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Synthesis of *C*-1 Alkyl and Aryl Glycals from Pyranosyl or Furanosyl Chlorides by Treatment with Organolithium Reagents

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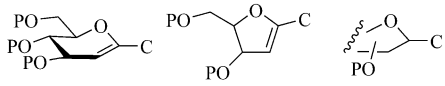
Glycosyl chlorides, with ether or isopropylidene acetal protecting groups, readily available from furanoses or pyranoses, can be conveniently transformed into *C*-1 alkyl or aryl glycals by reaction with alkyl or aryl organolithium reagents.

Introduction

C-1 Substituted glycals (e.g., **1**, **2**) have become key carbohydrate precursors in a variety of synthetic transformations leading to carbohydrate mimetics.[1,2] Compared to glycals,[3] they incorporate a substituent at C-1 while maintaining their enol ether functionality. The former facilitates an easy retrosynthetic correlation with biologically relevant *C*-glycosides (e.g., **3**; Figure 1),[4,5] whereas the latter permits the incorporation of further functionalities to the carbohydrate moiety. Accordingly, the unsaturation in these compounds has been submitted to a variety of synthetic transformations that include: epoxidation,[6] hydroboration,[7] hydrogenation,[8] dihydroxylation,[9] mercuration,[10] and azidoselenation.[11] *C*-1 glycals have also been used as substrates in Claisen rearrangements,[12] hetero Diels–Alder reactions,[13] acid-catalyzed spiroacetal formation,[14] selenium-induced spirocyclization,[15] radical addition of electrophilic radicals,[16] or Ferrier rearrangement,[17] all of them leading to functionalized *C*-glycosides.



1 **2** **3**

Figure 1. *C*-1 glycals **1** and **2** and *C*-glycoside **3**.

Synthetic strategies to the title compounds based on *C*-1 deprotonation of substituted glycal derivatives were pioneered by Nicolaou's,[17] Hanessian's[18] and Beau's[19] groups.[20] They showed that *C*-1 lithiated glycals could be generated by either direct proton abstraction[17] or by transmetalation of *C*-1 tributylstannyl glycals.[18,19,21] The reaction of the resulting alkenyllithium species with electrophiles (e.g., alkyl halides,[17] aldehydes,[6b,18,19] ketones,[19,22] oxiranes,[23] quinones,[24] or hexacarbonyl chromium[25]) generated the sought *C*-1 substituted glycals (Scheme 1a, X = H). Despite the straightforward nature of this approach, the preparation and handling of these lithio reagents is not trivial[26] and the alkylation reactions are particularly challenging, as the intermediate *C*-1 lithioglycals might cause undesired side reactions.[27] In this context, Schmidt and coworkers described the direct 1-*C*-lithiation of 2-phenylsulfinyl-D-glucals, which was facilitated by both inductive effects and intramolecular complexation of the lithiated species [Scheme 1a, X = S(O)Ph].[28,29] In contrast, *C*-1 stannyl,[30,31] or *C*-1 iodo glycals, obtained therefrom, have been successfully used in palladium-mediated coupling reactions[15,32,33] with activated substrates (Scheme 1b). This approach was also applied to furanoid *C*-1 glycals.[34] These methods generally lead to good yields of *C*-1 glycals; however, they necessitate an initial metalation step for the preparation of the required *C*-1 stannyl glycal.

Approaches to *C*-1 alkyl glycals, based on open-chain derivatives, have also been described (Scheme 1c, d).[1] In this context, Postema and co-workers designed an approach based on an enol ether–olefin ring closing metathesis protocol (Scheme 1c),[8,14,35,36–38] whereas Mootoo and coworkers employed an intramolecular oxocarbenium ion–alkene cyclization on an acetal–enol ether precursor, as the key step in the ring forming reaction (Scheme 1d).[39]

Base-induced elimination of 1-CN glycosides has been used in the preparation of 1-cyanoglycals (Scheme 1e, X = CN), which are useful precursors of heterocyclic *C*-1 glycals.[10,40] 2,3-Dehydroneuraminic acid derivatives, which can be regarded as C-1 substituted glycals, have been ob-

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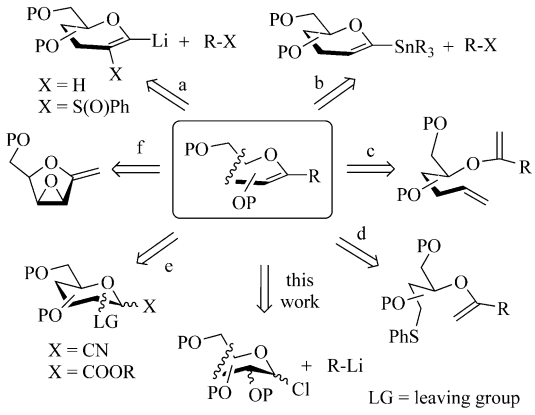


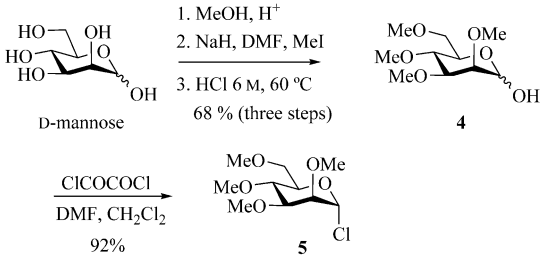
Scheme 1. Strategies for the synthesis of *C*-1 glycals.

tained mainly by elimination procedures on peracetylated neuraminic ester derivatives (Scheme 1e, X = COOR).[41] These biologically relevant compounds, related to neuraminidase inhibitors,[42,43] can be used in the preparation of sialic acid derivatives functionalized at C-3.[44] Other methods have also been used in the preparation of C-1 substituted glycals.[45]

Our group has been interested in the synthesis of *C*-1 glycals. We recently reported a method for the preparation of furanosyl *C*-1 glycals based on the reaction of π-allyl palladium complexes generated from epoxy-*exo*-glycals (Scheme 1f).[46] In contrast, some time ago, as part of our interest in the reaction of sugar derivatives with organolithium reagents,[47] we described the synthesis of pyranosyl *C*-1 glycals by reaction of glycosyl chlorides with organolithium reagents.[48,49] In this paper we would like to report on the continuation of our studies on the scope of the transformation, including its extension to the preparation of furanoid *C*-1 glycals.

Results and Discussion

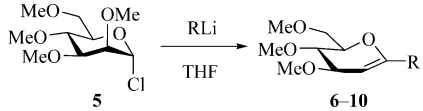
Our initial studies were carried out with permethylated glycosyl chloride **5**. Its synthesis was effected from D-mannose and involved Fischer glycosylation,[50] methylation, and acidic hydrolysis to provide hexose **4** (Scheme 2). Glycosyl chloride **5** was obtained by treatment of the latter with oxalyl chloride in the presence of a catalytic amount of *N*,*N*-dimethylformamide (DMF).



Scheme 2. Preparation of glycosyl chloride **5**.

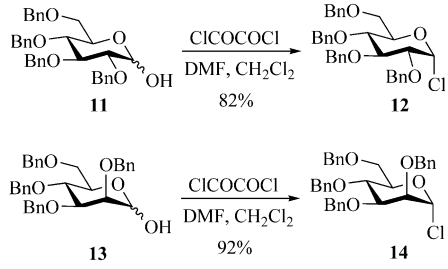
Our studies with chloride **5** started with its reaction with methyllithium (5 equiv.) in THF at room temperature, which afforded *C*-1 methyl glycal **6** in 66% yield (Table 1, Entry i). Next, we explored the reaction of compound **5** with various (primary, secondary, and tertiary) alkyl organolithium reagents for the preparation of *C*-1 glycals **6**–**9** (Table 1, Entries ii–iv). Modest yield of *C*-1 glycal **8** was obtained when *sec*-butyllithium was used (Table 1, Entry iii). The reaction with *tert*-butyllithium was best carried out at 0 °C and permitted the preparation of *tert*-butyl glycal **9** in 62% yield (Table 1, Entry iv). In contrast, treatment of **5** with phenyllithium gave raise to aryl *C*-1 glycal **10** in 77% yield (Table 1, Entry v). Finally, treatment of **5** with a combination of *tert*-butyllithium and phenyllithium yielded *tert*-butyl glycal **9** exclusively (vide infra; Table 1, Entry vi).

