

Synthesis of Highly Functionalized Chiral Nitriles by Radical Fragmentation of β -Hydroxy Azides. Convenient Transformation of Aldononitriles into 1,4- and 1,5-Iminoalditols

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The synthesis of highly functionalized nitriles by an alkoxyl radical fragmentation of cyclic β -hydroxy azides is described. The alkoxyl radicals were generated by reaction of the alcohols with (diacetoxyiodo)benzene and iodine under mild conditions compatible with the presence of sensitive substituents and the protective groups most frequently used in carbohydrate chemistry. To explore the scope and limitations of this methodology, experiments were carried out using a variety of β -hydroxy azides of the carbohydrate (1-6, 33, and 41), monoterpenoid (21 and 22), and steroid (23-25) families of natural products. Of special interest are the aldopentonitriles (15-18, 34, and**42**) and aldotetrononitriles (**19** and **20**) synthesized from the corresponding 2-azido-2-deoxycarbohydrates. To demonstrate the versatility of these aldononitriles as chiral synthons, 1,4-imino-1deoxysugar (37) and 1,5-imino-1-deoxysugar (43) analogues of the polyhydroxypyrrolidine and -piperidine types were prepared.

Introduction

The synthesis of ϵ -ketonitriles from cyclic α -hydroxy oximes through a Beckmann fragmentation has frequently been utilized in synthetic organic chemistry.¹ Related methodologies for the synthesis of ϵ -ketonitriles by cleavage of trisubstituted cyclic olefins with DIB/ (TMS)N₃ or LTA/(TMS)N₃,² CAN/NaN₃,³ or photooxygenation in the presence of NaN₃/Cu(OTf)₂⁴ have also been described.

On the other hand, several methods for preparing aldononitriles from carbohydrates are described in the literature, involving direct addition of HCN to aldoses (Fischer-Kiliani cyanohydrin synthesis),⁵ dehydration of

aldose oximes,^{5b,6} and the reaction of N-bromoglycosylimines with Zn/Ag-graphite.⁷ The first method provides aldononitriles with one more carbon atoms than the starting carbohydrate, while the aldononitriles synthesized by the other two methods retain the same number of carbon atoms. Also, special types of sugar nitriles, the 2,6-anhydro- and 2,5-anhydroaldononitriles (pyranosyl and furanosyl cyanides), have attracted considerable attention since they are valuable intermediates in the synthesis of C-glycosides.⁸

We have recently published the latest results of several of our ongoing studies of the alkoxyl radical fragmentation (ARF) of reducing sugars.⁹ In this paper, we report on an extension of the ARF methodology to cyclic β -hydroxy azides that may be suitable for the synthesis of δ or ϵ -ketonitriles. The reaction is triggered by the alkoxyl

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entrv	substrate	time (h)	products	yield
	Aco Aco Aco Aco Aco		AcO AcO HOCŌ OAc	N
1	1	2	15	88
β-⊏	ACO O-GalO ^W N ₃ ACO		β-D-GalO AcO HOCŌ OAc	N
2	2	1	16	97
3	MeO N ₃	0.5	HOCO C≡ O TO OMe 17	N 71
	AcO AcO AcO AcO		AcQ AcO HOCO OAc	Ν
4	4	2	18	65
5	Ph ³ 5	1.3	Ph O HOCOC≡ 0 19	N 64
^t BuM	e ₂ SiO O MOMO ⁵ N ₃	^t B	MOMO uMe₂SiOC≡ HOCŌ	N
6	6	2	20	90

TABLE 1. Aldononitriles by β -Fragmentation of β -Hydroxy Azides in Carbohydrate Systems^{*a*}

 a All reactions were performed at 20 °C under nitrogen containing (diacetoxyiodo)benzene (1.2 mmol) and iodine (1 mmol), per millimole of substrate, in dry $\rm CH_2Cl_2$ under normal laboratory lighting conditions.

