions were refined, although the behaviour of some thermal ellipsoids (methyl groups and one phenyl ring connected to the atom Si2) was indicative of disorder (see ORTEP plot, Figure 1)[22c]. The absolute structure was tested by refining the inverted structure, which yielded less good R values and a poor Flack-x parameter[23]. Crystallographic data (excluding structure factors) for the structure reported in this paper have been deposited with the Cambridge Crystallographic Data Centre. Copies of the data can be obtained free of charge on application to The Director, CCDC, 12 Union Road, Cambridge CB2 1EZ, UK [Fax (internat.) +44 (0)1223 336-033; e-mail: deposit@chemcrys.cam.ac.uk].

General Procedure for the Alkylation of Glycals: A solution of the glycal (1 equiv.) in absolute THF (2 ml/mmol) under nitrogen was stirred for 5 min. at −78°C. After addition of *tert*-BuLi (2.2 equiv., 1.6 M in hexane) the solution was allowed to warm to −10°C. The yellow mixture was maintained at this temp. for 1 h. Then, the alkylating agent (2.5 equiv.) was added and the mixture was stirred for a further 2 h at room temp. For work-up, the phases were separated after addition of saturated NH_4Cl solution. The aqueous phase was separated and extracted twice with diethyl ether. The combined organic layers were dried ($MgSO_4$) and concentrated in vacuo.

(+)-1,5-Anhydro-3,4-bis(O-tert-butyldiphenylsilyl)-2,6-didesoxy-1-C-ethyl-L-arabino-hex-1-enitol (**10a**): Preparation from 0.49 g (0.8 mmol) of (**9a**); FC with PE/EE/NEt_3 (80:1:1)[21] gave 0.3 g (61%), colorless crystals; m.p. 98°C (ether). – $[\alpha]_D^{20} = +43.5$ (c = 1, $CHCl_3$). – ^1H NMR (C_6D_6): δ = 7.77, 7.66 and 7.18 (3 m, 20 H, arom. H), 4.66 (dd, $J_{2,3}$ = 2.0, $J_{2,4}$ = 1.0 Hz, 1 H, 2-H), 4.43 (ddq, $J_{5,Me}$ = 6.4 Hz, $J_{5,4}$ = 2.0 Hz, $J_{5,3}$ = 2.0 Hz, 1 H, 5-H), 4.38 (ddd, $J_{3,4}$ = 5.2 Hz, $J_{3,2} = J_{3,5}$ = 2.0 Hz, 1 H, 3-H), 4.12 (ddd, $J_{4,3}$ = 5.2 Hz, $J_{4,5}$ = 2.0 Hz, $J_{4,2}$ = 1.0 Hz, 1 H, 4-H), 2.10 (q, J = 7.6 Hz, 2 H, CH_2CH_3), 1.42 (d, $J_{Me,5}$ = 6.4 Hz, 3 H, 6-H), 1.12 (m, 21 H, 2 × *t*Bu, CH_2CH_3). – ^{13}C NMR (C_6D_6): δ = 155.3, 136.3–136.0 (arom. C), 134.8–134.0 (4 q), 129.9–127.9 (arom. C), 94.7, 74.3, 73.8, 67.9, 28.1, 27.2, 19.4, 16.4, 11.9. – $C_{40}H_{50}O_3Si_2$ (635.0): calcd. C 75.66, H 7.94; found C 75.50, H 8.12.

1,5-Anhydro-3,4-bis(O-tert-butyldimethylsilyl)-2,6-didesoxy-1-C-methyl-L-arabino-hex-1-enitol (**10b**): Preparation from 553 mg (1.48 mmol) of (**9b**); FC with PE/EE/NEt_3 (180:1:1)[24] gave 412 mg (74%); analytical details of **10b** have been reported previously[25].