Table 1. Preparation of *C*-1 alkyl and *C*-1 phenyl glycals **6**–**10** by reaction of mannopyranosyl chloride **5** with organolithium reagents (5 equiv.).



Entry	*T* [°C]	RLi	Glycal	Yield [%]
i	r.t.	MeLi	**6**, R = Me	66
ii	r.t.	*n*BuLi	**7**, R = *n*Bu	50
iii	r.t.	*s*BuLi	**8**, R = *s*Bu	36
iv	0	*t*BuLi	**9**, R = *t*Bu	62
v	r.t.	PhLi	**10**, R = Ph	77
vi	0	*t*BuLi (1equiv.) + PhLi (5equiv.)	**9**, R = *t*Bu	20

We subsequently turned our attention to the influence, in the reaction yield, of the configuration of the substituent at C-2 in the glycosyl chloride and to more synthetically useful benzyl protecting groups. Accordingly, we prepared gluco- and mannopyranosyl chlorides **12** and **14** (Scheme 3) from tetra-*O*-benzyl-D-glucopyranose **11** and tetra-*O*-benzyl-D-mannopyranose **13**, respectively, by treatment of the former with the Vilsmeier reagent.

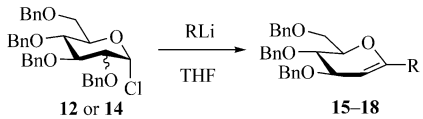


Scheme 3. Synthesis of gluco- and mannopyranosyl chlorides **12** and **14**.

The results from the reaction of pyranosyl chlorides **12** and **14** with organolithium reagents are outlined in Table 2. Then, no reaction was observed when chloride **12** was

treated with MeLi at –78 °C (Table 2, Entry i). However, at 0 °C a smooth reaction took place that permitted the isolation of *C*-1 methyl glycal **15** in 74% yield (Table 2, Entry ii).

Table 2. Preparation of *C*-1 alkyl and *C*-1 phenyl glycals by reaction of glycopyranosyl chlorides with organolithium reagents.



12 or **14** **15–18**

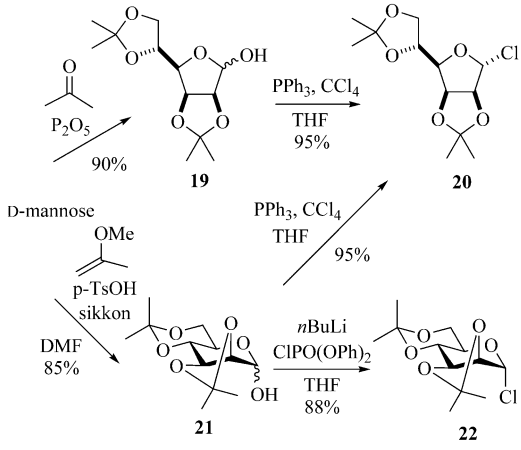
Entry	Chloride	RLi	*T* [°C]	Glycal	Yield [%]
i	**12**	MeLi	–78	**15**, R = Me	no reaction
ii	**12**	MeLi	0	**15**, R = Me	74
iii	**12**	*n*BuLi	0 or r.t.	**16**, R = *n*Bu	decomposition
iv	**12**	*n*BuLi	–78	**16**, R = *n*Bu	50
v	**12**	PhLi	–78	**17**, R = Ph	no reaction
vi	**12**	PhLi	0	**17**, R = Ph	65
vii	**12**	*t*BuLi	0	**18**, R = *t*Bu	35
viii	**14**	*n*BuLi	0 or r.t.	**16**, R = *n*Bu	decomposition
ix	**14**	*n*BuLi	–78	**16**, R = *n*Bu	55
x	**14**	PhLi	–78	**17**, R = Ph	no reaction
xi	**14**	PhLi	0	**17**, R = Ph	72

Reaction of chlorides **12** and **14** with 3 equiv. of *n*BuLi at 0 °C or at room temperature caused extensive decomposition of the starting material (Table 2, Entries iii and viii). It was found, however, that lowering the temperature to –78 °C had a beneficial effect on the reaction, thus allowing the isolation of *C*-1 butyl glycal **16** in 50 and 55% yield from the reaction of **12** and **14**, respectively (Table 2, Entries iv and ix). No reaction of either **12** or **14** and phenyllithium was observed at –78 °C (Table 2, Entries v and x); however, upon warming to 0 °C phenyl *C*-1 glycal **17** could be obtained in 65 and 72% yield, respectively (Table 2, Entries vi and xi). Finally, reaction of glucopyranosyl chloride **12** with *tert*-butyllithium at 0 °C yielded *C*-1 glycal **18** in 35% yield. Albeit, the observed yields in the reactions with benzyl-protected glycosyl chlorides were only moderate, we were not able to observe any byproducts.

From the results in Tables 1 and 2 it could be inferred that the relative orientation of the oxygen substituent at C-2 has little or no effect on the formation of the *C*-1 glycals. The *C*-1 glycal formation reaction proceeded smoothly at room temperature with chloride **5**, but required lower temperatures in the case of chlorides **12** and **14**, very likely as a result of the relatively acidic nature of the benzylic protons. Regarding the organolithium reagents, PhLi led consistently to higher yields of *C*-1 glycals than the corresponding alkyllithiums.

Our interest in the preparation of furanosyl and pyranosyl glycal derivatives in which the allylic (3)-OH group is unprotected[43,51] led us to consider 2,3-*O*-isopropylidene derivatives as interesting substrates for this reaction.

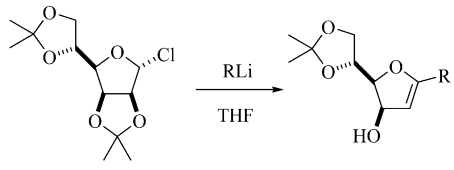
Along this line, we prepared mannose-derived furanosyl and pyranosyl chlorides **20** and **22**, respectively, from D-mannose as outlined in Scheme 4. Acetonation of D-mannose under thermodynamic control[52] granted access to furanose **19**, whereas kinetic acetonation of D-mannose[53] led to pyranose **21**. The former was conveniently transformed into furanosyl chloride **22** upon treatment with PPh_3 and CCl_4 in THF at 60 °C.[54] However, unlike previously reported by us, application of these reaction conditions to pyranose **21** caused isomerization previous to chlorination and resulted in the formation of **20**. The formation of pyranosyl chloride **22** was carried out without isomerization under the conditions recommended by Hung and Wong[55] by treatment of **21** with *n*BuLi followed by $ClPO(OPh)_2$ in THF at –78 °C.



Scheme 4. Preparation of mannofuranosyl and mannopyranosyl chlorides **20** and **22**, respectively, from D-mannose.

The results obtained in the reaction of mannosyl chlorides **20** and **22** with organolithium reagents are outlined in Tables 3 and 4, respectively. They displayed a similar behavior giving raise to *C*-1-glycals in moderate to good yields. We found that slightly better yields of *C*-1 glycals were obtained when the reaction was carried out at 0 °C than at room temperature (Table 3, compare Entries i, ii and v, vi). Best yields of *C*-1 glycals were obtained when *sec*-butyllithium was used as the organolithium partner (Table 3, Entry iv; Table 4, Entry iii), a result that contrasts the one obtained with pyranosyl chloride **5** (Table 1, Entry iii). *tert*-

Table 3. Preparation of *C*-1 alkyl and *C*-1 phenyl glycals **23**–**27** by reaction of mannofuranosyl chloride **20** with organolithium reagents (3 equiv.) in THF.