radical generated in situ by reaction of the alcohol with the hypervalent iodine reagent (diacetoxyiodo)benzene (DIB) in the presence of iodine under mild conditions. Of special interest is the ARF of glycopyranosyloxy and glycofuranosyloxy radicals in 2-azido-2-deoxycarbohydrates, which leads to aldononitriles with one carbon less than the starting saccharide. In a previous paper we described the preliminary results obtained,¹⁰ and we now disclose herein the full details of these experiments. To examine the scope of this reaction, we attempted the fragmentation of a variety of substrates of the pentose and hexose series of carbohydrates in both pyranose and furanose forms as depicted in Table 1. The reaction can also be extended to β -hydroxy azides belonging to the

TABLE 2.	Ketonitriles by β -Fragmentation of
B-Hvdroxv	Azides in Terpene and Steroid Systems



 a All reactions were performed under nitrogen containing (diacetoxyiodo)benzene (1.2 mmol) and iodine (1 mmol) per millimole of substrate, in dry CH₂Cl₂ and under irradiation with two 80 W tungsten-filament lamps. b DIB (2.5 mmol) was used.

terpenic and steroid families of natural products (Table 2). The structures of the new compounds were routinely confirmed by ¹H and ¹³C NMR spectroscopy including COSY, HSQC, HMBC, and DEPT experiments. To our knowledge the radical fragmentation of β -hydroxy azides has not previously been attempted. The methodology developed here has been used by Wipf and Mareska in a study of the reversal of regioselectivity in the fragmentation of hydroindoles.¹¹

The present study also shows the utility of these aldononitriles as chiral synthons for the preparation of polyhydroxypiperidines (1,5-iminoalditols) and polyhydroxypyrrolidines (1,4-iminoalditols) related to glycosidase inhibitors.

Results and Discussion

Synthesis of Substrates. Several excellent methods exist in the literature for the synthesis of β -hydroxy azides in general by electrophilic or radical additions to olefins.¹² The known 2-azido-2-deoxysaccharides 1¹³ and 2¹⁴ (Table 1) were prepared by a sequence of azidonitra-

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 a Reagents and conditions: (a) TBAF, (TMS)N₃, *N*-(phenylse-leno)phthalimide, CH₂Cl₂, 83%; (b) *N*-iodosuccinimide, THF-H₂O, 81%.

tion of the respective glycals with the CAN/NaN₃ reagent according to the procedure of Lemieux and Ratcliffe,¹⁵ followed by anomeric denitration with hydrazine acetate.¹⁶ The mixtures of D-gluco and D-manno (1) and β -D-Galp-(1→4)-D-Glcp and β -D-Galp-(1→4)-D-Manp (2) diastereoisomers were subjected to the radical fragmentation without previous separation.

The 2-azido-2-deoxy-D-glucofuranose derivative **3** and 2-azido-2-deoxy-D-galactopyranose derivative **4** were obtained starting from 1,4-anhydro-2-deoxy-3-O-methyl-5,6-O-isopropylidene-D-arabino-hex-1-enitol (**7**)¹⁷ and 2,6anhydro-5-deoxy-D-arabino-hex-5-enitol, respectively, by azidophenylselenation with N-(phenylseleno)phthalimide and (TMS)N₃ followed by anomeric dephenylselenation with N-iodosuccinimide, as illustrated for **3** (Scheme 1).¹⁸

Compounds **5** and **6** were prepared as described in Scheme 2 starting from 3,4-*O*-benzylidene-D-ribono-1,5lactone (**9**). Nucleophilic displacement of the triflate group in **10** with lithium azide afforded deoxy derivative **11**, which was subsequently reduced with L-Selectride to give the desired β -hydroxy azide **5**. The hydrolysis of the 3,4-*O*-benzylidene protective group in compound **11** afforded the rearranged¹⁹ 1,4-lactone **12**, which was consecutively protected with (TBDMS)Cl and (MOM)Cl, leading to compound **14**. Under the benzylidene hydrolysis reaction conditions, concomitant partial isomerization

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of the 2-azide group also occurred. In this case, as a precursor of a nonstereogenic center, the C2 stereochemistry is irrelevant, and no diastereoisomeric separation of compound 14 was attempted at this stage. Finally, the reduction of the carboxyl group with L-Selectride afforded the required β -hydroxy azide **6**.

