Polymer-bound haloate(I) anions by iodine(III)-mediated oxidation of polymer-bound iodide: synthetic utility in natural product transformations

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Dedicated to Professor Anastassios Varvoglis on the occasion of his 65th birthday

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Abstract

A set of polymer-attached hypervalent iodate(I) complexes were prepared from polymer-bound iodide anion by ligand transfer of acetate and trifluoro acetate present in the corresponding iodine(III) reagents onto the iodide anion. The synthetic versatility of these polymer-bound reagents in terms of efficacy and ease of workup is demonstrated for selected examples in natural product synthesis and natural product derivatization. Thus, iodoacetoxylation of glycals is the initial step for the preparation of two deoxygenated disaccharides which are part of the carbohydrate units of the landomycins. In a second example, a one-pot multistep rearrangement of the decanolide decarestrictine D backbone is shown which is initiated by iodotrifluoroacylation of the olefinic double bond.

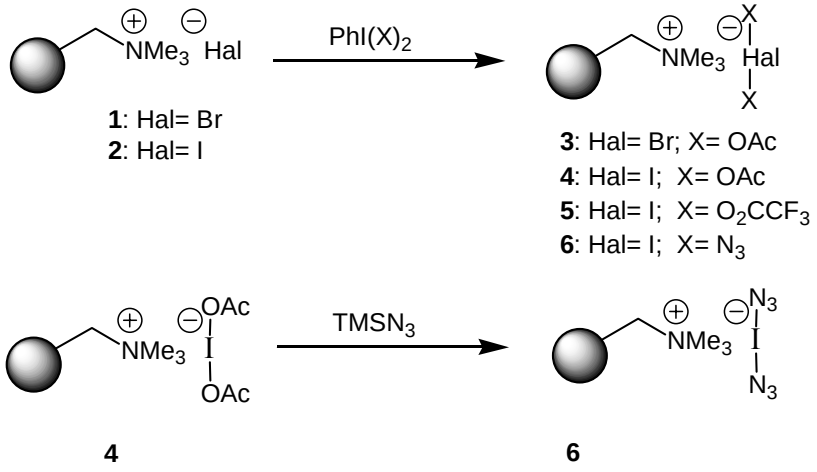
Keywords: Natural products, decanolide, glycosides, polymer-bound reagents, hypervalent iodine reagents, rearrangement

Introduction

Cohalogenation of alkenes constitutes one of the most important classes of reaction used to form a carbon heteroatom bond in a regio-, chemo- and stereoselective manner.[1] Among this class of reactions, haloacylations, haloazidations and the 1,2-addition of iodine isocyanate are of

particular relevance. Recently, we described a new class of anionic reagents, namely haloate(I) complexes, which synthetically behave like acylated hypohalite or iodoazide. The development of this new group of reagents was based on the observation that hypervalent iodine reagents[2] in the oxidation state III are able to oxidize iodide and bromide anions by ligand transfer from the hypervalent reagent onto the halide anion (Scheme 1).[3,4] The preparation of the acylated hypoiodite by this route proved to be superior to the thermal decomposition of aryl iodine diacetate which proceeds via three mechanisms. One of these routes was the nucleophilic displacement within an ion pair to give aryl acetate and acylated hypoiodite.[5] In another study, Varvoglis and coworkers showed that 4-nitrophenyl hypoiodite can be prepared by treatment of iodine with phenyliodine(III) diphenolate.[6]

The potential of these reagents was extended by immobilizing them onto polystyrene support via ion exchange. Thus, conventional anion exchange resins loaded with bromide **1** or iodide **2**, respectively, were oxidized by various hypervalent iodine reagents to yield resins **3** – **6** which were purified by filtration and washing in order to remove traces of iodobenzene and excess of the iodoso reagent. Alternatively, bisazidoiodate(I) anion **6** can be prepared by ligand exchange of bisacetoxy anion **4** using trimethylsilyl azide. The polymer-bound ate(I) complexes can be applied for various synthetic purposes. E. g., reagent **3** was employed for the bromoacetoxylation of alkenes and the oxidation of alcohols.[7] In addition, reagents **3** – **6** were successfully employed in iodoacylation and iodoazidation of alkenes.[8,9] Finally, electrophilic activation of phenylthio groups can be achieved with polymer-bound reagent **5**.[10]



Scheme 1

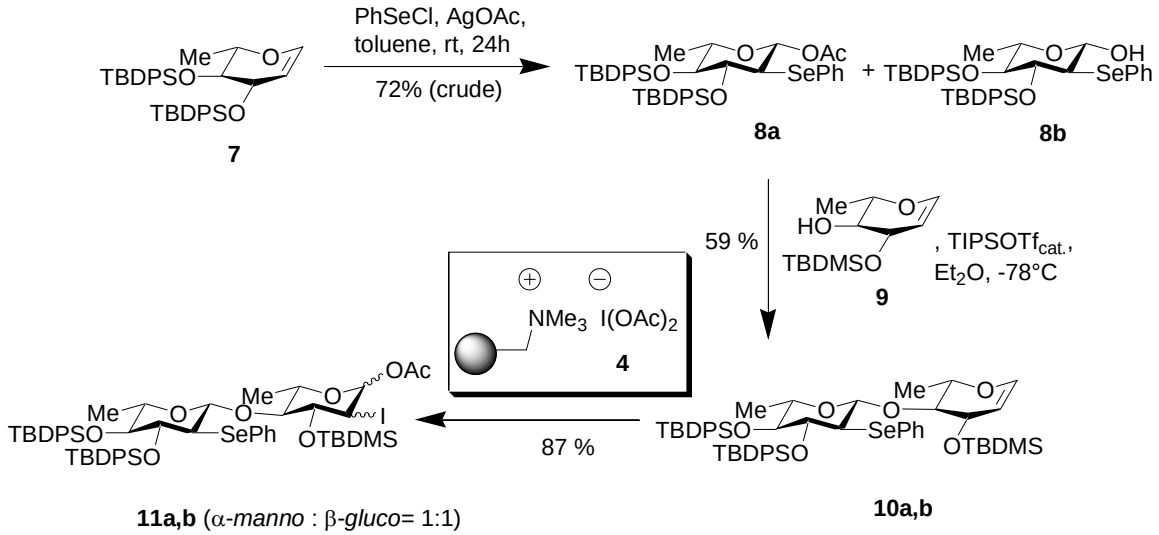
It is generally accepted that the synthetic power of new reagents becomes particularly evident when applications for the synthesis of complex molecules and natural products can be developed. In this article the utility of these reagents is extended to applications of natural product transformations.

Results and Discussion

Transformations in oligosaccharide synthesis

Glycoconjugates that are composed of an (oligo)deoxysugar portion and an aglycon are widely distributed in nature and are of wide clinical importance.[11] Importantly, alterations of the saccharide structures can result in improved biological activity, in particular against drug-resistant microorganisms. However, preparation of these glycoconjugates is still a challenging topic. In view of the importance and success of solid-phase chemistry various polymer-supported syntheses of oligosaccharides including deoxysugar analogues[12] have been developed.[13]

In conjunction with our research activities in this field,[14] polymer-bound haloate(I) complexes **3 - 6** were used for the polymer-assisted solution phase synthesis of deoxysugar-based glycoconjugates. In the context of deoxyglycoside synthesis, 2-iodo-glycosyl acetates are excellent glycosyl donors which can be activated for glycosidation with Lewis acids such as TMSOTf. Earlier studies had proven, that iodate(I)-complexes may promote 1,2-functionalization of glycals under very mild conditions and with excellent yields.[15]