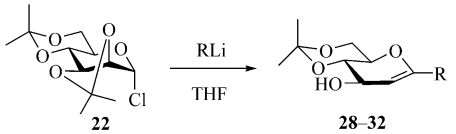


20 **23–27**

Entry	*T* [°C]	RLi	Glycal	Yield [%]
i	r.t.	MeLi	**23**, R = Me	50
ii	0	MeLi	**23**, R = Me	60
iii	0	*n*BuLi	**24**, R = *n*Bu	54
iv	0	*s*BuLi	**25**, R = *s*Bu	71
v	r.t.	*t*BuLi	**26**, R = *t*Bu	37
vi	0	*t*BuLi	**26**, R = *t*Bu	46
vii	0	PhLi	**27**, R = Ph	58

Butyllithium gave modest yields of *C*-1 glycals **26** and **31** (Table 3, Entries v and vi; Table 4, Entry iv), in agreement with the results observed with chlorides **5**, **12**, and **14**.

Table 4. Preparation of *C*-1 alkyl and *C*-1 phenyl glycals **28**–**32** by reaction of mannopyranosyl chloride **22** with organolithium reagents (3 equiv.) in THF.

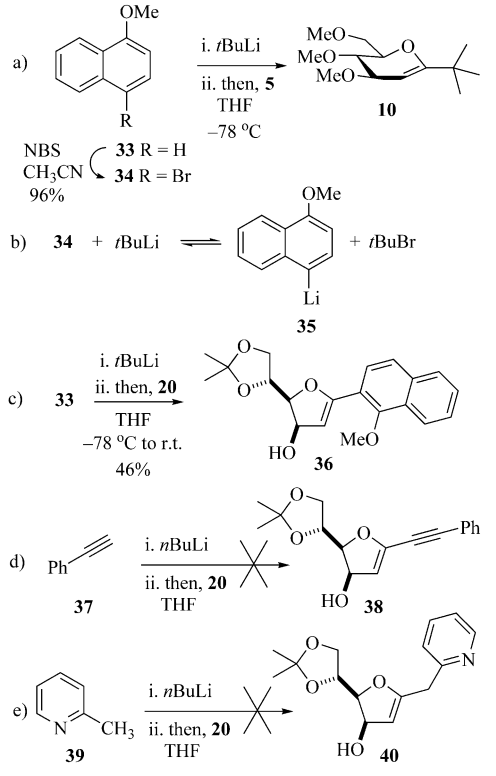


22 **28**–**32**

Entry	*T* [°C]	RLi	Glycal	Yield [%]
i	0	MeLi	**28**, R = Me	65
ii	0	*n*BuLi	**29**, R = *n*Bu	62
iii	0	*s*BuLi	**30**, R = *s*Bu	82
iv	0	*t*BuLi	**31**, R = *t*Bu	49
v	0	PhLi	**32**, R = Ph	60

Next, we decided to evaluate if this method could be extended to aryl organolithiums other than PhLi. Thus, bromomethoxy naphthalene **34**, prepared by NBS-mediated bromination[56] of 1-methoxynaphthalene (**33**) in acetonitrile, was treated with *t*BuLi in THF at –78 °C to generate the corresponding lithiated species **35**. Upon exposure of pyranosyl chloride **5** to lithiated **35**, we observed a complex reaction mixture from which only *tert*-butyl glycal **10** could be isolated (Scheme 5a). This result was explained on the basis of the equilibrium shown in Scheme 5b, where the regenerated *t*BuLi could react with chloride **5** to give *C*-1 glycal **10**. We then reasoned that aryllithium derivatives generated by directed *ortho*-metalation,[57] devoid of this equilibrium, could be used in the preparation of *C*-1 glycals. Accordingly, 2-lithio-1-methoxynaphthalene generated by reaction of 1-methoxynaphthalene (**33**) with *t*BuLi reacted with furanosyl chloride **20** to furnish *C*-1 glycal **36** in 46% yield (Scheme 5c).

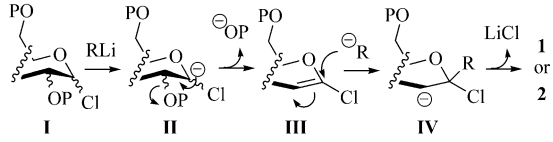
Finally, we attempted the reaction of lithium phenylacetylide and 2-lithiomethylpyridine[58] [generated by treatment of phenyl acetylene (**37**) and 2-methylpyridine (**39**) with *n*BuLi, respectively] with furanosyl chloride **20** (Scheme 5d, e). Under a variety of reaction conditions, we were not able to detect any of the desired *C*-1 glycals, **38** or **40**, and most of glycosyl chloride **20** could be recovered unreacted.



Scheme 5. Reaction of different organolithiums with chlorides **5** and **20**.

Conclusions

The reaction of pyranosyl and furanosyl chlorides with organolithium reagents provides an efficient method for the preparation of *C*-1 substituted glycals. Regarding the organolithium reagents, commercially available alkyllithiums provide from modest to good yields of *C*-1 glycals and PhLi gives good yields of *C*-1 phenyl glycals. Organolithium reagents obtained by directed *ortho*-metalation also gave moderate yields of aryl *C*-1 glycals. In contrast, less basic organolithium derivatives such as lithium phenylacetylide or 2-lithiomethylpyridine did not give any of the sought *C*-1 glycals. In this context, the basicity of the organolithium reagent appears to be an important issue, as we have already observed in the exclusive formation of glycal **10** when chloride **5** was treated with a mixture of *tert*-butyllithium and phenyllithium (Table 1 Entry vi) or *tert*-butyllithium and 4-lithium-1-methoxynaphthalene (Scheme 5a, b). These results will be in agreement with the suggested mechanism for this transformation advanced by Kurihara and coworkers,[49] in which abstraction of the anomeric proton was proposed to take place in the first step (e.g., **I** → **II**, Scheme 6).



Scheme 6. Possible reaction pathway for the formation of *C*-1 glycals from glycosyl chlorides, as proposed by Kurihara and coworkers.[49]

Concerning the chloride counterparts, furanosyl and pyranosyl chlorides displayed a similar behavior, and they both can be successfully used in this reaction. Nevertheless, the presence of ether protecting groups seems to be of prime importance for the reaction to proceed towards *C*-1 glycals.

Indeed, previous investigations on the reaction of organolithiums with acyl-substituted glycosyl chlorides reported the mere replacement of the anomeric chlorine to afford anomeric mixtures of *C*-glycosides.[59] In this context, ether or isopropylidene acetal substituents can be used as protecting groups, although benzyl groups do require lower reaction temperatures than methyl, probably due to the higher acidity of the benzylic protons. Further studies are under consideration in our laboratory.

Experimental Section

General: All reactions were performed in dry flasks fitted with glass stoppers or rubber septa under a positive pressure of argon, unless otherwise noted. Air- and moisture-sensitive liquids and solutions were transferred by syringe or stainless steel cannula. Optical rotations were determined with a Perkin–Elmer 241 MC polarimeter. Flash column chromatography was performed by using 230–400 mesh silica gel. Thin-layer chromatography was conducted on Kieselgel 60 F254 (Merck). Spots were observed first under UV irradiation (254 nm) then by charring with a solution of 20% aqueous H_2SO_4 (200 mL) in AcOH (800 mL). Anhydrous $MgSO_4$ or Na_2SO_4 were used to dry organic solutions during workup, and evaporation of the solvents was performed under vacuum by using a rotary evaporator. Solvents were dried and purified by using standard methods. ^1H and ^{13}C NMR spectra were recorded with an Inova-300 (300 and 50 MHz, respectively) as $CDCl_3$ or C_6D_6 solutions. Chemical shifts are expressed in parts per million (δ scale) downfield from tetramethylsilane and are referenced to residual protium in the NMR solvent ($CHCl_3$: δ = 7.25 ppm). Compounds **20** and **36** (Supporting Information) were prepared according to ref.[60]