Monoterpenoid azides **21** and **22** were prepared by photooxygenation in the presence of sodium azide of the corresponding olefins (+)-limonene and (-)- α -pinene and subsequent reduction, with sodium sulfite, of the hydroperoxy azide intermediates (Table 2).²⁰

The reaction of cholesterol α -epoxide with sodium azide gave β -hydroxy azide **23** following a previously reported procedure.²¹ The diol was later transformed into the monoacetate **24** with acetic anhydride and pyridine. The pregnene derivative **25** was also synthesized by acidcatalyzed opening of the corresponding α -epoxide. It is worthy of note that, under exactly the same reaction conditions, Ponsold described the formation of a derivative with ring D rearranged to a six-membered hydroxy azide (3β -acetoxy- 16β -azido- 17α -hydroxy- 17β -methyl-Dhomoandrost-5-en-17a-one) as the sole product²² but, in our hands, the hitherto unknown five-membered hydroxy azide **25** (77%) is the principal product, the six-membered azide being formed in only 9% yield.

Our fragmentation procedure was applied to differently protected 2-azido-2-deoxyglucopyranose and -glucofuranose derivatives 1-3 to give arabinononitriles 15-17 in good yields. The reactions proceeded smoothly under the conditions shown in Table 1 (entries 1-3), using approximately equimolecular amounts of DIB and iodine

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at room temperature. The diastereoisomeric mixture of D-galacto and D-talo azides 4 gave the lyxononitrile derivative 18 (entry 4). For the sake of completeness this methodology was also extended to several additional examples of the pentose series of carbohydrates, the results of which are also included in Table 1. We have involved in this study two different D-ribo-protected compounds, 5 and 6, which gave the erythrononitriles 19 and 20 (entries 5 and 6).

The ARF reaction also occurred in β -hydroxy azides on carbocyclic systems as depicted in Table 2. The reaction of β -hydroxy azides **21** and **22** belonging, respectively, to the (+)-limonene and (-)- α -pinene monoterpene families, afforded ϵ -ketonitriles **26**^{23b} and **27**²³ (entries 1 and 2). The reaction is compatible with other hydroxyl groups present in the molecule, but in this case it might be necessary to tune the reaction conditions to increase the chemoselectivity. For example, the temperature of the fragmentation of the steroidal diol 23 had to be lowered with an ice-water bath for optimum yield (entry 3), while a higher temperature led to clearly inferior results (a 51% yield of nitrile $\mathbf{28}^{24}$ was obtained at 20 °C, and a complex mixture of unidentified products was produced at higher temperatures). In any case, a significantly higher yield of ketonitrile 29^{25} (88%) was obtained when the 3β -alcohol was protected with an acetyl group such as compound 24 (entry 4).

An interesting α -diketone, **30**, was obtained when the β -hydroxy azide of the pregnane type **25** was submitted to the DIB/I₂ system; the reaction proceeded in moderate yield at 0 °C (entry 5). Control of the reaction temperature was found to be critical since the yield was significantly reduced at room temperature. Taking into account the possibility of further oxidation of the sensitive α -diketone by the excess of reagent, we examined whether the yield could be improved by decreasing the oxidant ratio. However, this did not result in a significant increase in yield. The α -diketone **30** obtained as light yellow crystals was characterized by spectroscopic means, and by analogy with the related progestomimetic steroid oxopromegestone.²⁶

Although in all cases shown in Table 2 the reaction proceeded under natural lighting conditions, assisted irradiation with 2×80 W tungsten filament lamps reduced the reaction times, this shortening being especially significant in low-temperature reactions (entries 3 and 5).

The reaction mechanism deserves special comment. According to the above results, it seems reasonable that the first step is an alkoxyl radical generation through a hypoiodite intermediate, supported by the fact that in the SCHEME 3. Mechanism of the ARF Reaction



absence of iodine the starting material was recovered quantitatively. As shown in Scheme 3, the C2 radical consequently formed must be oxidized by the reagent to a carbocation which generates the nitrile group after loss of a molecule of nitrogen.