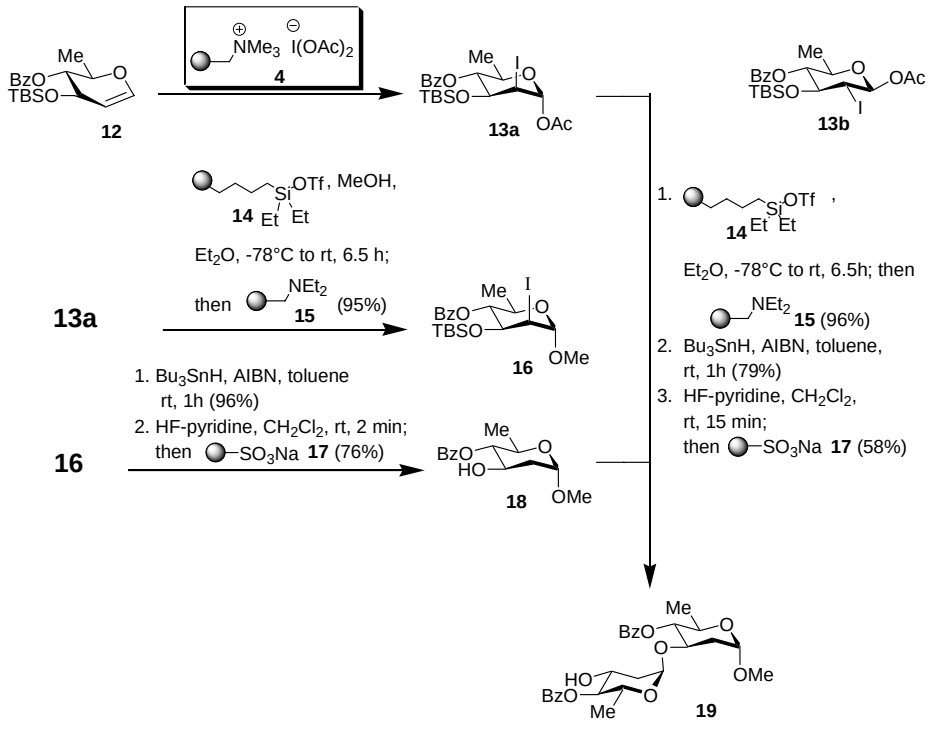


Scheme 2

As part of a synthesis directed towards the carbohydrate portion of the angucycline antibiotic landomycin,[16] it became necessary to prepare 2-seleno glycosyl acetate **8a** by following the method first described by Beau and coworkers.[17] Thus, glycal **7** was treated with phenylselenyl chloride in the presence of silver acetate to yield the 1,2-addition product **8a** as a single isomer. However at this stage it was difficult to prove the β-*gluco*-configuration of product **8a** because the coupling constants *J* for the ring protons in the ^{1}H NMR-spectrum are not diagnostic ($J_{1,2}$= 4.0 Hz, $J_{2,3}$= 3.6 Hz, $J_{3,4}$= 3.6 Hz, $J_{4,5}$ not determined). Furthermore, the acetyl group in pyranosyl acetate **8a** turned out to be very sensitive and was hydrolyzed upon attempted purification on silica gel which yielded pyranose **8b**. In accordance with the observations by

Beau and Perez, the β-*gluco* configured isomer was formed predominantly. Thus, the crude mixture was directly transferred into disaccharides by activation of the glycosyl acetate moiety with TIPS-triflate[18] in the presence of glycal **9**. As a result disaccharides **10a**,**b** were formed which contains a glycal moiety (Scheme 2). At this point, we tested the utility of the polymer-bound hypervalent iodate(I) reagent **4** as the resulting 2-iodo-glycosyl acetate is ideally suited for further glycosidations (*vide supra*). The functionalization of the enol ether bond in disaccharide of β-*gluco*-**10a** is a particular challenge, because the phenylseleno group is present in the molecule which is prone to oxidation. Iodonium cations are soft electrophiles which can coordinate to the seleno group inducing undesired side reactions. Polymer-bound iodate(I) complex **4** turned out to be a very mild reagent for the 1,2-iodoacetoxylation of the glycal double bond yielding glycosyl acetates **11a**,**b** as a diastereomeric mixture (α-*manno* : β-*gluco*= 1:1).

In the following this concept was further extended to disaccharide **19**, again using polymer-bound iodate(I) reagent **4** as the key reagent for the 1,2-functionalization of a glycal olefinic double bond (Scheme 3). In addition, polymer-bound silyl triflate **14**[19], used as an activator of the anomeric acyl group was used in this example.



Scheme 3

Thus, activation of the D-glucal derivative 12 with reagent 4 yielded the separable diastereomeric mixture of 2-iodo-glycosyl acetates 13a,b. Synthesis was continued with isomer 13a by treatment with silyltriflate 14 and methanol as acceptor which led to methyl glycoside 16. Polymer-bound amine (Amberlyst A-21) 15 was added at the end of the synthesis in order to

remove traces of CF_3SO_2H. Further modification included deiodination and *O*-desilylation. The former step was conducted under conventional deiodination conditions (Bu_3SnH, AIBN). Subsequently, desilylation was achieved using the HF-pyridine complex.[20] Excess desilylating reagent was removed with Amberlite A-200 (Na^+-form) 17. This scavenging reagent turned out to be very efficient for trapping protonated pyridine as well as the fluoride anion as its sodium salt. Both solids were simply filtered off and methyl glycoside 18 was isolated in pure form. Now, the stage was set for a second glycosidation step using olivosyl acetate 13a and polymer-bound silyl triflate 14. After neutralization, filtration and removal of the solvent in the usual manner, disaccharide was deiodinated and desilylated as described before to yield the target disaccharide 19. These sequences are a clear proof for the highly versatile synthetic properties of iodate(I) complex 4.

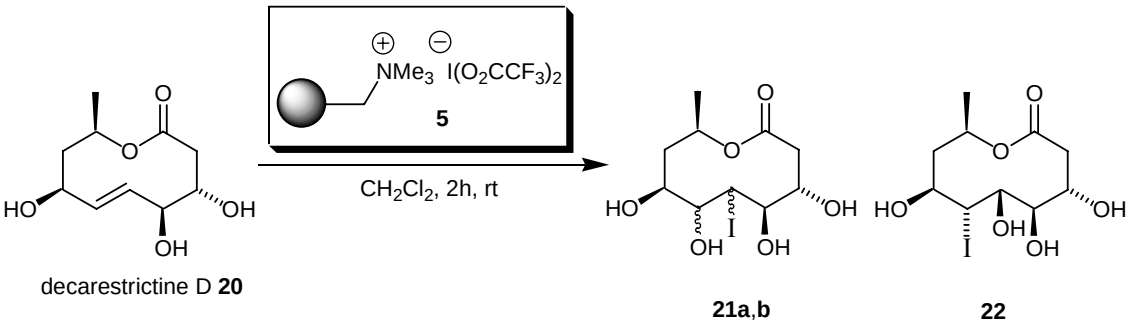
Polymer-assisted one-pot multistep rearrangement of decarestrictine D

In a second set of experiments, we envisaged synthetic multistep one-pot derivatizations of pharmaceutically important natural products using polymer-bound haloate(I) reagents. Recently, it became clear that combinatorial derived compound libraries are often large in size but lack quality because of defficiencies in structural uniqueness and diversity. This also includes multifunctionality and chirality. Due to the complexity of natural products only a few efforts have been made to synthesize libraries of natural products and analogues.[21] One of the best examples in this context are the sarcodyctynes for which the group of Nicolaou developed a solid-phase approach.[22] Alternatively, the inherent biological potency, the structural complexity and the threedimensional character of most natural products make them ideal templates for the creation of compound libraries which fulfill the requirements for quality. One approach is the stepwise "decoration" of individual functional groups on the chiral natural product-derived template employing combinatorial chemistry techniques. In this respect, carbohydrates served as templates in various applications, lately.[23] Alternatively but rarely tested, natural products can be the starting point of cascade-type transformations, which may include rearrangments of the carbon backbone.[24] Consequently, new natural product like systems with some of the chiral centers kept intact are generated for which structurally no reminiscence is desrcibed from natural sources.

Following this latter approach it was believed that as natural products are precious and are often available in only minute quantities, polymer-bound reagents like the electrophilic haloate(I) complexes **4** and **5** are ideally suited to carry out multistep transformations on a small scale. This technique allows simplification of work-up procedures and loss of material is reduced to a minimum.

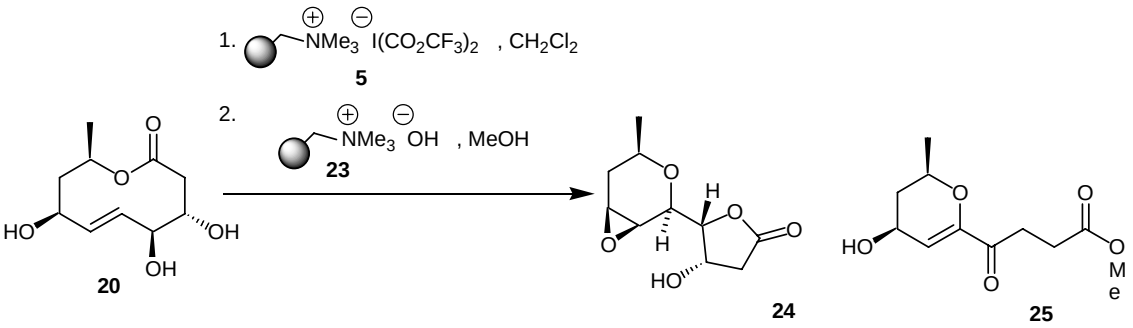
As a multifunctional natural product the ten-membered lacton decarestrictine D **20**[25] was chosen which among other decanolides was isolated from the fermentation broth of *Penicillium corylophilum, simplicissimum*, and independently from the fungus *polyphorus tuberaster*[26] it is an important new member of the growing class of ten-membered lactones of natural origin.[27] It was demonstrated that decanolide **20** is a potent *in vivo* inhibitor of de novo cholesterol

biosynthesis. Analyzing the donor and acceptor properties of all functional groups of decarestrictine, it is obvious that nucleophilic groups like the hydroxy group and the ester oxygen atoms and a masked carboxylate functionality prevail. The olefinic double bond, however can easily act as a counterpart if approached by an electrophilic species. Here, either the intermediate cation or the 1,2-addition products could initiate a cascade reaction.



Scheme 4

In an initial phase of the project, it was first tried to evaluate the reactivity of the olefinic double bond in decarestrictine D **20** by treatment of the unprotected natural product with polymer-bound bis-trifluoacetoxy iodate(I) **5** (Scheme 4). Purification on silica-gel afforded one fraction which contained a mixture of 1,2-functionalized products of which diastereomers **21a** and **21b** could be analytically deduced. Regio- and stereoisomer **22** was isolated as a second fraction. The formation of iodo hydrines can be rationalized by assuming that the primary 1-iodo-2-trifluoroacylation products hydrolyze upon work-up.