2,3,4,6-Tetra-*O*-methyl-D-mannose (4): Required hemiacetal **4** was prepared from D-mannose following the procedure of Nicolaou and co-workers.[61] Concentrated H_2SO_4 (2 mL) was added to a solution of D-mannose (3.6 g, 20.0 mmol) in MeOH (60 mL) at room temperature. After 9 h of stirring, the reaction mixture was neutralized by the addition of 3 N aqueous NaOH and concentrated. The resulting solid was then taken up in EtOAc (100 mL), filtered through a short pad of silica gel, and concentrated. The residue was then dried under high vacuum and dissolved in DMF (20 mL), cooled to 0 °C, and treated portionwise with 60% NaH (6.40 g, 160.0 mmol, 8 equiv.). After 30 min, methyl iodide (9.8 mL, 160.0 mmol, 6 equiv.) was added by syringe over 5 min. The reaction was warmed to room temperature and stirred overnight. The solution was carefully quenched with water, diluted with Et_2O, washed with H_2O, dried, and concentrated. The resulting residue was then dissolved in 6 M aqueous HCl (15 mL) and warmed to 60 °C. After 24 h, the reaction mixture was concentrated in vacuo directly. The resulting residue was purified by flash chromatography (60% EtOAc/hexane) to give desired hemiacetal **5** (3.21 g, 68%). ^1H NMR (300 MHz, $CDCl_3$): δ = 5.25 (s, 1 H, 1-H), 4.62 (br. s, 1 H), 3.86 (td, *J* = 7.3, 1.8 Hz, 1 H), 3.59–3.51 (m, 4 H), 3.45 (s, 3 H, OMe), 3.44 (s, 3 H, OMe), 3.43 (s, 3 H, OMe), 3.32 (s, 3 H, OMe), 3.26 (t, *J* = 9.2 Hz, 1 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 91.5, 80.8, 74.5, 77.1, 72.7, 70.3, 60.6, 59.1, 58.8, 57.6 ppm.

2,3,4,6-Tetra-*O*-methyl-α-D-mannopyranosyl Chloride (5): To a solution of **4** (590 mg, 1.7 mmol) and DMF (170 μL) dissolved in dry CH_2Cl_2 (6 mL) was added a solution of oxalyl chloride (445 μL, 5.1 mmol, 3 equiv.) in dry CH_2Cl_2 (2 mL) dropwise at 0 °C. The mixture was stirred at that temperature for 30 min, after which time it was warmed to room temperature and stirred for 1 h. The reaction crude was then concentrated, the residue was taken up in EtOAc/hexane (1:1), and the suspension was filtered through silica gel to give after evaporation of the solvents pyranosyl chloride **5** (583 mg, 92%). ^1H NMR (300 MHz, $CDCl_3$): δ = 3.39 (s, 3 H, OMe), 3.50 (s, 3 H, OMe), 3.53 (s, 3 H, OMe), 3.54 (s, 3 H, OMe), 3.51–3.85 (m, 6 H), 6.18 (d, *J* = 1.4 Hz, 1 H, 1-H) ppm.

General Procedure for *C*-1 Glycal Formation: A solution of the glycosyl chloride (1 mmol) in dry THF was cooled to the appropriate temperature and then treated with the corresponding organolithium reagent (3 equiv.). After stirring for 0.5–2 h, and once TLC analyses showed total disappearance of the starting material, the reaction mixture was quenched with a saturated aqueous solution of NH_4Cl. After partitioning between water and diethyl ether, the organic layer was dried with $MgSO_4$ and concentrated. The ensuing residue was then purified by flash chromatography.

1,5-Anhydro-3,4,6-tri-*O*-methyl-2-deoxy-1-*C*-methyl-D-*arabino*-hex-1-enitol (6): Using the general procedure, chloride **5** (103 mg, 0.41 mmol) was treated with MeLi (1.6 M in diethyl ether, 0.82 mL, 1.23 mmol) at room temperature. Extractive workup was followed by flash chromatography (5% EtOAc/hexane) to give *C*-1 glycal **7** (54 mg, 66%). $[a]_D^{25}$ = +13.1 (*c* = 0.92, $CHCl_3$).^1H NMR (300 MHz, C_6D_6): δ = 1.64 (d, *J* = 1.2 Hz, 3 H, Me), 3.16 (s, 3 H, OMe), 3.18 (s, 3 H, OMe), 3.39 (s, 3 H, OMe), 3.62 (m, 3 H, 2 × 6-H, 4-H), 3.90 (m, 1 H, 3-H), 4.00 (ddd, *J* = 2.7, 4.7, 7.9 Hz, 1 H, 5-H), 4.56 (m, 1 H, 2-H) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 19.6, 56.5, 58.9, 59.2, 70.9, 75.7, 76.3, 77.1, 95.2, 152.7 ppm. MS (EI): *m*/*z* = 171.0 $[M - 31]^+$, 149.0, 127.0, 125.0, 102.0, 101.0, 85.0, 71.0, 55.0. $C_{10}H_{18}O_4$ (202.12): calcd. C 59.37, H 8.98; found C 59.09, H 8.97.

1,5-Anhydro-3,4,6-tri-*O*-methyl-2-deoxy-1-*C*-*n*-butyl-D-*arabino*-hex-1-enitol (7): According to the general procedure, this compound was prepared at room temperature from chloride **5** (151 mg, 0.59 mmol) and *n*BuLi (1.6 M in *n*-hexane, 1.1 mL, 1.77 mmol). Purification by flash chromatography (10% EtOAc/hexane) afforded pure *C*-1 glycal **7** (72 mg, 50%). $[a]_D^{25}$ = –1.9 (*c* = 1.07, $CHCl_3$). $[a]_{Hg(365)}^{25}$ = –5.3 (*c* = 1.07, $CHCl_3$). $[a]_{Hg(435)}^{25}$ = –2.1 (*c* = 1.07, $CHCl_3$). $[a]_{Hg(546)}^{25}$ = –1.6 (*c* = 1.07, $CHCl_3$). $[a]_{Hg(578)}^{25}$ = –1.1 (*c* = 1.07, $CHCl_3$). $C_{13}H_{24}O_4$ (244.33): calcd. C 63.89, H 9.91; found C 64.17, H 9.61. ^1H NMR (300 MHz, $CDCl_3$): δ = 0.90 (t, *J* = 7.3 Hz, 3 H, Me), 1.35 (m, 2 H, CH_2), 1.46 (m, 2 H, CH_2), 2.06 (t, *J* = 7.5 Hz, 2 H, CH_2), 3.39 (s, 3 H, OMe), 3.41 (s, 3 H, OMe), 3.43 (dd, *J* = 5.5, 7.8 Hz, 1 H, 4 H) 3.53 (s, 3 H, OMe), 3.64 (m, 2 H, 6-H), 3.83 (m, 1 H, 3-H), 3.98 (ddd, *J* = 2.7, 4.7, 7.8 Hz, 1 H, 5-H), 4.62 (d, *J* = 3.1 Hz, 1 H, 2-H) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 13.7, 22.1, 28.8, 33.1, 55.4, 58.8, 59.1, 70.9, 75.7, 76.2, 76.9, 94.2, 156.3 ppm. MS (EI): *m*/*z* = 171.0 $[M - 31]^+$, 167.3, 144.3, 143.2, 125.2, 112.2, 102.3, 101.1, 85.1. $C_{13}H_{24}O_4$ (244.32): calcd. C 63.91, H 9.90; found C 63.84, H 9.75.

1,5-Anhydro-3,4,6-tri-*O*-methyl-2-deoxy-1-*C*-*sec*-butyl-D-*arabino*-hex-1-enitol (8): Using the general procedure, chloride **5** (72 mg, 0.28 mmol) was treated with *s*BuLi (1.4 M in cyclohexane, 0.6 mL, 0.84 mmol) at room temperature. Extractive workup was followed by flash chromatography (10% EtOAc/hexane) to give *C*-1 glycal **8** as a 1:1 mixture of diastereomers (22 mg, 36%). ^1H NMR (300 MHz, $CDCl_3$) selected data: δ = 3.84 (m, 1 H, 3-H), 3.97 (m, 1 H, 5-H), 4.58 (d, *J* = 3.4 Hz, 0.5 H, 2-H one isomer), 4.61 (d, *J* = 3.4 Hz, 0.5 H, 2-H other isomer) ppm. MS (EI): *m*/*z* = 244.4 $[M]^+$, 212.2, 167.1, 144.3, 143.2, 125.2, 102.3, 101.2, 85.1, 71.1.