From the products obtained in Table 1, it can be inferred that the aldononitriles possess an easily hydrolyzable formate group at C3 or C4 and that this position only depends on the furanose or pyranose form of the starting carbohydrate. We believe that this is a characteristic of these compounds that could be most valuable in synthetic organic chemistry. 1-Deoxyiminosugar analogues of the polyhydroxypyrrolidine and -piperidine types were prepared to demonstrate the versatility of these aldononitriles as chiral synthons. The methodology developed by Buchanan et al.²⁷ for the synthesis of 1,4imino sugar was used.

1,4-Anhydro-5-O-benzyl-(4-*tert*-butoxycarbonyl)amino-1,4-dideoxy-2,3-isopropylidene-L-ribitol (**37**) was synthesized in six steps from the D-galactal derivative **31**²⁸ as described in Scheme 4. Azidophenylselenation of the double bond followed by anomeric deselenation afforded alcohol **33**,^{18f} which was submitted to the ARF reaction to give the D-lyxononitrile **34**.

Hydrolysis of the formate group under mild conditions afforded the alcohol **35**, which afterward was mesylated, leading to compound **36**. After some experimentation with several well-known nitrile reductants (Raney Ni,²⁹ BH₃·THF,³⁰ and activated NaBH₄³¹) we were pleased to find that the simple addition of LiAlH₄ in Et₂O is quite effective at reducing the nitrile group and promoting the desired cyclization.³² The crude pyrrolidine was protected as its Boc-carbamate to give the L-iminoribitol derivative **37** since the aminocyclization occurred with inversion of configuration at C4.³³

Alternatively, this protocol can be used for the synthesis of 1,5-iminoalditols. As described in Scheme 5, the

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 a Reagents and conditions: (a) TBAF, (TMS)N₃, N-(phenylseleno)phthalimide, CH₂Cl₂, 67%; (b) N-iodosuccinimide, THF–H₂O, 79%; (c) DIB, I₂, CH₂Cl₂, 86%; (d) CSA, MeOH, 70%; (e) MsCl, Et₃N, CH₂Cl₂, 71%; (f) LiAlH₄, Et₂O, then di-*tert*-butyl dicarbonate, 69%.





 a Reagents and conditions: (a) TBAF, (TMS)N₃, *N*-(phenylseleno)phthalimide, CH₂Cl₂, 51%; (b) MsCl, Et₃N, CH₂Cl₂, 85%; (c) NIS, THF-H₂O, 87%; (d) DIB, I₂, CH₂Cl₂, 71%; (e) LiAlH₄, Et₂O, then di-*tert*-butyl dicarbonate, 62%.

galactal derivative **38** was transformed into the 1,5imino-D-arabinitol **43**. In a very similar sequence of reactions, the synthesis commenced with azidoselenation of the double bond,^{18f} followed by mesylation of the primary alcohol, and anomeric deselenation. The ARF reaction of β -hydroxy azide **41** afforded the D-arabinononitrile **42**, which was subsequently reduced with LiAlH₄ to give the required 1,5-iminoarabinitol $43.^{34}$ From the above examples, it is clear that this methodology may be useful for the preparation of 1,4- and 1,5-iminopentitols from a common precursor, in this case 3,4-isopropylidene-D-galactal.

In summary, the application of the ARF reaction to five- and six-membered carbocyclic β -hydroxy azides led to acyclic δ - and ϵ -ketonitriles, respectively. One especially important use of this methodology was the fragmentation of 2-azido-2-deoxyaldoses, which afforded aldononitriles in good yield. The pyranose and furanose models, prepared to study the scope of this method, were constructed to incorporate a variety of commonly employed carbohydrate protecting groups, each of which proved tolerant to the mild reaction conditions. The utility of these aldononitriles as chiral building blocks has been demonstrated by a short synthesis of 1,4- and 1,5-imino-1-deoxypentitols, which are considered to be potential glycosidase inhibitors.^{33,34}

Experimental Section

General Procedure for the Preparation of Compounds 15–20. A solution of the β -hydroxy azide (1 mmol) in CH₂Cl₂ (20 mL) containing DIB (1.2 mmol) and iodine (1 mmol) was stirred at 20 °C for the time specified in Table 1, under exposure to ambient light but without irradiation from an external source. The reaction mixture was then poured into a 10% aqueous Na₂S₂O₃ solution, extracted with CH₂Cl₂, dried (Na₂SO₄), and concentrated in vacuo. Chromatotron chromatography of the residue (hexanes–EtOAc) as specified gave the nitriles.