General Procedure for the Iodine(III)-Promoted Oxidation of Glycals: A suspension of the glycal (1 equiv.) and powdered molecular sieves (3 Å, 0.5 g/g glycal) in absolute acetonitrile (20 ml/mmol) under nitrogen was stirred for 5 min at 0°C. [Hydroxy(tosyloxy)iodo]benzene [1.2 equiv. (0.6 equiv. when glycal **14a** was employed)] was then added and the temperature was raised to ambient. After 1 h, the suspension was filtered through a pad of Celite and the residue was washed with CH_2Cl_2. The combined filtrate and washings were extracted with aqueous $NaHCO_3$ (10 ml/mmol), dried ($MgSO_4$), and concentrated under reduced pressure to afford a yellow oil.

(−)-(2R,3S)-3-(Benzyloxy)-2-[(benzyloxy)methyl]-2,3-dihydro-4H-pyran-4-one (**5**), *(+)-(2S,3S, 4R,5R)-5-[(Benzyloxy)methyl]-2,4-bis-(benzyloxy)-3-[1',1'-bis(benzyloxy)-methyl]tetrahydrofuran* (**6**) and *(−)-(2R,3S,4R,5R)-5-[(Benzyloxy)methyl]-2,4-bis-(benzyloxy)-3-[1',1'-bis[(benzyloxy)-methyl] tetrahydrofuran* (**7**): From **4** (3.5 g, 8.5 mmol); CC with PE/EE (12:1) gave two fractions:

1st Fraction: **5**, yield 1.6 g (58%); physical and spectroscopic data have been reported in ref.[2b].

2nd Fraction: mixture of **6** and **7**, yield 0.86 g (16%); FC with PE/EE (30:1) gave two fractions:

1st Fraction: **6**, colorless crystals, m.p. 70°C. – $[\alpha]_D^{21.5} = +46.3$ (c = 1.05, $CHCl_3$). – ^1H NMR (C_6D_6): δ = 7.37-7.04 (m, 25 H, arom. H), 5.30 (d, $J_{2,3}$ = 5.2 Hz, 1 H, 2-H), 5.18 (d, $J_{3',3}$ = 8.4 Hz, 1 H, 3'-H), 4.75, 4.37 (2 d, ^2J = 11.9 Hz, 2 H, OCH_2Ph at C-2), 4.70, 4.62, 4.52, 4.51 (4 d, ^2J = 11.9 and 11.7 Hz, 4 H, 2 × OCH_2Ph at C-3'), 4.60, 4.47 (2 d, ^2J = 11.4 Hz, 2 H, OCH_2Ph at C-4), 4.45, 4.40 (2 d, ^2J = 12.1 Hz, 2 H, CH_2OCH_2Ph at C-5), 4.63 (ddd, $J_{5,4}$ = 5.7 Hz, $J_{5,5'}$ = 5.7 Hz, $J_{5,5''}$ = 5.5 Hz, 1 H, 5-H), 4.31 (dd, $J_{4,5}$ = 5.7 Hz, $J_{4,3}$ = 5.2 Hz, 1 H, 4-H), 4.02 (dd, $J_{5',5''}$ = 10.0 Hz, $J_{5',5}$ = 5.5 Hz, 1 H, 5'-H, HCHOBn), 3.89 (dd, $J_{5'',5'}$ = 10.0 Hz, $J_{5'',5}$ = 5.7 Hz, 1 H, 5''-H, HCHOBn), 3.06 (ddd, $J_{3,3'}$ = 8.4 Hz, $J_{3,4}$ = 5.2 Hz, $J_{3,2}$ = 5.2 Hz, 1 H, 3-H). – ^{13}C NMR (C_6D_6): δ = 139.3–138.6 and 128.8–127.4 (arom. C), 101.9 (C-2), 101.6 (C-3'), 80.9 (C-4), 79.2 (C-5), 73.6 (5-CH_2OCH_2Ph), 73.0 (4-OCH_2Ph), 69.6 ($CH_2OCH2Ph$), 69.2 (2-OCH_2Ph), 68.9, 67.4 (2 × 3'-OCH_2Ph), 55.2 (C-3). – $C_{41}H_{42}O_6$ (630.78): calcd. C 78.07, H 6.71; found C 78.14, H 6.91.