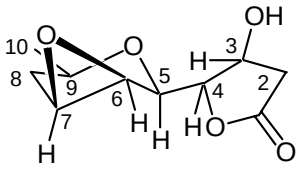


Scheme 5

Based on these preliminary results we reacted unprotected decarestrictine D with polymer-bound bis(trifluoroacetoxy)iodate(I) 5 (Scheme 5). As expected the intermediate addition products turned out to be rather labile (refer also to the results summarized in Scheme 4) so that the crude material was used for the next step. Indeed, when it was treated with polymer-bound hydroxide 23 in methanol two major products were identified by t.l.c. (about 50% crude). After

filtration and careful chromatographic purification, the natural product like compounds 24 and 25 were isolated. Obviously, the second reaction was accompanied with substantial rearrangement of the decanolide backbone. Structural evidence for the two products was gained from detailed NMR-spectroscopic analysis. Thus, a series of COSY, selective NOESY (Table 1), HMBC and selective TOCSY-experiments were carried out to assign the ^{1}H and ^{13}C signals as well as the relative stereochemistry between 5-H and 6-H in epoxylactone 24. Final structural proof was obtained from an X-ray analysis (Figure 1, Table 2).

Table 1. Observed NOEs in compound **24**



24

	Nuclear Overhauser Effects
10-H	8-H_{eq}, 8-H_{ax}, H-9
9-H	5-H, 8-H_{eq}(+), 8-H_{ax} (-), 10-H
7-H	6-H, 8-H_{eq}
6-H	5-H, 9-H
5-H	4-H, 9-H, 6-H, 3-OH
3-H	4-H, 6-H, 3-OH, 2-H_{eq}, 2-H_{ax}

It is worth to note that the relative orientation of the pyran ring and the lactone are opposite to each other in solution and in the crystal.

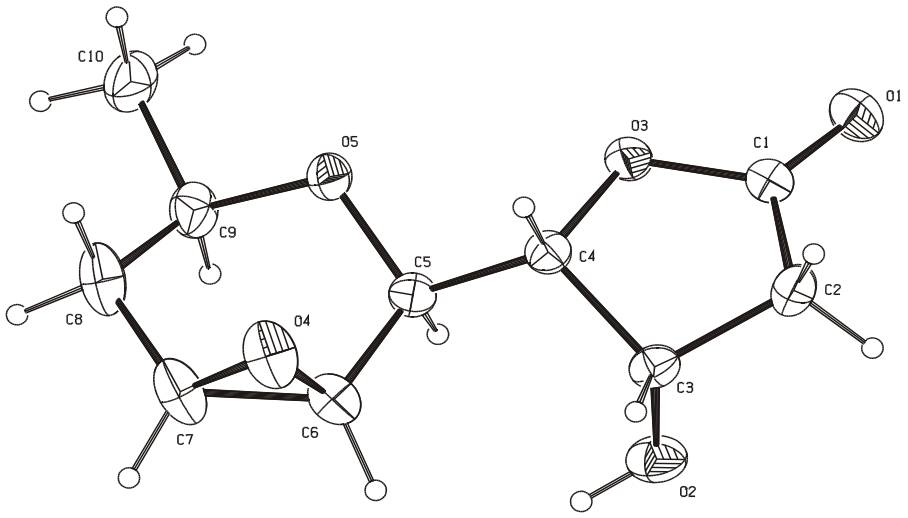
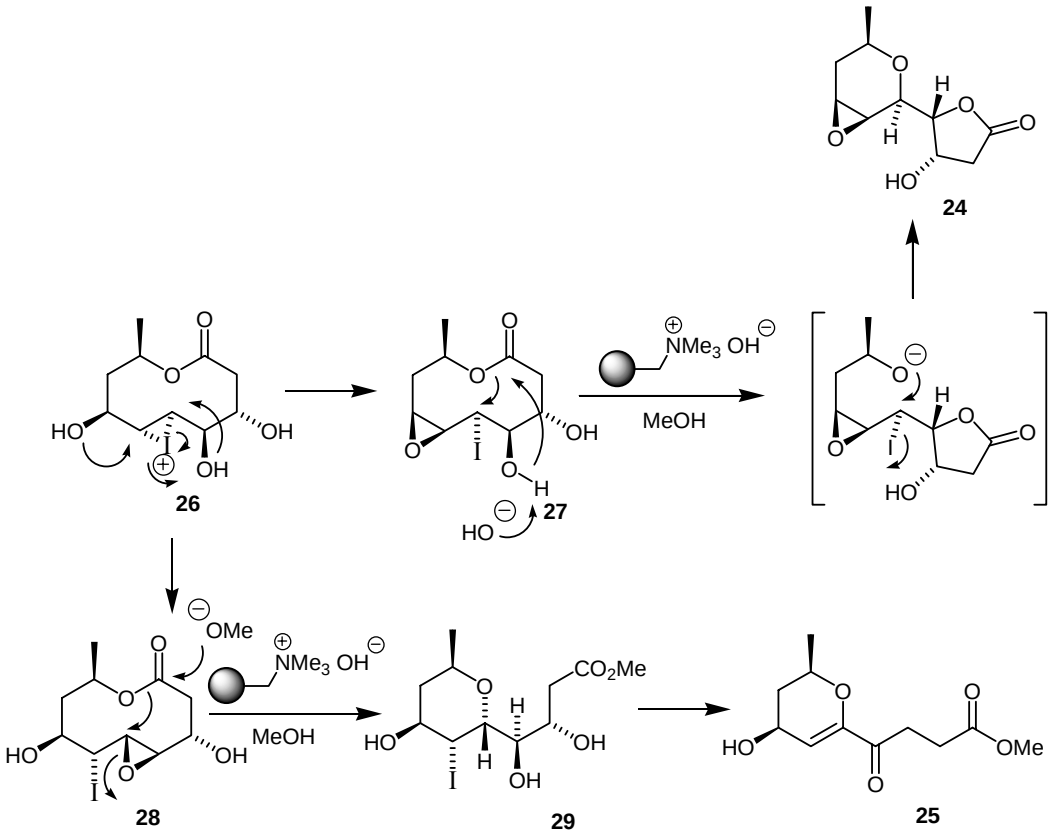


Figure 1. ORTEP representation of **24**.

Table 2. Significant interatomic bond distances and angles in **24**

Bond lengths [A]			
O(1)-C(1)	1.204(2)	C(2)-C(3)	1.501(2)
O(2)-C(3)	1.413(2)	C(3)-C(4)	1.529(2)
O(3)-C(1)	1.344(2)	C(4)-C(5)	1.506(2)
O(3)-C(4)	1.456(2)	C(5)-C(6)	1.491(2)
O(4)-C(6)	1.426(2)	C(6)-C(7)	1.446(2)
O(4)-C(7)	1.439(2)	C(7)-C(8)	1.485(3)
O(5)-C(5)	1.419(2)	C(8)-C(9)	1.510(3)
O(5)-C(9)	1.437(2)	C(9)-C(10)	1.509(3)
C(1)-C(2)	1.471(3)		
Bonding angles [°]			
C(1)-O(3)-C(4)	109.79(12)	C(5)-C(4)-C(3)	115.14(13)
C(6)-O(4)-C(7)	60.65(12)	O(5)-C(5)-C(6)	112.41(13)
C(5)-O(5)-C(9)	111.10(13)	O(5)-C(5)-C(4)	107.75(12)
O(1)-C(1)-O(3)	121.0(2)	C(6)-C(5)-C(4)	111.14(13)
O(1)-C(1)-C(2)	128.9(2)	O(4)-C(6)-C(7)	60.11(12)
O(3)-C(1)-C(2)	110.10(14)	O(4)-C(6)-C(5)	116.6(2)
C(1)-C(2)-C(3)	103.33(12)	C(7)-C(6)-C(5)	119.7(2)
O(2)-C(3)-C(2)	108.54(13)	O(4)-C(7)-C(6)	59.25(10)
O(2)-C(3)-C(4)	110.34(12)	O(4)-C(7)-C(8)	116.6(2)
C(2)-C(3)-C(4)	101.23(12)	C(6)-C(7)-C(8)	119.2(2)
O(3)-C(4)-C(5)	110.14(11)	C(7)-C(8)-C(9)	112.1(2)
C(10)-C(9)-C(8)	114.8(2)	O(5)-C(9)-C(10)	107.7(2)
O(3)-C(4)-C(3)	103.52(11)	O(5)-C(9)-C(8)	108.39(14)

Based on these data, it was possible to propose hypothetical mechanisms for the formation of rearranged products **24** and **25**. After α-attack of the iodonium cation to the olefinic double bond, intermediate **26** was either trapped by the hydroxy group at C-7 to yield oxirane **27** or alternatively by the 4-OH to furnish oxirane **28**. Deprotonation of the 4-hydroxy group by the polymer-bound hydroxide anion initiated lactonization followed by ring closure of the intermediate alkoxy anion at C-9. The second route begins with methanolysis of **28** which creates the methyl ester. Hence, the alkoxy anion at C-9 cyclized to yield tetrahyropyran **29**. In order to end up with dihydropyran **26** two elimination steps and a final tautomerization are required although the driving force of the process remains obscure. In order to get a more precise insight into the latter mechanism it will become necessary to search for additional byproducts.