1,5-Anhydro-3,4,6-tri-*O*-methyl-2-deoxy-1-*C*-*tert*-butyl-D-*arabino*-hex-1-enitol (9): According to the general procedure, this compound was prepared at 0 °C from chloride **5** (99 mg, 0.39 mmol) and *t*BuLi (1.7 M in *n*-pentane, 0.7 mL, 1.17 mmol). Purification by

flash chromatography (5% EtOAc/hexane) afforded pure *C*-1 glycal **9** (59 mg, 62%). $[\alpha]_D^{25}$ = –3.1 (*c* = 0.97, $CHCl_3$). ^1H NMR (300 MHz, C_6D_6): δ = 1.07 (s, 9 H, *t*Bu), 3.40 (s, 3 H, OMe), 3.40 (m, 1 H, 4-H), 3.41 (s, 3 H, OMe), 3.51 (s, 3 H, OMe), 3.63 (m, 2 H, 6-H), 3.82 (dd, *J* = 3.2, 5.6 Hz, 1 H, 3-H), 3.94 (ddd, *J* = 3.5, 5.1, 7.7 Hz, 1 H, 5-H), 4.66 (d, *J* = 3.2 Hz, 1 H, 2-H) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 24.6, 26.3, 57.5, 59.6, 60.3, 72.3, 76.3, 79.9, 80.6, 101.0, 156.4 ppm. MS (EI): *m*/*z* = 244.4 $[M]^+$, 244.1675, 212.3, 197.2, 167.1, 144.3, 143.2, 142.5, 125.2, 102.3, 101.2, 85.1, 71.1, 57.1. $C_{13}H_{24}O_4$ (244.33): calcd. C 63.91, H 9.90; found C 63.80, H 9.83.

1,5-Anhydro-3,4,6-tri-*O*-methyl-2-deoxy-1-*C*-phenyl-D-*arabino*-hex-1-enitol (10): Using the general procedure, chloride **5** (140 mg, 0.55 mmol) was treated with PhLi (1.8 M in di-*n*-butyl ether, 0.92 mL, 1.65 mmol) at 0 °C. Extractive workup was followed by flash chromatography (15% EtOAc/hexane) to give *C*-1 glycal **10** (112 mg, 77%). $[\alpha]_D^{25}$ = –8.9 (*c* = 0.90, $CHCl_3$). ^1H NMR (300 MHz, C_6D_6): δ = 3.19 (s, 3 H, OMe), 3.21 (s, 3 H, OMe), 3.40 (s, 3 H, OMe), 3.68 (m, 3 H, 2 × 6-H and 4-H), 4.04 (dd, *J* = 3.1, 6.1 Hz, 1 H, 3-H), 4.11 (ddd, *J* = 2.7, 5.1, 8.3 Hz, 1 H, 5-H5), 5.38 (d, *J* 3.1 Hz, 1 H, 2-H), 7.10 (m, 3 H, Ph), 7.39 (m, 1 H, Ph), 7.68 (m, 1 H, Ph) ppm. ^{13}C NMR (50 MHz, C_6D_6): δ = 55.4, 58.8, 59.0, 71.3, 76.3, 77.6, 78.6, 96.2, 125.6, 127.2, 129.0, 135.3, 152.9 ppm. MS (EI): *m*/*z* = 264.2 $[M]^+$, 239.2, 233.2, 187.0, 164.2, 163.2, 162.5, 161.5, 128.3, 115.1, 105.1, 102.1, 85.1, 71.1, 70.4, 45.3. $C_{15}H_{20}O_4$ (264.13): calcd. C 68.15, H 7.63; found C 68.32, H 7.18.

2,3,4,6-Tetra-*O*-benzyl-α-D-glucopyranosyl Chloride (12): To a solution of **11** (704 mg, 1.1 mmol) and DMF (110 μL) dissolved in dry CH_2Cl_2 (6 mL) was added a solution of oxalyl chloride (288 μL, 3.3 mmol, 3 equiv.) in dry CH_2Cl_2 (3 mL) dropwise at 0 °C. The mixture was stirred at that temperature for 30 min, after which time it was warmed to room temperature and stirred for 1 h. The reaction crude was then concentrated, the residue was taken up in EtOAc/hexane (1:2), and the suspension was filtered through silica gel to give after evaporation of the solvents chloride **12**[62] (546 mg, 75%). ^1H NMR (200 MHz, $CDCl_3$): δ = 3.63 (dd, *J* = 2.0, 11.2 Hz, 1 H, 6-H), 3.82 (m, 2 H), 3.86 (dd, *J* = 2.7, 11.0 Hz, 1 H, 6-H), 4.11–4.20 (m, 2 H), 4.44–4.99 (m, 8 H), 6.06 (d, *J* = 3.7 Hz, 1 H, 1-H), 7.14–7.34 (m, 20 H) ppm.

2,3,4,6-Tetra-*O*-benzyl-α-D-mannopyranosyl Chloride (14): To a solution of **13** (1.4 g, 2.1 mmol) and DMF (210 μL) dissolved in dry CH_2Cl_2 (8 mL) was added a solution of oxalyl chloride (550 μL, 6.3 mmol, 3 equiv.) in dry CH_2Cl_2 (4 mL) dropwise at 0 °C. The mixture was stirred at that temperature for 30 min, after which time it was warmed to room temperature and stirred for 1 h. The reaction crude was then concentrated, the residue was taken up in EtOAc/hexane (1:2), and the suspension was filtered through silica gel to give after evaporation of the solvents chloride **14**[55,63] (1.2 g, 81%). ^1H NMR (400 MHz, $CDCl_3$): δ = 3.69 (dd, *J* = 11.2, 1.2 Hz, 1 H, 6-H), 3.81 (dd, *J* = 11.2, 4.4 Hz, 1 H, 6-H), 3.87 (dd, *J* = 3.1, 1.4 Hz, 1 H, 2-H), 4.01 (m, 1 H, 5-H), 4.09 (t, *J* = 9.4 Hz, 1 H, 4-H), 4.18 (dd, *J* = 9.4, 3.1 Hz, 1 H, 3-H), 4.49–4.79 (m, 7 H), 4.89 (d, *J* = 10.7 Hz, 1 H, C*H*$_2$Ph), 6.10 (d, *J* = 1.4 Hz, 1 H, 1-H), 7.16–7.34 (m, 20 H) ppm.

1,5-Anhydro-3,4,6-tri-*O*-benzyl-2-deoxy-1-*C*-methyl-D-*arabino*-hex-1-enitol (15): Using the general procedure, chloride **12** (120 mg, 0.21 mmol) was treated with MeLi (1.6 M in diethyl ether, 0.40 mL, 0.63 mmol) at 0 °C. Extractive workup was followed by flash chromatography (5% EtOAc/hexane) to give *C*-1 glycal **15**[19] (67 mg, 74%). M.p. 29–30 °C. $[\alpha]_D^{25}$ = +9.1 (*c* = 0.79, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ = 1.82 (br. s, 3 H, Me), 3.78 (m, 2 H, 6-H), 3.85 (dd, *J* = 5.8, 8.2 Hz, 1 H, 4-H), 4.11 (m, 1 H, 3-H), 4.52–4.60 (m, 4 H, 2 × OC*H*$_2$Ph), 4.65 (d, *J* = 11.2 Hz, 1 H, OC*H*$_2$Ph), 4.69 (d, *J* = 2.8 Hz, 1 H, 2-H), 4.82 (d, *J* = 11.4 Hz, 1 H, OC*H*$_2$Ph), 7.32 (m, 15 H, Ph) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 20.3, 69.2, 70.8, 73.9, 74.0, 74.7, 77.6, 78.2, 96.1, 128.1, 128.3, 128.5, 128.9, 138.8, 139.1, 153.4 ppm. MS (EI): *m*/*z* = 430.1 $[M]^+$, 408.8, 376.2, 134.2, 339.1, 323.2, 309.1, 253.0, 181.0, 163.0, 107.9, 91.0, 90.2, 79.0 ppm. $C_{28}H_{30}O_4$ (430.54): calcd. C 78.11, H 7.02; found C 77.97, H 7.45.