2nd Fraction: **7**, colorless crystals, m.p. 64°C. – $[\alpha]_D^{21.5} = -44.3$ (c = 1.04, $CHCl_3$). – ^1H NMR (C_6D_6): δ = 7.36-7.05 (m, 25 H, arom. H), 5.41 (d, $J_{2,3}$ = 2.6 Hz, 1 H, 2-H), 4.92, 4.54 (2 d, ^2J = 11.9 Hz, 2 H, OCH_2Ph at C-2), 4.60 (d, $J_{3',3}$ = 6.6 Hz, 1 H, 3'-H), 4.59 (dddd, $J_{5,5'}$ = 6.6 Hz, $J_{5,4}$ = 6.3 Hz, $J_{5,5''}$ = 5.3 Hz, $J_{5,3}$ = 0.25 Hz, 1 H, 5-H), 4.54, 4.40, 4.37, 4.34 (4 d, ^2J = 14.6 and 11.8 Hz, 4 H, 2 × OCH_2Ph at C-3'), 4.47, 4.40 (2 d, ^2J = 11.9 Hz, 2 H, OCH_2Ph at C-4), 4.46, 4.42 (2 d, ^2J = 11.9 Hz, 2 H, CH_2OCH_2Ph at C-5), 4.25 (dd, $J_{4,5}$ = 6.2 Hz, $J_{4,3}$ = 4.0 Hz, 1 H, 4-H), 4.10 (dd, $J_{5'',5'}$ = 10.0 Hz, $J_{5'',5}$ = 5.3 Hz, 1 H, 5''-H, HCHOBn), 4.03 (dd, $J_{5',5''}$ = 10.0 Hz, $J_{5',5}$ = 6.6 Hz, 1 H, 5'-H, HCHOBn), 3.12 (dddd, $J_{3,3'}$ = 6.6 Hz, J3,4 = 4.0 Hz, $J_{3,2}$ = 2.6 Hz, $J_{3,5}$ = 0.25 Hz, 1 H, 3-H). – ^{13}C NMR (C_6D_6): δ = 139.3–138.4 and 128.6–127.4 (arom. C), 104.4 (C-2), 101.1 (C-3'), 80.9 (C-5), 80.5 (C-4), 73.5 (5-CH_2OCH_2Ph), 72.2 (4-OCH_2Ph), 70.8 (CH_2OCH_2Ph), 69.8 (2-OCH_2Ph), 68.5, 68.1 (2 × 3'-OCH_2Ph), 55.7 (C-3). – $C_{41}H_{42}O_6$ (630.78): calcd. C 78.07, H 6.71; found C 78.17, H 6.76.

(–)-(2S,3S)-3-(tert-Butyldimethylsiloxy)-2-methyl-2,3-dihydro-4H-pyran-4-one (**11a**) and *(+)-3,4-Bis(O-tert-butyldimethylsilyl)-1,2-bis-O-tosyl-6-desoxy-α-L-manno-pyranose* (**11b**): From **9b** (0.66 g, 1.85 mmol); CC with PE/EE (20:1) gave two fractions:

1st fraction: **11a**, yield 0.318 g (71%); physical and spectroscopic data have been reported in ref.[2b].

2nd fraction: **11b**, yield 86.5 mg (7%); colorless crystals, m.p. 58–61°C. – $[\alpha]_D^{20} = +42.1$ (c = 1.02, $CHCl_3$). – ^1H NMR (C_6D_6): δ = 7.96, 7.90 (2 d, 4 H, arom. H), 7.16 (d, $J_{1,2}$ = 8.4 Hz, 1 H, 1-H), 6.70 (2 d, 4 H, arom. H), 4.69 and 3.97 (2 s, 2 H, 3-H/4-H), 4.36 (d, $J_{2,1}$ = 8.4 Hz, 1 H, 2-H), 4.02 (q, $J_{5,Me}$ = 6.4 Hz, 1 H, 5-H), 1.79, 1.77 (2 s, 6 H, 2 × $PhCH_3$), 1.23 (d, $J_{Me,5}$ = 6.4 Hz, 3 H, 6-H), 1.12, 0.95 (2 s, 18 H, 2 × *t*Bu), 0.29, 0.23, 0.22, 0.20 (4 s, 12 H, 2 × $SiMe_2$). – ^{13}C NMR (C_6D_6): δ = 155.3, 136.3–136.0 (arom. C), 134.8–134.0 (4 q), 129.9–127.9 (arom. C), 94.7, 74.3, 73.8, 67.9, 28.1, 27.2, 19.4, 16.4, 11.9. – $C_{32}H_{52}O_9S_2Si_2$ (700.3): calcd. C 54.83, H 7.48; found C 55.09, H 7.69.