Scheme 6

Conclusions

In summary, it was demonstrated that the oxidation of polymer-bound iodide by hypervalent iodine reagents in the oxidation state III results in the formation of polymer-bound iodate(I) complexes. These are versatile synthetic tools for transformations in natural product chemistry.

Experimental Section

General Procedures. Melting Points were determined on a melting point apparatus from Büchi. Flash chromatography was performed on silica gel (Merck 60, 70-230 mesh). Thin layer chromatography was performed on aluminium backd plates of silica gel 60 F254 (Merck, 0.2 mm) with the indicated eluent. NMR spectra were recorded on a Bruker ARX-400 (9.4 Tesla, 400.13 MHz for ^{1}H, 100.62 MHz for ^{13}C and on a Bruker ARX-500 (500.13 MHz for ^{1}H, 125.03 for ^{13}C). If not otherwise noted, chemical shifts are reported relative to the internal standard (TMS: δ = 0.0 ppm) for ^{1}H NMR and ^{13}C NMR. Coupling constants (*J* in Hz) are accurate to +/-

0.2 Hz. Mass spectra were recorded on a LC/MSD Series 1100, Hewlett Packard with the Kayak XA processing unit. Optical rotations $[\alpha]_D$ were measured with a Perkin Elmer 243B polarimeter (sodium line). Combustion analysis were carried out at the institute of pharmaceutical chemistry of the Technical University of Braunschweig.

Detailed descriptions for obtaining polymer-bound reagents **4** and **5** can be found in references[7,9,12]. The preparation of glycals **7**, **9** and **12** are reported in reference[28] and in the literature cited therein. Their preparation is based on a procedure disclosed by Beau and coworkers.[17]

Acetyl 3,4-bis-*O*-(*tert*-butyldiphenylmethylsilyl)-2,6-dideoxy-2-phenylseleno-β-L-*gluco*-hexopyranose 8a and 3,4-bis-*O*-(*tert*-butyldiphenylmethylsilyl)-2,6-dideoxy-2-phenylseleno-β-L-*gluco*-hexopyranose (8b). A solution of glycal **7** (1.05 g, 1.7 mmol) in abs. toluene (50 ml) was treated with PheSeCl (422 mg, 2.2 mmol) and AgOAc (435 mg, 2.6 mmol) at rt under nitrogen atmosphere. Stirring was continued for 3h after which time the silver salts were filtered off. The solution was concentrated in vacuo. The crude material (1.01 g, 1.23 mmol; 72%) obtained after gel filtration (silica gel; petroleum ether / ethyl acetate 12:1) can be used for the next step. For analytical purposes a small amount was purified by column chromatography (silica gel; petroleum ether / ethyl acetate 20:1).

1st fraction 8a. colorless oil; ^{1}H NMR (400 MHz, C_6D_6): δ = 7.70-7.10 (m, 25H, Ar), 6.32 (d, *J*= 4.0 Hz, 1H 1-H), 4.39 (dd, *J*= 3.6, 3.6 Hz, 1H, 3-H), 3.81 (dd, *J*= 3.6, 4.0 Hz, 1H, 2-H), 3.64 (m, 2H, 4-H, 5-H), 2.12 (s, 3H, OAc), 1.12 (d, *J*= 7.2 Hz, 3H, 6-H), 0.97, 0.79 (2s, 18H, 2x *t*Bu); ^{13}C-NMR (100 MHz, C_6D_6) δ: 169.5 (s, OAc), 132.4, 132.3, 131.9, 131.8, 129.0 (s, Ar), 135.6, 135.4, 134.6, 134.5, 132.0, 128.8, 128.7, 128.6, 128.5, 126.6, 126.5, 126.4, 126.3, 126.2 (d, Ar), 91.0 (d, C-1), 72.4, 71.5, 70.8 (d, C-3, C-4, C-5), 44.6 (d, C-2), 26.2, 25.6 (2q, CH_3 of *t*Bu), 20.5 (q, OAc), 19.0 (q, C-6), 18.5, 17.9 (2s, *t*Bu);

2nd fraction 8b. colorless solid; m.p.: 58°C; $[\alpha]_D^{23}$ = +32.5° (*c*= 0.93, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.7-7.0 (m, 25H, Ar), 5.30 (d, *J*= 2.0, 13.2 Hz, 1H, 1-H), 4.78 (dd, *J*= 2.0, 2.0 Hz, 1H, 3-H), 3.96 (q, *J*= 7.2 Hz, 1H, 5-H), 3.78 (d, *J*= 13.2 Hz, 1H, OH), 3.54 (d, *J*= 2.0 Hz, 1H, 4-H), 3.14 (dd, *J*= 2.0, 2.0 Hz, 1H, 2-H), 1.22 (d, *J*= 7.2 Hz, 3H, 6-H), 1.06, 0.95 (2s, 18H, 2x *t*Bu); ^{13}C-NMR (50 MHz, $CDCl_3$) δ: 133.4, 132.9, 132.3 (s, Ar), 135.9, 135.8, 135.6, 132.6, 130.0, 129.9, 129.7, 129.0, 128.2, 127.8, 127.7, 127.6, 127.5, 126.8 (d, Ar),84.9 (d, C-1), 76.9, 75.9, 71.2 (d, C-3, C-4, C-5), 54.3 (d, C-2), 27.0, 26.9 (2q, CH_3 of *t*Bu), 19.1, 18.9 (2s, *t*Bu), 16.6 (q, C-6); combustion analysis calcd (%) for $C_{44}H_{52}IO_4SeSi_2$: C 67.73, H 6.72; found C 67.38, H 7.06.

[3´,4´-bis-*O*-(*tert*-butyldiphenylmethylsilyl)-2´,6´-dideoxy-2´-phenylseleno-β-L-*gluco*-hexopyranosyl] (1-4)-1,5-anhydro-3-*O*-*tert*-butyldimethylsilyl-2,6-dideoxy-L-*arabino*-hex-1-enitol (10a). A solution of glycosyl acetate **8a** (1.45 g, 1.76 mmol) in abs. diethyl ether (50 ml) was cooled to –78°C and TIPSOTf (0.048 ml, 55 mg, 0.18 mmol) was added. After 10 minutes, glycal **9** (0.52 g, 2.1 mmol) was added. After 2h the reaction mixture was hydrolyzed with aqueous bicarbonate and the aqueous phase was extracted with dichloromethane. The combined

organic extracts were dried ($MgSO_4$), filtered and concentrated under reduced pressure. The crude material obtained was purified by column chromatography (silica gel; petroleum ether / ethyl acetate 30:1).

1st fraction 10a. (1.06 g, 1.05 mmol; 59%): colorless solid; m.p.: 95°C; $[\alpha]_D^{19}$ = +63.3° (*c*= 1.01, $CHCl_3$); ^{1}H NMR (200 MHz, C_6D_6, C_6H_6= 7.20 ppm): δ = 7.8-7.6 (m, 10H, Ar), 7.3-7.0 (m, 15H, Ar), 6.34 (dd, *J*= 0.8, 6.0 Hz, 1H 1-H), 5.69 (d, *J*= 6.4 Hz, 1H, 1-H'), 5.13 (d, *J*= 3.2 Hz, 1H, 4-H'), 4.80 (dd, *J*= 3.6, 6.0 Hz, 1H, 2-H), 4.50 (ddt, *J*= 0.8, 3.6, 4.0 Hz, 1H, 3-H), 4.24 (dq, *J*= 6.0, 6.4 Hz, 1H, 5-H), 3.96 (dd, *J*= 4.0, 6.0 Hz, 1H, 4-H), 3.86 (m, 2H, 2-H´, 5-H´), 3.72 (d, *J*= 3.6 Hz, 1H, 3-H´), 1.64 (d, *J*= 6.4 Hz, 3H, 6-H), 1.21, 1.14, 1.08 (3s, 27H, 3x *t*Bu), 1.0 (d, *J*= 6.4 Hz, 3H, 6-H´), 0.33, 0.25 (2s, 6H, $Si(CH_3)_2$); ^{13}C-NMR (100 MHz, C_6D_6, C_6H_6= 128.0 ppm) δ: 136.5, 136.4, 136.3, 136.2, 131.9, 130.2, 130.1, 130.0, 129.9, 129.0, 128.3, 128.1, 126.5 (d, Ar), 133.7, 133.6, 133.5, 133.4 (s, Ar), 143.1 (d, C-1), 103.8 (d, C´-1), 103.1 (d, C-2), 79.7 (d, C-4), 78.9, 78.8 (d, C´-4, C´-5), 73.7 (d, C´-3), 73.3 (d, C-5), 67.1 (d, C-3), 49.5 (d, C´-2), 27.4, 27.2, 26.2 (3q, CH_3 of *t*Bu), 20.2 (q, C´-6), 19.3, 19.2, 18.3 (3s, *t*Bu), 17.6 (q, C-6), -4.0, -4.6 (q, $Si(CH_3)_2$); combustion analysis calcd (%) for $C_{56}H_{74}O_6SeSi_3$: C 66.83, H 7.41; found C 66.89, H 7.83.