1,5-Anhydro-3,4,6-tri-*O*-benzyl-2-deoxy-1-*C*-butyl-D-*arabino*-hex-1-enitol (16): According to the general procedure, this compound was prepared at –78 °C from chloride **12** (102 mg, 0.18 mmol) and *n*BuLi (1.6 M in *n*-hexane, 0.33 mL, 0.54 mmol). Purification by flash chromatography (5% EtOAc/hexane) afforded pure *C*-1 glycal **16** (42 mg, 50%). In a different experiment, this compound was prepared from chloride **14** (131 mg, 0.24 mmol) and *n*BuLi (1.6 M in *n*-hexane, 0.45 mL, 0.72 mmol). Purification by flash chromatography (5% EtOAc/hexane) afforded *C*-1 glycal **16** (61 mg, 55%). $[\alpha]_D^{25}$ = –4.7 (*c* = 0.56, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ = 0.91 (t, *J* = 7.3 Hz, 3 H, Me), 1.32 (m, 2 H, CH_2), 1.49 (m, 2 H, CH_2), 2.09 (t, *J* = 7.3 Hz, 2 H, CH_2), 3.81 (m, 3 H, 6-H, 4-H), 4.09 (ddd, *J* = 3.4, 4.9, 8.0 Hz, 1 H 5-H), 4.17 (m, 1 H, 3-H), 4.54 (d, *J* = 11.7 Hz, 1 H, OC*H*$_2$Ph), 4.56 (d, *J* = 12.2, 1 H, OC*H*$_2$Ph), 4.61 (d, *J* = 12.2 Hz, 1 H, OC*H*$_2$Ph), 4.62 (d, *J* = 11.7 Hz, 1 H, OC*H*$_2$Ph), 4.66 (d, *J* = 11.5 Hz, 1 H, OC*H*$_2$Ph), 4.68 (d, *J* = 3.4 Hz, 1 H, 2-H), 4.81 (d, *J* = 11.5, 1 H, OC*H*$_2$Ph), 7.32 (m, 15 H, Ph) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 13.9, 22.3, 29.0, 33.3, 68.7, 70.2, 73.3, 73.4, 76.0, 76.7, 94.7, 127.6, 127.7, 127.8, 128.3, 138.3, 138.6, 156.5 ppm. MS (EI): *m*/*z* = 473.3 $[M + 1]^+$, 391.2, 366.2, 365.2, 285.2, 257.0, 219.2, 197.1, 181.0, 90.9. $C_{31}H_{36}O_4$ (472.62): calcd. C 78.77, H 7.68; found C 78.38, H 7.43.

1,5-Anhydro-3,4,6-tri-*O*-benzyl-2-deoxy-1-*C*-phenyl-D-*arabino*-hex-1-enitol (17): Using the general procedure, chloride **12** (120 mg, 0.21 mmol) was treated with PhLi (0.35 mL, 1.8 M in di-*n*-butyl ether, 0.63 mmol) at 0 °C. Extractive workup was followed by flash chromatography (15% EtOAc/hexane) to give *C*-1 glycal **17** (65 mg, 65%). In a different experiment, this compound was prepared from chloride **14** (120 mg, 0.21 mmol) and PhLi (1.8 M in di-*n*-butyl ether, 0.35 mL, 0.63 mmol). Purification by flash chromatography (5% EtOAc/hexane) afforded *C*-1 glycal **17** (75 mg, 72%). M.p. 63–65 °C (Et_2O/Hexane) (ref.[32d] 65–66 °C). $[\alpha]_D$ = –6.2 (*c* = 0.71, $CHCl_3$) {ref.[32d] $[\alpha]_D$ = –7.0 (*c* = 1.0, $CHCl_3$)}. ^1H NMR (300 MHz, $CDCl_3$): δ = 3.93 (m, 2 H, 6-H), 4.00 (dd, *J* = 6.1, 7.7 Hz, 4-H), 4.29 (ddd, *J* = 3.1, 4.8, 7.7 Hz, 1 H,5-H), 4.41 (dd, *J* = 2.6, 6.1 Hz, 1 H, 3-H), 4.66 (m, 4 H, 2 × OC*H*$_2$Ph), 4.74 (d, *J* = 11.5 Hz, 1 H, OC*H*$_2$Ph), 4.89 (d, 1 H, *J* = 11.5 Hz, OC*H*$_2$Ph), 5.46 (d, *J* = 2.6 Hz, 1 H, 2-H), 7.20–7.60 (m, 20 H, Ph) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 68.6, 70.5, 73.4 (×2), 74.4, 76.6, 77.4, 96.0, 127.3, 127.5, 127.6, 127.7, 127.9, 128.1, 128.4, 128.6, 134.5, 138.3, 138.5, 152.7 ppm. MS (EI): *m*/*z* = 493.3 $[M + 1]^+$, 461.2, 425.2, 415.2, 385.2, 295.0, 253.0, 217.0, 181.0, 157.0, 91.0. $C_{33}H_{32}O_4$ (492.23): calcd. C 80.45, H 6.55; found C 80.15, H 6.63.

1,5-Anhydro-3,4,6-tri-*O*-benzyl-2-deoxy-1-*C*-*tert*-butyl-D-*arabino*-hex-1-enitol (18): According to the general procedure, this compound was prepared at 0 °C from glycosyl chloride **12** (137 mg, 0.25 mmol) and *t*BuLi (1.7 M in *n*-pentane, 0.44 mL, 0.75 mmol). Purification by flash chromatography (5% EtOAc/hexane) afforded *C*-1 glycal **18** (41 mg, 35%). $[\alpha]_D^{25}$ = –3.5 (*c* = 0.60, $CHCl_3$). $[\alpha]_{Hg365}^{25}$ = –8.6 (*c* = 0.60, $CHCl_3$). $[\alpha]_{Hg435}^{25}$ = –6.7 (*c* = 0.60, $CHCl_3$). $[\alpha]_{Hg546}^{25}$ = –5.5 (*c* = 0.60, $CHCl_3$). $[\alpha]_{Hg578}^{25}$ = –4.4 (*c* = 0.60, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ = 1.10 (s, 9 H, *t*Bu), 3.81 (m, 3 H, 6-H, 4-H), 4.03 (m, 1 H, 5-H), 4.19 (dd, *J* = 2.9, 5.8 Hz, 1 H, 3-H), 4.59 (m, 4 H, OC*H*$_2$Ph), 4.69 (d, *J* = 11.3 Hz, 1 H, OC*H*$_2$Ph),

4.70 (d, J = 2.9 Hz, 1 H, 2-H), 4.81 (d, J = 11.3 Hz, 1 H, OCH_2Ph), 7.32 (m, 15 H, Ph) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 25.9, 27.0, 68.8, 70.3, 73.2, 73.4, 74.6, 76.6, 76.9, 91.8, 127.4, 127.5, 127.6, 127.8, 128.0, 128.3, 138.7, 138.8, 163.3 ppm. MS (EI): m/z = 473.3 [M + 1], 393.2, 366.2, 365.2, 275.0, 257.0, 219.2, 197.0, 181.0, 90.9. $C_{31}H_{36}O_4$ (472.62): calcd. C 78.77, H 7.68; found C 78.39, H 7.72.