2,3,5-Tri-O-acetyl-4-O-formyl-D-arabinononitrile (15). The product was isolated by chromatography (hexanes–EtOAc, 70:30) as a crystalline solid (88%): mp 82–83 °C (from *n*-hexane–EtOAc); $[\alpha]_D$ –10 (*c* 0.4); IR 2100, 1764, 1740 cm⁻¹; ¹H NMR δ_H 2.07 (3H, s), 2.17 (3H, s), 2.20 (3H, s), 4.21 (1H, dd, J = 5.0, 12.6 Hz), 4.32 (1H, dd, J = 3.0, 12.6 Hz), 5.39 (1H, dd, J = 3.4 Hz), 5.61 (1H, dd, J = 3.4, 5.4 Hz), 8.01 (1H, s); ¹³C NMR δ_C 20.1 (CH₃), 20.4 (CH₃), 20.5 (CH₃), 59.5 (CH), 61.0 (CH₂), 67.2 (CH), 67.7 (CH), 113.8 (C), 159.0 (CH), 168.5 (C), 168.8 (C), 170.3 (C); FABMS *m/z* (glycerol, NaCl) (rel intens) 302 (M⁺ + H, 21). Anal. Calcd for C₁₂H₁₅NO₈: C, 47.84; H, 5.02; N, 4.65. Found: C, 47.92; H, 5.11; N, 4.56.

2,5-Di-O-acetyl-4-O-formyl-3-O-(2,3,4,6-tetra-O-acetylβ-D-galactopyranosyl)-D-arabinononitrile (16). The product was isolated by chromatography (hexanes-EtOAc, 1:1) as a crystalline solid (97%): mp 36-38 °C (from n-hexane-EtOAc); $[\alpha]_D$ +4 (c 0.74); IR 2125, 1756 cm⁻¹; ¹H NMR δ_H 1.97 (3H, s), 2.03 (3H, s), 2.06 (3H, s), 2.07 (3H, s), 2.15 (3H, s), 2.16 (3H, s), 3.96 (1H, dd, J = 6.5, 6.4 Hz), 4.20 - 4.11 (4H, m),4.51 (1H, dd, J = 3.1, 12.4 Hz), 4.67 (1H, d, J = 7.9 Hz), 5.00 (1H, dd, J = 3.4, 10.5 Hz), 5.21 (1H, dd, J = 7.9, 10.5 Hz),5.37 (1H, d, J = 3.3 Hz), 5.39 (1H, ddd, J = 3.1, 5.8, 6.0 Hz),5.75 (1H, d, J = 4.3 Hz), 8.02 (1H, s); ¹³C NMR (100.4 MHz) $\delta_{\rm C}$ 20.1 (CH₃), 20.4 (CH₃), 20.5 (2 × CH₃), 20.56 (CH₃), 20.60 (CH₃), 60.6 (CH), 61.2 (2 × CH₂), 66.7 (CH), 68.5 (CH), 69.0 (CH), 70.6 (CH), 71.2 (CH), 76.4 (CH), 101.8 (CH), 114.3 (C), 159.1 (CH), 168.3 (C), 169.2 (C), 170.0 (C), 170.1 (C), 170.13 (C), 170.4 (C); MS m/z (rel intens) 529 (M⁺ – AcOH, 1), 516 (<1), 331 (56), 169 (100); HRMS m/z calcd for $C_{22}H_{27}NO_{14}$ 529.1432, found 530.1437. Anal. Calcd for C₂₄H₃₁NO₁₆: C, 48.88; H, 5.30; N, 2.38. Found: C, 48.69; H, 5.23; N, 2.31.