(–)-(2R,3S,4S,5S)-3,4-Bis(tert-butyldiphenylsiloxy)-2-formyl-5-methyltetrahydrofuran (**12a**): Preparation from **9a** (350 mg, 0.57 mmol); FC with PE/EE (80:1) gave 110 mg (31%) (630 mg crude) as a colorless oil. – $[\alpha]_D^{24} = -23.4$ (c = 1.08, $CHCl_3$). – IR (film): $\tilde{\nu}$ = 2960, 2930, 2860, 1732, 1260, 1115, 860 cm^{-1}. – ^1H NMR (C_6D_6): δ = 9.51 (s, 1 H, CHO), 7.43–6.85 (m, 20 H, arom. H), 4.46, 4.23 (2 s, 2 H, 3-H, 4-H), 4.08 (q, $J_{5,Me}$ = 6.4 Hz, 1 H, 5-H), 3.77 (s, 1 H, 2-H), 0.95 (d, $J_{Me,5}$ = 6.4 Hz, 3 H, CH-CH_3), 0.78, 0.69 (2 s, 18 H, 2 × *t*Bu). – ^{13}C NMR (C_6D_6): δ = 201.6, 136.2, 133.5 (q), 133.2 (q), 133.0 (q), 132.9 (q), 130.3, 130.1, 128.2, 128.1, 127.7, 91.1, 85.7, 83.2, 82.6, 27.1, 27.0, 19.5, 19.3 (q), 19.2 (q), 19.1 (q), 18.9 (q). – CI-MS, m/z = 640.3 [M–NH_4^+]. – $C_{38}H_{46}O_4Si_2$ (622.29): calcd. C 73.26, H 7.44; found C 73.29, H 7.60.

(–)-3,4-Bis-O-(tert-butyldiphenylsilyl)-6-desoxy-1C-ethyl-α-L-manno-pyranose (**12b**): Preparation from **10a** (103 mg, 0.16 mmol); CC with PE/EE (80:1) gave 11 mg (10%) of a colorless oil. – $[\alpha]_D^{20} = -39.2$ (c = 0.4, $CHCl_3$). – ^1H NMR (C_6D_6): δ = 7.80–7.55 and 7.30–7.10 (2 m, 20 H, arom. H), 4.67 (dd, $J_{3,4}$ = 3.2 Hz, $J_{2,3}$ = 0.8 Hz, 1 H, 3-H), 4.41 (dq, $J_{5,Me}$ = 6.4 Hz, $J_{5,4}$ = 0.8 Hz, 1 H, 5-H), 4.24 (d, $J_{2,3}$ = 0.8 Hz, 1 H, 2-H), 3.95 (dd, $J_{4,3}$ = 3.2 Hz, $J_{4,5}$ = 0.8 Hz, 1 H, 4-H), 2.16, 1.96 (dq, ^2J = 14.0 Hz, ^3J = 7.2 Hz, 2 H, CH_2CH_3), 1.26 (t, ^3J = 7.2 Hz, 3 H, CH_2CH_3), 1.21 (d, $J_{Me,5}$ = 6.4 Hz, 3 H, 6-H), 1.12, 1.08 (2 s, 18 H, 2 × *t*Bu). – ^{13}C NMR (C_6D_6): δ = 211.6, 92.2, 84.9, 83.7, 82.9, 32.1, 25.8, 25.7, 19.8, 18.0 17.9, 7.2, –4.8, –4.9. – $C_{40}H_{52}O_5Si_2$ (668.34): CI-MS, m/z = 686.7 [M–NH_4^+].