Acetyl [3´,4´-bis-*O*-(*tert*-butyldiphenylmethylsilyl)-2´,6´-dideoxy-2´-phenylselenyl-β-L-*gluco*-hexopyranosyl] (1-4)-3-*O*-*tert*-butyldimethylsilyl-2,6-dideoxy-2-iodo-β-L-*gluco*-hexopyranose 11a and acetyl [3´,4´-bis-*O*-(*tert*-butyldiphenylmethylsilyl)-2´,6´-dideoxy-2´-phenylselenyl-β-L-*gluco*-hexopyranosyl] (1-4)-3-*O*-*tert*-butyldimethylsilyl-2,6-dideoxy-2-iodo-α-L-*manno*-hexopyranose (11b). A solution of disaccharide **10** (215 mg, 0.21 mmol) in abs. dichloromethane (8 ml) was treated with polymer-bound reagent **4** (100mg) for 48 h at rt. Filtration and removal of the solvent in vacuo gave an oil which contained two diastereomers **11a** and **11b**. These were separated by column chromatography (silica gel; petroleum ether / ethyl acetate 50:1; 221 mg, 0.185 mmol; 87%).

1st fraction 11a. colorless solid; m.p.: 102°C; $[\alpha]_D^{22}$ = +22.9° (*c*= 0.99, $CHCl_3$); ^{1}H NMR (400 MHz, C_6D_6): δ = 7.78-7.50 (m, 9H, Ar), 7.31-7.02 (m, 16H, Ar), 6.01 (d, *J*= 10.0 Hz, 1H 1-H), 5.66 (d, *J*= 7.6 Hz, 1H, 1-H'), 5.20 (d, *J*= 3.2 Hz, 1H, 3-H'), 4.04 (dd, *J*= 10.0, 10.0 Hz, 1H, 2-H), 3.99 (m, 1H, 2-H´), 3.80 (dd, *J*= 8.0, 10.0 Hz, 1H, 3-H), 3.69 (q, *J*= 6.8 Hz, 1H, 5´-H), 3.56 (dd, *J*= 8.0, 8.8 Hz, 1H, 4-H), 3.50 (d, *J*= 3.2 Hz, 1H, 4-H´), 3.44 (dq, *J*= 6.4 8.8 Hz, 1H, 5-H), 1.90 (d, *J*= 6.4 Hz, 3H, 6-H), 1.72 (s, 3H, OAc), 1.32, 1.20, 1.15 (3s, 27H, 3x *t*Bu), 0.86 (d, *J*= 6.8 Hz, 3H, 6-H´), 0.68, 0.54 (2s, 6H, $Si(CH_3)_2$); ^{13}C-NMR (100 MHz, C_6D_6) δ: 168.2 (s, OAc), 136.5, 136.4, 136.3, 136.2, 131.8, 130.2, 130.1, 129.9, 129.2, 128.3, 128.0, 127.9, 127.8, 126.8 (d, Ar), 133.9, 133.6, 133.3, 133.2, 133.0 (s, Ar), 103.3 (d, C´-1) 94.4 (d, C-1), 81.5 (d, C-4), 80.3 (d, C-5), 80.1 (d, C´-3), 76.9 (d, C-3), 73.6 (d, C´-4), 73.1 (d, C´-5), 49.9 (d, C´-2), 35.8 (d, C-2), 27.4, 27.2, 27.0 (3q, CH_3 of *t*Bu), 20.3 (q, OAc), 19.9 (q, C-6), 19.6 (q, C´-6), 19.3, 18.9, 18.5 (3s, *t*Bu), 0.3, -2.4 (2q, $Si(CH_3)_2$); combustion analysis calcd (%) for $C_{58}H_{77}IO_8SeSi_3$: C 58.42, H 6.51; found C 58.68, H 6.43.

2nd fraction 11b. colorless solid; m.p.: 68°C; $[\alpha]_D^{22}$ = +31.9° (*c*= 1.01, $CHCl_3$); ^{1}H NMR (400 MHz, C_6D_6): δ = 7.82-7.60 (m, 9H, Ar), 7.32-7.00 (m, 16H, Ar), 6.74 (d, *J*= 4.0 Hz, 1H 1-H),

5.72 (d, *J*= 7.2 Hz, 1H, 1-H'), 5.14 (d, *J*= 4.0 Hz, 1H, 3-H'), 4.47 (dd, *J*= 4.0, 4.0 Hz, 1H, 2-H), 4.00 (m, 2H, 4-H, 5-H), 3.92 (d, *J*= 7.2 Hz, 1H, 2-H´), 3.90 (dq, *J*= 4.0, 7.2 Hz, 1H, 5´-H), 3.81 (br s, 1H, 3-H), 3.71 (d, *J*= 4.0 Hz, 1H, 4-H´), 1.82 (d, *J*= 4.8 Hz, 3H, 6-H), 1.66 (s, 3H, OAc), 1.21, 1.19, 1.18 (3s, 27H, 3x *t*Bu), 1.02 (d, *J*= 7.2 Hz, 3H, 6-H´), 0.47, 0.32 (2s, 6H, $Si(CH_3)_2$); ^{13}C-NMR (100 MHz, C_6D_6) δ: 168.1 (s, OAc), 136.5, 136.4, 136.3, 136.2, 131.8, 130.3, 130.1, 129.0, 127.9, 127.3, 126.5 (d, Ar), 133.7, 133.5, 133.4, 133.3, 133.0 (s, Ar), 104.8 (d, C´-1) 94.6 (d, C-1), 82.0 (d, C-5), 79.6 (d, C-5), 79.0 (d, C´-3), 73.8 (d, C´-4), 71.6 (d, C-4), 71.2 (d, C-3), 49.8 (d, C´-2), 30.2 (d, C-2), 27.3, 27.2, 26.4 (3q, CH_3 of *t*Bu), 20.3 (q, OAc), 20.1 (q, C-6), 19.6 (q, C´-6), 19.3, 19.1, 18.4 (3s, *t*Bu), -3.2, -4.8 (2q, $Si(CH_3)_2$); combustion analysis calcd (%) for $C_{58}H_{77}IO_8SeSi_3$: C 58.42, H 6.51; found C 58.12, H 6.67.

Acetyl 4-*O*-benzoyl-3-*O*-*tert*-butyldimethylsilyl-2,6-dideoxy-2-iodo-α-D-*manno*-hexopyranose 13a and acetyl 4-*O*-benzoyl-3-*O*-*tert*-butyldimethylsilyl-2,6-dideoxy-2-iodo-β-D-*gluco*-hexopyranose (13b). A solution of glycal **12** (6.2 g, 17.8 mmol) in abs. dichloromethane (50 ml) was treated with polymer-bound reagent **4** (4.7 g) for 52 h at rt. Filtration and removal of the solvent in vacuo gave an oil which contained two diastereomers **13a** and **13b** (2.7 : 1; >95% crude yield). These were separated by column chromatography (silica gel; petroleum ether / ethyl acetate 40:1).

1st fraction 13a. (5.9 g, 11.1 mmol; 62.4 %); colorless crystals, mp: 90°C; $[\alpha]_D^{23.5}$ = -37.2° (*c* = 1.25, $CHCl_3$); ^{1}H-NMR (200 MHz, $CDCl_3$, $CHCl_3$ = 7.26 ppm) δ: 8.10-7.97 (m, 2H, Ph_{ortho}), 7.64-7.52 (m, 1H, Ph_{para}), 7.51-7.38 (m, 2H, Ph_{meta}), 6.41 (d, 1H, *J*= 1.9 Hz, 1-H), 5.32 (dd, 1H, *J*= 9.6, 8.8 Hz, 4-H), 4.31 (dd, 1H, *J*= 4.3, 1.9 Hz, 2-H), 4.08 (ddq, 1H, *J* = 9.6, 6.3, 0.5 Hz, 5-H), 3.41 (ddd, 1H, *J*= 8.8, 4.3, 0.5 Hz, 3-H), 2.17 (s, 3H, 1-O-Ac), 1.27 (d, 3H, *J* = 6.3 Hz, 6-H), 0.78 (s, 9H, 3-O-Si-*t*Bu), 0.05, -0.12 (2s, 6H, 3-O-Si-Me_2); ^{13}C-NMR (50 MHz, $CDCl_3$, $CDCl_3$ = 77.0 ppm) δ: 168.6, 165.2 (2s, O-(O)CMe, O-(O)CPh), 133.2 (d, Ph_{para}), 129.8 (s, Ph_{ipso}), 129.8, 128.4 (2d, arom. CH), 95.3 (d, C-1), 75.5, 69.9, 67.7 (3d, C-3, C-4, C-5), 34.9 (d, C-2), 25.4 (s, Si-*t*Bu), 20.9 (q, O-(O)C*C*H_3), 17.7 (q, Si-*t*Bu), 17.6 (q, C-6), -4.6, -4.7 (2q, $Si(CH_3)_2$); combustion analysis calcd (%) for $C_{21}H_{31}IO_6Si$: C 47.19, H 5.85; found: C 47.01; H 5.87.