2,3:4,6-Di-*O*-isopropylidene-α-D-mannopyranosyl Chloride (22):[55] A solution of 2,3:4,6-di-*O*-isopropylidene-D-mannopyranose (3.4 g, 13.1 mmol) in dry THF (60 mL) was cooled to 0 °C and treated with *n*BuLi (1.6 M in *n*-hexane, 8.2 mL, 13.1 mmol) followed by chlorodiphenylphosphate (2.6 mL, 13.0 mmol). After stirring for 15 min, the reaction mixture was warmed up to room temperature and then stirred for an additional 15 h. Solids were filtered, and the filtrate was evaporated in vacuo. Purification by flash chromatography (15% EtOAc/hexane) afforded chloride **22** (2.8 g, 78%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.36 (s, 3 H, Me), 1.45 (s, 3 H, Me), 1.52 (s, 3 H, Me), 1.55 (s, 3 H, Me), 3.86 (m, 4 H), 4.31 (m, 1 H), 4.44 (dd, J = 0.7, 5.3 Hz, 1 H, 2-H), 6.20 (d, J = 0.7 Hz, 1 H, 1-H) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 18.8, 26.6, 28.4, 29.0, 61.4, 64.4, 72.3, 74.0, 79.0, 90.7, 100.0, 110.5 ppm. MS (API-ES+): m/z = 279.1 [M + 1]$^+$.

1,4-Anhydro-5,6-*O*-isopropyliden-2-deoxy-1-*C*-methyl-D-*arabino*-hex-1-enitol (23): Using the general procedure, chloride **20** (250 mg, 0.89 mmol) was treated with MeLi (1.6 M in diethyl ether, 1.7 mL, 2.67 mmol) at 0 °C. Extractive workup was followed by quick flash chromatography (10% EtOAc/hexane) to give *C*-1 glycal **23** (65 mg, 60%). $[\alpha]_D^{25}$ = –4.5 (c = 0.42, $CHCl_3$). ^{1}H NMR (300 MHz, C_6D_6): δ = 1.28 (s, 3 H, Me), 1.41 (s, 3 H, Me), 1.56 (s, 3 H, Me), 4.05 (m, 2 H, 6-H), 4.14 (dd, J = 6.1, 7.4 Hz, 1 H, 4-H), 4.53 (dt, J = 7.4, 6.0 Hz, 1 H, 5-H), 4.68 (m, 1 H, 3-H), 4.69 (m, 1 H, 2-H) ppm. ^{13}C NMR (50 MHz, C_6D_6): δ = 25.3, 25.8, 27.4, 67.5, 74.0, 74.6, 86.3, 100.6, 105.9, 169.0 ppm. MS (EI): m/z = 201.0 [M + 1]$^+$, 200.0 [M]$^+$, 199.0, 185.0, 167.0, 141.0, 127.0, 125.0, 101.0, 73.0, 59.0, 43.0.

1,4-Anhydro-5,6-*O*-isopropyliden-2-deoxy-1-*C*-*n*-butyl-D-*arabino*-hex-1-enitol (24): Using the general procedure, chloride **20** (108 mg, 0.39 mmol) was treated with *n*BuLi (1.6 M in hexane, 0.73 mL, 1.17 mmol) at 0 °C. Extractive workup was followed by quick flash chromatography (20% EtOAc/hexane) to give *C*-1 glycal **24** (50 mg, 54%). $[\alpha]_D^{25}$ = –30.8 (c = 0.78, $CHCl_3$). ^{1}H NMR (300 MHz, C_6D_6): δ = 0.79 (t, J = 7.3 Hz, 3 H, Me), 1.11 (m, 2 H, CH_2), 1.20 (m, 2 H, CH_2), 1.28 (s, 3 H, Me), 1.42 (s, 3 H, Me), 2.02 (t, J = 7.3 Hz, 2 H, CH_2), 4.07 (m, 2 H, 6-H), 4.18 (t, J = 7.0 Hz, 1 H, 4-H), 4.55 (dt, J = 6.0, 7.0 Hz, 1 H, 5-H), 4.70 (m, 1 H, 3-H), 4.75 (m, 1 H, 2-H) ppm. ^{13}C NMR (50 MHz, C_6D_6): δ = 13.9, 22.5, 25.5, 27.0, 28.1, 28.8, 67.1, 73.7, 74.0, 85.6, 99.2, 109.1, 164.0 ppm. MS (EI): m/z = 243.1 [M + 1]$^+$, 227.0, 225.1, 207.1, 199.0, 185.1, 183.0, 167.0, 165.0, 125.0, 100.9.

1,4-Anhydro-5,6-*O*-isopropyliden-2-deoxy-1-*C*-*sec*-butyl-D-*arabino*-hex-1-enitol (25): Using the general procedure, chloride **20** (90 mg, 0.32 mmol) was treated with *s*BuLi (1.4 M in cyclohexane, 0.69 mL, 0.97 mmol) at 0 °C. Extractive workup was followed by quick flash chromatography (20% EtOAc/hexane) to give *C*-1 glycal **25** (50 mg, 54%) as a 2:1 mixture of diastereomers. Selected peaks for the major isomer.^{1}H NMR (200 MHz, $CDCl_3$): δ = 0.87 (t, J = 7.4 Hz, 3 H, Me), 1.07 (d, J = 6.9 Hz, 3 H, Me), 1.37 (s, 3 H, Me), 1.39 (m, 2 H, CH_2), 1.45 (s, 3 H, Me), 2.2 (m, 1 H, CH), 4.01 (m, 2 H), 4.16 (dd, J = 6.2, 8.0 Hz, 1 H, 6-H), 4.47 (dt, J = 8.0, 6.2 Hz, 1 H, 6-H), 4.86 (m, 2 H) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 11.3, 17.2, 25.3, 26.8, 26.9, 34.5, 66.9, 73.2, 73.8, 84.6, 97.4, 109.1, 168.6 ppm. MS (API-ES+): m/z = 243.3 [M + 1]$^+$.

1,4-Anhydro-5,6-*O*-isopropyliden-2-deoxy-1-*C*-*tert*-butyl-D-*arabino*-hex-1-enitol (26): Using the general procedure, chloride **20** (95 mg, 0.34 mmol) was treated with *t*BuLi (1.7 M in pentane, 0.60 mL, 1.02 mmol) at 0 °C. Extractive workup was followed by quick flash chromatography (20% EtOAc/hexane) to give *C*-1 glycal **26** (38 mg, 46%). M.p. 83–85 °C (hexane/EtOAc). $[\alpha]_D^{25}$ = –27.8 (c = 0.64, $CHCl_3$). ^{1}H NMR (300 MHz, C_6D_6): δ = 1.13 (s, 9 H, *t*Bu), 1.35 (s, 3 H, Me), 1.48 (s, 3 H, Me), 4.10 (m, 2 H, 6-H), 4.25 (t, J = 6.4 Hz, 1 H, 4-H), 4.58 (m, 1 H, 5-H), 4.71 (m, 1 H, 3-H), 4.75 (d, J = 2.0 Hz, 1 H, 2-H) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 25.4, 26.2, 27.7, 32.2, 66.7, 73.3, 77.7, 84.8, 95.4, 109.1, 172.3 ppm. MS (EI): m/z = 243.1 [M + 1], 225.1, 203.1, 185.0, 183.0, 167.0, 101.0.

1,4-Anhydro-5,6-*O*-isopropyliden-2-deoxy-1-*C*-phenyl-D-*arabino*-hex-1-enitol (27): Using the general procedure, chloride **20** (87 mg, 0.32 mmol) was treated with PhLi (1.8 M in di-*n*-butyl ether, 0.53 mL 0.96 mmol) at 0 °C. Extractive workup was followed by quick flash chromatography (20% EtOAc/hexane) to give *C*-1 glycal **27** (58 mg, 71%). $[\alpha]_D^{25}$ = +7.8 (c = 0.33, $CHCl_3$). ^{1}H NMR (300 MHz, C_6D_6): δ = 1.31 (s, 3 H, Me), 1.45 (s, 3 H, Me), 4.10 (m, 2 H, 6-H), 4.25 (t, J = 6.7 Hz, 1 H, 4-H), 4.55 (m, 1 H, 5-H), 4.70 (dd, J = 2.9, 6.7 Hz, 1 H, 3-H), 5.39 (d, J = 2.9 Hz, 1 H, 2-H), 7.10 (m, 3 H, Ph), 7.56 (m, 2 H, Ph) ppm. ^{13}C NMR (50 MHz, C_6D_6): δ = 25.5, 27.0, 67.0, 73.6, 74.0, 85.6, 99.2, 109.2, 124.1, 125.9, 128.3, 129.4, 159.8 ppm. MS (EI): m/z = 263.1 [M + 1]$^+$.