(–)-(2R,3S,4S,5S)-2-Acetyl-3,4-bis(tert-butyldimethylsiloxy)-5-methyltetrahydrofuran (**13a**) and *(–)-(2R,3S,4R)-4-Acetoxy-2,3-bis(tert-butyldimethylsiloxy)pentanal* (**13b**): From **10b** (214 mg, 0.55 mmol); CC with PE/EE (80:1) gave two fractions:

1st Fraction: **13a**, yield 54.4 mg (26%) colorless oil. – $[\alpha]_D^{22} = -9.6$ (c = 0.88, $CHCl_3$). – IR (film): $\tilde{\nu}$ = 2955, 2930, 2860, 1718, 1260, 1110, 837 cm^{-1}. – ^1H NMR (C_6D_6): δ = 4.54, 4.43 (2 s, 2 H, 3-H, 4-H), 4.23 (q, $J_{5,Me}$ = 6.4 Hz, 1 H, 5-H), 3.85 (d, ^4J = 0.8 Hz, 1 H, 2-H), 2.26 (bs, 3 H, $COCH_3$), 1.40 (d, $J_{Me,5}$ = 6.4 Hz, 3 H, CH-CH_3), 0.97, 0.90 (2 s, 18 H, 2 × *t*Bu), 0.18, 0.16, 0.05, 0.00 [4 s, 12 H, 2 × $Si(CH_3)_2$]. – ^{13}C NMR (C_6D_6): δ = 209.6, 92.1, 84.9, 83.6, 82.9, 26.6, 25.8, 19.7, 18.0 (q), 17.9 (q), –4.7, –4.9. – $C_{19}H_{40}O_4Si_2$ (388.19): CI-MS, m/z = 406.2 [M–NH_4^+].

2nd Fraction: **13b**, yield 13.0 mg (6%) colorless oil. – $[\alpha]_D^{22} = -44.1$ (c = 0.65, $CHCl_3$). – IR (film): $\tilde{\nu}$ = 2955, 2930, 2860, 1740, 1255, 840 cm^{-1}. – ^1H NMR (C_6D_6): δ = 9.83 (d, $J_{1,2}$ = 0.4 Hz, 1 H, CHO), 5.35 (dq, $J_{4,Me}$ = 6.4 Hz, $J_{4,3}$ = 3.2 Hz, 1 H, 4-H), 4.22 (dd, $J_{3,2}$ = 4.8 Hz, $J_{3,4}$ = 3.2 Hz, 1 H, 3-H), 4.12 (dd, $J_{2,3}$ = 4.8 Hz, $J_{2,1}$ = 0.4 Hz, 1 H, 2-H), 1.71 (s, 3 H, OAc), 1.29 (d, $J_{Me,4}$ = 6.4 Hz, 3 H, H-5), 1.01, 0.98 (2 s, 18 H, 2 × *t*Bu), 1.10, 0.95, 0.08, 0.05 [4 s, 12 H, 2 × $Si(CH_3)_2$]. – ^{13}C NMR (C_6D_6): δ = 201.3, 169.2, 79.7, 76.1, 71.2, 25.9, 25.8, 20.8, 18.4, 18.3, 15.6, –4.4, –4.5, –4.8, –5.4. – $C_{19}H_{44}O_5Si_2$ (404.22): CI-MS, m/z = 422.2 [M–NH_4^+].