2nd fraction 13b. (2.18 g, 4.1 mmol; 23.0 %); colourless crystals, mp: 118°C; $[\alpha]_D^{23.0}$ = +25.1° (*c* = 0.28, $CHCl_3$); ^{1}H-NMR (200 MHz, $CDCl_3$, $CHCl_3$ = 7.26 ppm) δ: 8.14-7.96 (m, 2H, Ph_{ortho}), 7.64-7.52 (m, 1H, Ph_{para}), 7.52-7.38 (m, 2H, Ph_{meta}), 5.91 (d, 1H, *J*= 9.5 Hz, 1-H), 5.01 (dd, 1H, *J*= 9.7, 8.4 Hz, 4-H), 4.15 (dd, 1H, *J*= 9.8, 8.4 Hz, 3-H), 3.95 (dd, 1H, *J*= 9.8, 9.5 Hz, 2-H), 3.73 (dq, 1H, *J*= 9.7, 6.2 Hz, 5-H), 2.15 (s, 3H, 1-O-Ac), 1.21 (d, 3H, *J* = 6.2 Hz, 6-H), 0.80 (s, 9H, 3-O-Si-*t*Bu), 0.22, -0.19 (2s, 6H, 3-O-Si-Me_2); ^{13}C-NMR (50 MHz, $CDCl_3$, $CDCl_3$ = 77.0 ppm) δ: 168.8, 165.4 (2s, O-(O)*C*Me, O-(O)*C*-Ph), 133.4 (d, Ph_{para}), 129.7 (s, Ph_{ipso}), 129.7, 128.5 (2d, Ph), 94.1 (d, C-1), 76.7, 76.5, 71.3 (3d, C-3, C-4, C-5), 33.7 (d, C-2), 26.0 (s, Si-*t*Bu), 20.8 (q, O-(O)CCH_3), 18.1 (q, Si-*t*Bu), 17.5 (q, C-6), -3.2, -3.5 (2q, $Si(CH_3)_2$); combustion analysis calcd (%) for $C_{21}H_{31}IO_6Si$: C 47.19, H 5.85; found: C 47.11; H 5.73.

Methyl 4-*O*-benzoyl-3-*O*-*tert*-butyldimethylsilyl-2,6-dideoxy-2-iodo-α-D-*manno*-hexopyranoside (16). To a solution of glycosyl acetate **13a** (200 mg, 0.374 mmol) in dry diethyl ether (20 ml) at -70°C was added dry methanol (1 ml) and polymer-bound silyl triflate **14** (150 mg, about 0.6 eq.). The reaction mixture was shaken for 18h at rt and Amberlyst A-21 **15** (250 mg) was added for neutralization. Filtration at -40°C and washing of the resin with diethyl ether (3x 10 ml) gave a solution which was concentrated in vacuo to yield target glycoside **16** (181 mg, 0.357 mmol; 95.4 %); colorless oil; $[\alpha]_D^{23.5}$ = -43.6° (*c* = 1.35, $CHCl_3$); ^{1}H-NMR (200 MHz, $CDCl_3$, $CHCl_3$ = 7.26 ppm) δ: 8.10-7.98 (m, 2H, Ph_{ortho}), 7.63-7.51 (m, 1H, Ph_{para}), 7.51-7.38 (m, 2H, Ph_{meta}), 5.26 (dd, 1H, *J*= 9.5, 9.0 Hz, 4-H), 5.08 (d, 1H, *J*= 1.2 Hz, 1-H), 4.32 (dd, 1H, *J*= 4.5, 1.2 Hz, 2-H), 3.96 (dq, 1H, *J*= 9.5, 6.5 Hz, 5-H), 3.45 (dd, 1H, *J*= 9.0, 4.5 Hz, 3-H), 3.40 (s, 3H, OMe), 1.26 (d, 3H, *J*= 6.5 Hz, 6-H), 0.77 (s, 9H, Si-*t*Bu), 0.05, -0.15 (2s, 6H, Si-Me_2); ^{13}C-NMR (50 MHz, $CDCl_3$, $CDCl_3$ = 77.0 ppm) δ: 165.4 (s, *C*O-Ph), 133.1 (d, Ph_{para}), 130.0 (s, Ph_{ipso}), 129.7, 128.3 (2d, Ph), 102.7 (d, C-1), 76.2, 67.7, 67.1 (3d, C-3, C-4, C-5), 55.2 (q, OMe), 37.2 (d, C-2), 25.5 (q, Si-*t*Bu), 17.8 (s, Si-*t*Bu), 17.7 (q, C-6), -4.6, -4.8 (2q, $SiMe_2$); combustion analysis calcd (%) for $C_{20}H_{31}IO_5Si$: C 47.43, H 6.17; found: C 47.57; H 6.25.

Methyl 4-*O*-benzoyl-2,6-dideoxy-α-D-*arabino*-hexopyranoside (18). To a solution of methyl glycoside **16** (160 mg, 0.32 mmol) and Bu_3SnH (0.33 ml, 1.26 mmol, 4 eq.) in dry toluene (15 ml) was added AIBN (10 mg). The solution was heated for 1h at reflux. The solution was concentrated under reduced pressure and the crude product was purified by column chromatography (petroleum ether / ethyl acetate 30:1) to yield the deiodinated glycoside (115 mg, 0.3 mmol, 95.6%).

This material (97 mg, 255 mmol) was dissolved in dichloromethane (10 ml) and was dropwise treated with HF/pyridine complex (0.1 ml, 3.8 mmol, 15 eq.) for 2 min at room temperature. To this reaction mixture was added Amberlite A-200 (Na^+-Form, 100 mg) and shaking was continued for 30 min. Filtration and washing of the resin with dichloromethane (3x 5 ml) gave a solution which was concentrated in vacuo to yield the target glycoside **18** (54 mg, 0.19 mmol; 75.5%); ^{1}H-NMR (200 MHz, $CDCl_3$, $CHCl_3$ = 7.26 ppm) δ: 8.10-7.96 (m, 2H, Ph_{ortho}), 7.62-7.50 (m, 1H, Ph_{para}), 7.49-7.35 (m, 2H, Ph_{meta}), 4.76 (dd, 1H, *J*= 3.8, 1.2 Hz, 1-H), 4.76 (dd, 1H, *J*= 9.7, 9.1 Hz, 4-H), 4.14 (ddd, 1H, *J*= 11.5, 9.1, 5.3 Hz, 3-H), 3.89 (dq, 1H, *J*= 9.7, 6.3 Hz, 5-H), 3.34 (s, 3H, OMe), 2.23 (ddd, 1H, *J*= 13.1, 5.3, 1.2 Hz, 2-H_{eq}), 1.78 (ddd, 1H, *J*= 13.1, 11.5, 3.8 Hz, 2-H_{ax}), 1.22 (d, 3H, *J*= 6.3 Hz, 6-H); ^{13}C-NMR (50 MHz, $CDCl_3$, $CDCl_3$ = 77.0 ppm) δ: 166.9 (s, 4-O-*C*O-Ph), 133.3 (d, Ph_{para}´), 129.7, 128.4 (2d, Ph), 129.5 (s, Ph_{ipso}), 98.2 (d, C-1), 79.3 (d, C-4), 67.4, 65.4 (dd, C-3, C-5), 54.7 (q, OMe), 38.0 (t, C-2), 17.6 (q, C-6); combustion analysis calcd (%) for $C_{14}H_{18}O_5$: C 63.15, H 6.81; found: C 63.04 H 6.77.

Methyl (4´-*O*-benzoyl-2´,6´-dideoxy-α-D-*arabino*-hexopyranosyl) (1-3)-4-*O*-benzoyl-α-D-*arabino*-hexopyranosid (19). To a solution of methyl glycoside **18** (50 mg, 0.19 mmol) and glycosyl acetate **13a** (160 mg, 0.30 mmol, 1.6 eq.) in dry diethyl ether (5 ml) at -70°C was added polymer-bound silyl triflate **14** (100 mg, about 0.54 eq.). The reaction mixture was shaken for 6.5h at room temperature and Amberlyst A-21 **15** (60 mg) was added for neutralization. Filtration and washing of the resin with diethyl ether (3x 3 ml) gave a solution which was

concentrated in vacuo. The crude oil was purified by gel filtration (silica gel; petroleum ether / ethyl acetate 15 : 1) to yield the disaccharide (120 mg, 0.16 mmol; 85.6 %); ^{1}H-NMR (400 MHz, $CDCl_3$, $CHCl_3$ = 7.26 ppm) δ: 8.07-7.99 (m, 4H, Ph_{ortho}), 7.63-7.52 (m, 2H, Ph_{para}), 7.51-7.38 (m, 4H, Ph_{meta}), 5.24 (br s, 1H, 1-H), 5.17 (dd, 1H, *J*= 9.8, 8.9 Hz, 4-H), 5.01 (dd, 1H, *J*= 9.8, 9.4 Hz, 4′-H), 4.80 (d, 1H, *J*= 3.4 Hz, 1′-H), 4.16 (ddd, 1H, *J*= 11.7, 9.4, 5.1 Hz, 3′-H), 4.01 (dq, 1H, *J*= 9.8, 6.4 Hz, 5-H), 3.94 (dq, 1H, *J*= 9.8, 6.4 Hz, 5′-H), 3.90 (dd, 1H, *J*= 4.2, 1.2 Hz, 2-H), 3.36 (s, 3H, OMe), 3.31 (dd, 1H, *J*= 8.9, 4.2 Hz, 3-H), 2.36 (ddd, 1H, *J*= 12.8, 5.1, 0.7 Hz, 2′-H_{eq}), 1.92 (ddd, 1H, *J*= 12.8, 11.7, 3.4 Hz, 2′-H_{ax}), 1.25 (d, 3H, *J*= 6.4 Hz, 6′-H), 1.20 (d, 3H, *J*= 6.4 Hz, 6-H), 0.66 (s, 9H, Si-*t*Bu′), -0.17, -0.22 (2s, 6H, Si-Me_2′); ^{13}C-NMR (100 MHz, $CDCl_3$, $CDCl_3$ = 77.0 ppm) δ: 165.8, 165.3 (2s, 4-O-*C*O-Ph, 4'-O-*C*O-Ph), 133.4, 133.0 (2d, Ph_{para}′), 129.9, 129.4 (2s, Ph_{ipso}′), 129.7, 129.7 (2d, Ph_{ortho}′), 128.6, 128.3 (2d, Ph_{meta}′), 103.4 (d, C-1), 98.1 (d, C-1′), 76.9 (d, C-4), 76.5 (d, C-3′), 76.1 (d, C-4′), 67.6 (d, C-5), 67.4 (d, C-3), 65.7 (d, C-5′), 54.7 (q, OMe), 37.2 (d, C-2′), 37.0 (t, C-2′), 25.4 (q, Si-*t*Bu′), 17.6 (q, C-6′), 17.6 (s, Si-*t*Bu′), 17.5 (q, C-6), -5.0 (q, Si-Me_2′).