1,5-Anhydro-4,6-*O*-isopropyliden-2-deoxy-1-*C*-methyl-D-*arabino*-hex-1-enitol (28): Using the general procedure, chloride **22** (150 mg, 0.75 mmol) was treated with MeLi (1.6 M in diethyl ether, 1.4 mL, 2.25 mmol) at 0 °C. Extractive workup was followed by quick flash chromatography (10% EtOAc/hexane) to give *C*-1 glycal **28** (97.5 mg, 65%). $[\alpha]_D^{25}$ = +23.8 (c = 1.0, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.42 (s, 3 H, Me), 1.51 (s, 3 H, Me), 1.72 (m, 3 H, Me), 3.71 (m, 2 H, 4-H, 5-H), 3.81 (t, J = 10.2 Hz, 1 H, 6-H), 3.93 (dd, J = 5.1, 10.2 Hz, 1 H, 6-H), 4.28 (br. s, 1 H, 3-H), 4.49 (m, 1 H, 2-H) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 19.3, 19.5, 29.2, 62.0, 68.0, 69.2, 73.9, 99.5, 99.9, 152.6 ppm. MS (API-ES+): m/z = 201.0 [M + 1]$^+$, 223.1 [M + Na]$^+$. $C_{10}H_{16}O_4$ (200.23): calcd. C 59.98, H 8.05; found C 59.77, H 8.09.

1,5-Anhydro-4,6-*O*-isopropyliden-2-deoxy-1-*C*-*n*-butyl-D-*arabino*-hex-1-enitol (29): Using the general procedure, chloride **22** (150 mg, 0.61 mmol) was treated with *n*BuLi (1.6 M in hexane, 1.14 mL, 1.83 mmol) at 0 °C. Extractive workup was followed by quick flash chromatography (20% EtOAc/hexane) to give *C*-1 glycal **29** (91 mg, 62%). $[\alpha]_D^{25}$ = +7.6 (c = 0.43, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.87 (t, J = 7.1 Hz, 3 H, Me), 1.29 (m, 4 H, CH_2), 1.42 (s, 3 H, Me), 1.51 (s, 3 H, Me), 1.98 (t, J = 7.1 Hz, 2 H, CH_2), 3.67 (m, 2 H, 4-H, 5-H), 3.80 (t, J = 10.0 Hz, 1 H, 6-H), 3.94 (dd, J = 5.4, 10.0 Hz, 1 H, 6-H), 4.28 (br. s, 1 H, 3-H), 4.48 (m, 1 H, 2-H) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 13.9, 19.1, 23.3, 26.6, 29.1, 32.9, 61.9, 67.7, 69.1, 73.9, 98.7, 99.8, 155.9 ppm. MS (API-ES+): m/z = 243.3 [M + 1]$^+$. $C_{13}H_{22}O_4$ (242.31): calcd. C 64.44, H 9.15; found C 63.96, H 9.01.

1,5-Anhydro-4,6-*O*-isopropyliden-2-deoxy-1-*C*-*sec*-butyl-D-*arabino*-hex-1-enitol (30): Using the general procedure, chloride **22** (150 mg, 0.61 mmol) was treated with *s*BuLi (1.4 M in cyclohexane, 1.31 mL, 1.83 mmol) at 0 °C. Extractive workup was followed by quick flash chromatography (20% EtOAc/hexane) to give *C*-1 glycal **30** (121 mg, 82%) as a 3:1 mixture of diastereomers. Selected peaks for the major isomer: ^{1}H NMR (200 MHz, $CDCl_3$): δ = 0.86 (t, J = 7.3 Hz, 3 H, Me), 1.02 (d, J = 7.1 Hz, 3 H, Me), 1.30 (m, 2 H, CH_2), 1.44 (s, 3 H, Me), 1.54 (s, 3 H, Me), 2.01 (m, 1 H, CH), 3.67 (m, 2 H, 4-H, 5-H), 3.82 (t, J = 10.0 Hz, 1 H, 6-H), 3.96 (dd, J = 5.4, 10.0 Hz, 1 H, 6-H), 4.32 (br. s, 1 H, H-3), 4.50 (m, 1 H, 2-H)

ppm.^{13}C NMR (50 MHz, $CDCl_3$): δ = 11.7, 17.9, 19.2, 27.0, 29.1, 39.0, 61.9, 68.1, 69.1, 74.0, 99.8, 159.5 ppm. MS (API-ES+): *m*/*z* = 243.1 $[M + 1]^+$, 265.0 $[M + Na]^+$. $C_{13}H_{22}O_4$ (242.31): calcd. C 64.44, H 9.15; found C 64.19, H 8.97.

1,5-Anhydro-4,6-*O*-isopropyliden-2-deoxy-1-*C*-*tert*-butyl-D-*arabino*-hex-1-enitol (31): Using the general procedure, chloride **22** (100 mg, 0.41 mmol) was treated with *t*BuLi (1.7 M in pentane, 0.72 mL, 1.23 mmol) at 0 °C. Extractive workup was followed by quick flash chromatography (20% EtOAc/hexane) to give *C*-1 glycal **31** (49 mg, 49%). $[\alpha]_D^{25}$ = +4.6 (*c* = 0.75, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.06 (s, 9 H, *t*Bu), 1.44 (s, 3 H, Me), 1.54 (s, 3 H, Me), 3.66 (m, 2 H, 4-H, 5-H), 3.83 (t, *J* = 10.2 Hz, 1 H, 6-H), 3.97 (dd, *J* = 5.4, 10.2 Hz, 1 H, 6-H), 4.33 (m, 1 H, 3-H), 4.56 (d, *J* = 2.1 Hz, 1 H, 2-H) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 19.4, 28.1, 29.3, 35.1, 62.1, 68.3, 69.2, 74.0, 95.5, 99.9, 163.4 ppm. MS (EI): *m*/*z* = 243.1 $[M + 1]^+$. $C_{13}H_{22}O_4$ (242.31): calcd. C 64.44, H 9.15; found C 64.27, H 9.11.

1,5-Anhydro-4,6-*O*-isopropyliden-2-deoxy-1-*C*-phenyl-D-*arabino*-hex-1-enitol (32): Using the general procedure, chloride **22** (120 mg, 0.45 mmol) was treated with PhLi (1.8 M in di-*n*-butyl ether, 0.75 mL, 1.35 mmol) at 0 °C. Extractive workup was followed by quick flash chromatography (20% EtOAc/hexane) to give *C*-1 glycal **32** (97 mg, 82%). $[\alpha]_D^{25}$ = +22.6 (*c* = 1.1, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.48 (s, 3 H, Me), 1.58 (s, 3 H, Me), 3.92 (m, 2 H, 4-H, 5-H), 3.98 (t, *J* = 10.2 Hz, 1 H, 6-H), 4.12 (dd, *J* = 3.7, 10.3 Hz, 1 H, 6-H), 4.52 (br. s, 1 H, 3-H), 5.32 (d, *J* = 2.4, 1 H, 2-H), 7.10 (m, 3 H, Ph), 7.56 (m, 2 H, Ph) ppm.^{13}C NMR (50 MHz, $CDCl_3$): δ = 19.4, 29.3, 62.0, 68.3, 69.6, 73.6, 99.6, 100.1, 125.3, 128.5, 129.2, 133.2, 196.9 ppm. MS (API-ES+): *m*/*z* = 263.0 $[M + 1]^+$. $C_{15}H_{18}O_4$ (262.30): calcd. C 68.68, H 6.92; found C 68.70, H 6.88.

Supporting Information (see footnote on the first page of this article): Characterization data for compounds **20** and **36**.

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