2-Benzyloxy-4-[1,1'-bis(benzyloxy)methyl]furan (**8**): A solution of **6** (200 mg, 0.32 mmol) in 2 N aqueous HCl (15 ml) was stirred for 5 h at 65°C. After cooling to room temp., the solution was extracted 4 times with CH_2Cl_2 and the combined organic extracts were neutralized with aqueous $NaHCO_3$, dried ($MgSO_4$) and concentrated under reduced pressure. CC with PE/EE (4.5 : 1 → 9 : 1) gave 120 mg (90.5%) of a colorless oil. – ^1H NMR ($CDCl_3$): δ = 7.55 (s, 1 H), 7.43–7.30 (m, 15 H, arom. H), 6.38 (s, 1 H), 5.82 (s, 1 H), 4.71, 4.69, 4.60, 4.48 (4 s, 8 H, 3 × CH_2Ph, CH_2OBn). – ^{13}C NMR ($CDCl_3$): δ = 152.5, 141.3, 138.0, 128.6–127.0, 124.6, 108.7, 96.1, 72.0, 66.8, 63.9. – $C_{27}H_{26}O_4$ (414.51): calcd. C 78.24, H 6.32; found C 78.29, H 6.41.

Under the conditions described above, acid hydrolysis of **7** gave an almost identical result (reaction time 9 h).

4,6-Di-O-acetyl-β-D-talopyranose 1,2,3-Orthoacetate (**17**), *(–)-(2R,3S)-3-(Acetoxy)-2-[(acetoxy)methyl]-2,3-dihydro-4H-pyran-4-one* (**15a**), and *2-Deoxy-3,4,6-tri-O-acetyl-α-D-erythro-hex-2-enopyranose* (**16a**): From **14a** (2.0 g, 7.35 mmol) and (1.73 g, 4.41 mmol; 0.6 equiv.) of PhI(OH)OTs; CC with PE/EE (8:1) gave three fractions:

1st Fraction: **5**, yield 1.6 g (58%).

2nd Fraction: mixture of **6** and **7**, yield 0.86 g (16%); FC with PE/EE (30:1) gave two fractions:

1st Fraction: **17**: yield 50 mg (2.4%). – $[\alpha]_D^{20} = -21.8$ (c = 0.93, $CHCl_3$). – IR (film): $\tilde{\nu}$ = 3005–2910, 1740, 1405, 1370, 1260–1220, 1140, 1080, 1060–1010 cm^{-1}. – ^1H NMR ($CDCl_3$): δ = 5.71 (d, $J_{1,2}$ = 5.0 Hz, 1 H, 1-H), 4.64 (ddd, $J_{1,2}$ = 5.0 Hz, $J_{2,3}$ = 3.6 Hz, $J_{2,4}$ = 2.4 Hz, 1 H, 2-H), 4.58 (dd, $J_{2,3}$ = 3.6 Hz, $J_{3,4}$ = 0.8 Hz, 1 H, 3-H), 4.30 (dd, $J_{6,6'}$ = 11.2 Hz, $J_{6,5}$ = 6.6 Hz, 1 H, 6-H), 4.25 (dd, $J_{6',6}$ = 11.2 Hz, $J_{6',5}$ = 6.6 Hz, 1 H, 6'-H), 4.22 (ddd, $J_{4,5}$ = 3.6 Hz, $J_{4,2}$ = 2.4 Hz, $J_{4,3}$ = 0.8 Hz, 1 H, 4-H), 4.15 (ddd, $J_{5,6}$ = $J_{5,6'}$ = 6.6 Hz, $J_{5,4}$ = 3.6 Hz, 1 H, 5-H), 2.15, 2.04, 1.63 [3 s, 9 H, 2 × OAc, $(RO)_3CCH_3$]. – ^{13}C NMR ($CDCl_3$): δ = 169.7, 169.6, 117.5 [$(RO)_3CCH_3$], 97.7 (C-1), 75.8 (C-5), 72.6 (C-2), 69.7 (C-3), 64.0 (C-4), 63.5 (C-6), 20.0, 19.8, 19.4. – MS, m/z = 289 [M^+ + 1], 245 [M^+ – Ac], 229 [M^+ – OAc]. – $C_{12}H_{16}O_8$ (288.25): calcd. C 50.00, H 5.49; found C 49.55, H 5.19.