This material (72 mg, 97 μmol) and Bu_3SnH (0.08 ml, 0.3 mmol, 3.1 eq.) in dry toluene (10 ml) was added AIBN (10 mg). The solution was heated for 5h at reflux. The solution was concentrated under reduced pressure and the crude product was purified by column chromatography (petroleum ether / ethyl acetate 50:1) to yield the deiodinated glycoside (47 mg, 76 μmol, 78.6%). ^{1}H-NMR (400 MHz, $CDCl_3$, $CHCl_3$ = 7.26 ppm) δ: 8.08-7.99 (m, 4H, Ph_{ortho}), 7.62-7.51 (m, 2H, Ph_{para}), 7.49-7.39 (m, 4H, Ph_{meta}), 5.00 (dd, 1H, *J* = 9.9, 9.4 Hz, 4′-H), 4.92 (d, 1H, *J* = 3.2 Hz, 1-H), 4.81 (dd, 1H, *J* = 9.7, 9.2 Hz, 4-H), 4.80 (d, 1H, *J* = 3.4 Hz, 1′-H), 4.12 (ddd, 1H, *J*= 11.6, 9.4, 5.2 Hz, 3′-H), 4.09 (ddd, 1H, *J*= 11.3, 9.2, 5.1 Hz, 3-H), 3.94 (dq, 1H, *J* = 9.7, 6.4 Hz, 5-H), 3.92 (dq, 1H, *J* = 9.9, 6.3 Hz, 5′-H), 3.36 (s, 3H, OMe), 2.33 (dd, 1H, *J* = 12.9, 5.2 Hz, 2′-H_{eq}), 1.92 (ddd, 1H, *J* = 12.9, 11.6, 3.4 Hz, 2′-H_{ax}), 1.72 (dd, 1H, *J* = 13.0, 5.1 Hz, 2-H_{eq}), 1.55 (ddd, 1H, *J* = 13.0, 11.3, 3.2 Hz, 2-H_{ax}), 1.24 (d, 3H, *J* = 6.3 Hz, 6′-H), 1.14 (d, 3H, *J* = 6.4 Hz, 6-H), 0.63 (s, 9H, Si-*t*Bu′), -0.18, -0.22 (2s, 6H, Si-Me_2′); ^{13}C-NMR (50 MHz, $CDCl_3$, $CDCl_3$ = 77.0 ppm) δ: 165.6 (s, 4-O-*C*O-Ph, 4'-O-*C*O-Ph), 133.2, 132.9 (2d, Ph_{para}), 130.1, 129.8 (2s, Ph_{ipso}), 129.6, 129.5 (2d, Ph_{ortho}), 128.5, 128.2 (2d, Ph_{meta}), 99.5 (d, C-1), 98.2 (d, C-1′), 79.3 (d, C-4), 76.8, 75.5 (2d, C-3′, C-4′), 67.2 (d, C-3), 66.4, 65.8 (2d, C-5, C-5'), 54.7 (q, OMe), 39.2 (t, C-2), 37.2 (t, C-2′), 25.4 (q, Si-*t*Bu′), 17.7, 17.5 (2q, C-6, C-6′), 17.5 (s, Si-*t*Bu′), -4.9, -5.1 (2q, Si-Me_2′).

This material (47 mg, 76 μmol) was dissolved in dichloromethane (10 ml) and was dropwise treated with HF/pyridine complex (0.05 ml, 1.9 mmol, 25 eq.) for 15 min at room temperature. To this reaction mixture was added Amberlite A-200 (Na^+-Form, 50 mg) and shaking was continued for 30 min. Filtration and washing of the resin with dichloromethane (3x 2 ml) gave a solution which was concentrated in vacuo to yield the target glycoside **19** (22 mg, 44 μmol; 57.7%); ^{1}H-NMR (400 MHz, $CDCl_3$, $CHCl_3$ = 7.26 ppm) δ: 8.09-8.00 (m, 4H, Ph_{ortho}), 7.62-7.54 (m, 2H, Ph_{para}), 7.50-7.41 (m, 4H, Ph_{meta}), 4.98 (dd, 1H, *J*= 9.9, 9.3 Hz, 4′-H), 4.97 (d, 1H, *J*= 3.8 Hz, 1-H), 4.80 (d, 1H, *J*= 3.4 Hz, 1′-H), 4.69 (dd, 1H, *J*= 9.6, 9.4 Hz, 4-H), 4.16 (ddd, 1H, *J*= 11.6, 9.3, 5.2 Hz, 3′-H), 4.09 (br m, 1H, 3-H), 3.96 (dq, 1H, *J*= 9.6, 6.3 Hz, 5-H), 3.93 (dq, 1H,

J= 9.9, 6.4 Hz, 5′-H), 3.37 (s, 3H, OMe), 2.28 (dd, 1H, *J*= 13.0, 5.2 Hz, 2′-H_{eq}), 2.22 (br s, 1H, 3-OH), 1.93 (dd, 1H, *J*= 12.8, 5.3 Hz, 2-H_{eq}), 1.92 (ddd, 1H, *J*= 13.0, 11.6, 3.4 Hz, 2′-H_{ax}), 1.55 (ddd, 1H, *J*= 12.8, 11.8, 3.8 Hz, 2-H_{ax}), 1.23 (d, 3H, *J*= 6.4 Hz, 6′-H), 1.20 (d, 3H, *J*= 6.3 Hz, 6-H); ^{13}C-NMR (100 MHz, $CDCl_3$, $CDCl_3$ = 77.0 ppm) δ: 166.9, 165.7 (2s, 4-O-*C*O-Ph, 4'-O-*C*O-Ph), 133.4, 133.3 (2d, Ph_{para}), 129.8, 129.6 (2d, Ph_{ortho}), 129.7, 129.5 (2s, Ph_{ipso}), 128.6, 128.5 (2d, Ph_{meta}), 99.1 (d, C-1), 98.2 (d, C-1′), 79.3 (d, C-4), 77.0 (d, C-4′), 74.8 (d, C-3′), 67.2 (d, C-3), 65.9 (d, C-5), 65.9 (d, C-5′), 54.7 (q, OMe), 38.3 (t, C-2), 37.2 (t, C-2′), 17.7, 17.6 (2q, C-6, C-6').

Reaction of decarestrictine D 20 with polymer-bound reagent (5). Decarestrictine D **20** (5mg, 23 μmol) was dissolved in dry dichloromethane (1 ml) at rt. Then, polymer-bound iodate(I) complex **5** (74.6 mg) was added and the suspension was shaken for 2h under the exclusion of light. The polymer was filtered off and washed with methanol. The solvent was removed under reduced pressure. The crude product (11 mg) was purified by gradient column chromatography over silica gel (dichloromethane : methanol = 20:1 to 1:1).

1st fraction 21a and **21b.** (1:0.36; 5 mg, 13.9 μmol, 60 %): colourless oil; first isomer **21a**: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 5.12 (d, *J*= 7.0 Hz, 1H, 3-OH), 4.80 (dddd, *J*= 9.0, 8.0, 7.0, 6.0 Hz, 1H, 3-H), 4.11(dd, *J*= 10.4, 3.6 Hz, 1H, 6-H), 4.07 (dd, *J*= 10.4, 1.2 Hz, 1H, 5-H), 3.91-3.88 (m, 1H, 7-H), 3.77, (ddq, *J*= 11.2, 6.2, 1.8 Hz, 1H, 9-H), 3.52 (d, *J*= 9.0, 1.2 Hz, 1H, 4-H), 2.83 (dd, *J*= 18.0, 8.0 Hz, 1H, 2-H_{eq}), 2.62 (dd, *J*= 18.0, 6.0 Hz, 1H, 2-H_{ax}), 2.44 (brs, 1H, 7-OH), 2.08 (ddd, *J*= 13.2, 4.6, 1.8 Hz, 1H, 8-H_{eq}), 1.50 (ddd, *J*= 13.2, 11.2, 11.2 Hz, 1H, 8-H_{ax}), 1.28 (d, *J*= 6.2 Hz, 3H, 10-H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 174.2 (q, C-1), 79.4 (t, C-6), 78.7 (t, C-4), 73.8 (t, C-7), 72.9 (t, C-9), 69.8 (t, C-3), 41.6 (s, C-8), 38.3 (t, C-5), 38.4 (s, C-2), 21.3 (p, C-10).