A solution of orthoester **17** (50 mg, 0.17 mmol) in THF (2 ml) was treated with 2 N HCl (0.5 ml) at room temp. After 5 min., the solution was neutralized with solid $NaHCO_3$. After extraction with CH_2Cl_2, the organic layer was dried ($MgSO_4$) and concentrated in vacuo. The yellow oil thus obtained was dissolved in dry pyridine and acetylated under standard conditions. After work-up, CC (petroleum ether/ethyl acetate, 1:1) gave 1,2,3,4,6-pentaacetyl-α/β-D-talose **18** (33 mg; 0.085 mmol, 50%) as a colorless oil.

2nd Fraction: **15a**: (0.48 g, 2.1 mmol, 29%). Physical and spectroscopic data for **15a** have been reported in ref.[2b].

3rd Fraction: **16a**: (21 mg; 0.73 mmol, 9.9%), semi-solid. – $[\alpha]_D^{20} = -161.3$ ($c = 0.96$, $CHCl_3$). – ^{1}H NMR ($CDCl_3$): δ = 5.77 (d, $J_{2,1} = 3.6$ Hz, 1 H, 2-H), 5.68 (d, $J_{1,2} = 3.6$ Hz, 1 H, 1-H), 5.42 (d, $J_{4,5} = 2.4$ Hz, 1 H, 4-H), 4.51 (ddd, $J_{5,6} = J_{5,6'} = 6.2$ Hz, $J_{5,4} = 2.4$ Hz, 1 H, 5-H), 4.19 (m, 2 H, 6-H, 6′-H), 2.14, 2.11, 2.06 (3 s, 9 H, 3 × OAc). – ^{13}C NMR ($CDCl_3$): δ = 170.5, 170.3, 168.8, (3 × OAc), 146.8 (C-3), 116.8 (C-2), 90.8 (C-1), 68.2 (C-5), 63.5 (C-4), 61.9 (C-6), 20.8, 20.7, 20.6 (3 × O_2CCH_3). – MS, *m/z* = 287 [$M^+ - 1$], 271 [$M^+ - OH$], 245 [$M^+ - Ac$], 229.1 [$M^+ - OAc$]. – $C_{12}H_{16}O_8$ (288.25): calcd. C 50.00, H 5.49; found C 50.61, H 5.73.

To a solution of **16a** (50 mg, 0.17 mmol) in CH_2Cl_2 (1 ml) was added a catalytic amount (1 mol%) of TfOH. Neutralization (solid $NaHCO_3$) after 5 min., concentration in vacuo and FC (petroleum ether/ethyl acetate, 1:1) afforded **15a** (38 mg, 0.16 mmol, 94%).

In Situ NMR Studies of Iodine(III)-Promoted Oxidations: **14a** (15 mg, 0.055 mmol) was dissolved in absolute CD_3CN at room temp. in an NMR tube, which had been flushed with nitrogen prior to use. Powdered molecular sieves (3 Å, 5 mg) were added, followed by [hydroxy(tosyloxy)iodo]benzene (26 mg, 0.066 mmol, 1.2 equiv.). ^{1}H-NMR spectra were recorded at intervals of about four minutes.

1st intermediate: **19b**. – The ^{1}H-NMR data of **19b** are presented in Table 3. After 4 h, the ^{1}H- and ^{13}C-NMR spectra showed enone **15a** to be the main product.

When **14b** (15 mg, 0.44 mmol) was treated under identical conditions with PhI(OH)OTs (20.5 mg, 0.52 mmol, 1.2 equiv.). NMR monitoring showed **19d** to be the primary intermediate. The ^{1}H-NMR data of **19d** are presented in Table 3. – ^{13}C NMR[16] (CD_3CN): δ = 99.9, 76.2, 65.2, 63.7, 61.6. After 4 h, the ^{1}H- and ^{13}C-NMR spectra showed the presence of enones **15b** and **20a**. Selected ^{1}H-NMR data of **20a** (CD_3CN): δ = 5.82 (m, 2 H, 1-H, 2-H), 4.76 (dt, $J = 4.6, 4.6, 10.4$ Hz, 1 H, 5-H). – ^{13}C NMR[16] (CD_3CN): δ = 145.6 (C-3), 106.1 (C-2), 91.8 (C-1), 69.4 (C-5), 61.9 (C-4), 61.1 (C-6).

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