Second isomer 21b. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.66 (ddd, *J*= 5.8, 5.8, 4.6 Hz, 1H, 3-H), 4.30 (ddd, *J*= 9.0, 5.8, 0.8 Hz, 1H, 4-H), 4.08 (brd, *J*= 7.0 Hz, 1H, 6-H), 3.91 (ddd, *J*= 11.2, 4.6, 1.2 Hz, 1H, 7-H), 3.60, (ddq, *J*= 11.2, 6.2, 1.8 Hz, 1H, 9-H), 3.52 (dd, *J*= 16.4, *J*= 6.0 Hz, 1H, 2-H_{eq}), 3.38 (dd, *J*= 16.4, 4.4 Hz, 1H, 2-H_{ax}), 2.49 (brd, *J*= 9.0 Hz), 2.44 (brs, 1H, 7-OH), 2.08 (ddd, *J*= 13.2, 4.6, 1.8 Hz, 1H, 8-H_{eq}), 1.44 (ddd, *J*= 13.2, 11.2, 11.2 Hz, 1H, 8-H_{ax}), 1.25 (d, *J*= 6.2 Hz, 3H, 10-H).

2nd fraction 22. (2.4 mg, 6.7 mmol; 29%): light yellow oil; ^{1}H NMR (400 MHz, CD_3OD, CH_3OH= 3.31 ppm) δ: 4.06-3.98 (m, 2H, 3-H and 4-H), 4.03 (dd, *J*= 10.6, 10.6, 1H, 6-H), 3.73 (brddd, *J*= 10.6, 10.6, 4.8 Hz, 1H, 7-H), 3.62 (dd, *J*= 10.6, 1.2 Hz, 1H, 5-H), 3.54 (ddq, *J*= 6.0, 10.6, 10.6 Hz, 9-H), 2.42 (dd, *J*= 15.2, 3.6 Hz, 1H, 2-H_{eq}), 2.28 (dd, *J*= 15.2, 8.4 Hz, 1H, 2-H_{ax}), 1.88 (dd, ^{2}*J*= 12.8, 4.8, 1.6 Hz, 1H, 8-H_{eq}), 1.25 (ddd, *J*= 12.8, 10.6. 10.6 Hz, 1H, 8-H_{ax}), 1.11 (d, *J*= 6.0 Hz, 10-H); ^{13}C NMR (100 MHz, CD_3OD, CD_3OD = 39.0 ppm) δ: 177.3 (q, C-1), 82.1 (t, C-5), 75.2 (t, C-4), 75.1 (t, C-7), 73.6 (t, C-3), 73.2 (t, C-9), 44.9 (s, C-8), 40.2 (s, C-2), 39.9 (t, C-6), 21.4 (p, C-10); LR-MS: (ESI) 383 $(M+Na^+)^+$.

Successive treatment of decarestrictine D 20 with polymer-bound reagents 5 and 23: Preparation of 4*R*-(2´*S*, 3´*S*-epoxy-5´-methyl-1´*R*-pyranosyl)-3*S*-hydroxy-butanolide 24 and 4-(4*S*-hydroxy-6*S*-methyl-5,6-dihydro-4*H*-pyran-2-yl)-4-oxo-butanoic acid methylester (25). Decarestrictine D (**1**) (39.9 mg, 185 μmol) was dissolved in dry dichloromethane (2 mL) under nitrogen. Polymer-bound iodate(I) complex **5** (550 mg) was added to the solution. The resulting suspension was shaken (300 rpm) After 30 min, the suspension had turned to red, the polymer was filtered off and washed with dry dichloromethane. The solvent was removed in vacuo and the crude product (60 mg) was dissolved in dry methanol and IRA-900(300 mg, hydroxide form) was added. The suspension was shaken (300 rpm) for three hours at room temperature. The polymer was filtered and washed with methanol. After removal of the solvent in vacuo the crude product was first purified by column chromatography on silica (dichloromethane : methanol = 30:1). Among other fractions pure γ-lactone **24** (3.6 mg, 16.8 μmol; 9%) was isolated. Then the eluent was switched (chloroform : methanol = 40 :1 and finally toluene : ethylacetate = 2 : 1) and a second pure compound **25** (2.5 mg, mmol; 6%) was isolated.

1st fraction 24. colourless crystals, mp.: 158°C; $[\alpha]_D^{22}$ = -26.3° (*c*= 0.3, $CDCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.8 (dddd, *J*= 5.4, 4.4, 3.8, 2.0 Hz, 1H, 3-H), 4.6 (dd, *J*= 6.8, 3.8, 1H, 4-H), 4.3 (brd, *J*= 6.8 Hz, 1H, 5-H), 3.5 (ddd, *J*= 11.2, 6.0, 4.0 Hz, 1H, 9-H), 3.41 (ddd, *J*= 5.6, 4.4 Hz, 1H, 7-H), 3.27 (dd, *J*= 1.5, 4.4 Hz, 1H, 6-H), 3.06 (d, *J*= 4.4 Hz, 1H, 3-OH), 2.79 (dd, *J*= 17.4, 5.4 Hz, 1H, 2-H_{eq}), 2.60 (dd, *J*= 17.4, 2.0 Hz, 1H, 2-H_{ax}), 1.95 (ddd, *J*= 15.4, 5.6, 4.0, 1H, 8-$_{Heq}$), 1.76 (dd, *J*= 15.4, 11.2 Hz, 1H, 8-H_{ax}), 1.18 (d, *J*= 6.0 Hz, 3H, 10-H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 21.3 (t, C-10), 30.7 (s, C-8), 39.2 (s, C-2), 47.8 (t, C-6), 50.7 (t, C-7), 68.2 (t, C-3), 70.3 (t, C-9), 72.7 (t, C-5), 83.0 (t, C-4), 174.9 (q, C-1).

2nd fraction 25. colourless oil; $[\alpha]_D^{22}$ = 7.6° (*c*= 0.25, $CDCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 5.6 (dd, *J*= 2.2, 2.2 Hz, 1H, 6-H), 4.6 (brddd, *J*= 9.0, 6.8, 2.2 Hz, 1H, 7-H), 4.15 (ddq, *J* =11.4, 6.4, 1.6 Hz, 1H, 9-H), 3.6 (s, 1H, OCH_3), 2.98 (t, *J*= 6.8 Hz, 1H, 3-H_α), 2.97 (t, *J*= 6.8 Hz, 1H, 3-H_β), 2.61 (t, *J*= 6.8 Hz, 2H, 2-H), 2.2 (ddd, *J*= 13.2, 6.8, 1.6 Hz, 1H, 8-H_{eq}), 1.6 (ddd, *J*= 13.2, 11.4, 9.8 Hz, 1H, 8-H_{ax}), 1.4 (d, *J*= 6.4 Hz, 3H, 10-H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 19.8 (p, C-10), 26.4 (s, C-2), 31.5 (t, C-3), 37.5 (s, C-8), 50.8 (p, OCH_3), 62.6 (t, C-7), 71.3 (t, C-9), 109.3 (t, C-6), 149.8 (t, C-5) , 172.3 (q, C-1), 194.3 (q, C-4).

X-ray crystallographic study of 24. Crystal data are given in Table 2. A single crystal (0.63 x 0.48 x 0.30 mm) of **24** was investigated on a Stoe IPDS area detector diffractometer using graphite-monochromated Mo-*K*α radiation (0.71073 A). The lattice constants were determined by the automatic Search and Indexing routines of the diffractometer. Indexing and refinement of 5271 reflections in the range 6.3° < 2θ < 55.3° led to a monoclinic unit cell with the dimensions a = 6.454(2) A, α = 90°, b = 8.509(2) A, β = 108.41(3)°, c = 10.032(3) A, γ = 90° (*V*= 522.7(3) A^3 , Z = 2, 1.361 Mg/m^3). The space group $P2_1^{29}$ was determined by the reflection conditions. The intensity data of 9205 reflections were measured at room temperature (300(2)K) in the range of 3.21° <- θ <- 28.24°. For Lp correction and data processing the programs of the Stoe IPDS software package were used. The structure was solved by direct methods using the program

SHELXS-86.[30] The atomic parameters of the molecule were then completed by Fourier differences syntheses and refined (anisotropic displacement parameters for non H-atoms) by full-matrix least squares (F^2) to the attainable *R* values *R*1 = 0.0310 [for 1757 reflections $F_o > 4\sigma(Fo)$], w*R*2 = 0.0661 (for all 2468 unique reflections). The hydrogen atoms were included as riding atoms. Crystallographic data (excluding structure factors) for the structure reported in this paper have been deposited with the Cambridge Crystallographic Data Center. Copies of the data can be obtained free of charge on application to The Director, CCDC, 12 Union Road, Cambridge CB2 1EZ, UK [Fax (intenational) +44(0)1223 336-033; email: deposit@chemcrys.cam.ac.uk].

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