⁽³³⁾ For other syntheses of 1,4-iminoalditols using different methodologies, see: (a) Huang, Y.; Dalton, D. R.; Carroll, P. J. Org. Chem. **1997**, 62, 372–376. (b) Takano, S.; Moriya, M.; Ogasawara, K. Tetrahedron: Asymmetry **1992**, 3, 681–684. (c) Fleet, G. W. J.; Son, J. C.; Green, D. St. C.; Bello, I. C.; Winchester, B. Tetrahedron **1988**, 44, 2649–2655. (d) Setoi, H.; Kayakiri, H.; Takeno, H.; Hashimoto, M. Chem. Pharm. Bull. **1987**, 35, 3995–3999. (e) Sawada, D.; Takahashi, H.; Ikegami, S. Tetrahedron Lett. **2003**, 44, 3085–3088. For the synthesis of ent-**37** see: (f) Kumareswaran, R.; Hassner, A. Tetrahedron: Asymmetry **2001**, 12, 3409–3415.

⁽³⁴⁾ Compound **43** has been previously prepared as an intermediate in the synthesis of 1-iminosugars but was not characterized; see: (a) Ichikawa, Y.; Igarashi, Y.; Ichikawa, M.; Suhara, Y. J. Am. Chem. Soc. **1998**, 120, 3007–3018. (b) Igarashi, Y.; Ichikawa, M.; Ichikawa, Y. Tetrahedron Lett. **1996**, 37, 2707–2708.

3-O-Formyl-4,5-O-isopropylidene-2-O-methyl-D-arabinononitrile (17). The product was isolated by chromatography (hexanes–EtOAc, 80:20) as a syrup (71%): $[\alpha]_D$ –11.0 (*c* 0.3); IR 2112, 1737 cm⁻¹; ¹H NMR δ_H 1.35 (3H, s), 1.43 (3H, s), 3.57 (3H, s), 3.90 (1H, dd, J = 5.0, 9.0 Hz), 4.06 (1H, dd, J = 6.3, 9.0 Hz), 4.34 (1H, m), 4.42 (1H, d, J = 3.0 Hz), 5.31 (1H, ddd, J = 0.7, 3.0, 7.4 Hz), 8.17 (1H, s); ¹³C NMR δ_C 25.1 (CH₃), 28.6 (CH₃), 58.8 (CH₃), 65.9 (CH₂), 69.5 (CH), 71.3 (CH), 72.5 (CH), 110.1 (C), 115.3 (C), 159.1 (CH); MS *m*/*z* (rel intens) 214 (M⁺ – Me, 100), 101 (27); HRMS *m*/*z* calcd for C₉H₁₂NO₅: 214.0715, found 214.0721. Anal. Calcd for C₁₀H₁₅NO₅: C, 52.39; H, 6.59; N, 6.11. Found: C, 52.48; H, 6.62; N, 6.01.

2,3,5-Tri-O-acetyl-4-O-formyl-D-lyxononitrile (18). The product was isolated by chromatography (hexanes–EtOAc, 70: 30) as a syrup (65%): $[\alpha]_D -11$ (*c* 0.12); IR 2115, 1757 cm⁻¹; ¹H NMR δ_H 2.08 (3H, s), 2.17 (3H, s), 2.22 (3H, s), 4.09 (1H, dd, J = 6.5, 12.0 Hz), 4.33 (1H, dd, J = 5.1, 12.0 Hz), 5.51 (1H, m), 5.53 (1H, d, J = 6.7 Hz), 5.58 (1H, dd, J = 3.3, 6.9 Hz), 8.09 (1H, s); ¹³C NMR δ_C 20.1 (CH₃), 20.3 (CH₃), 20.5 (CH₃), 59.3 (CH), 61.1 (CH₂), 67.1 (CH), 68.2 (CH), 114.0 (C), 159.4 (CH), 168.3 (C), 169.1 (C), 170.1 (C); MS *m*/*z* (rel intens) 302 (M⁺ + 1, <1), 203 (66), 141 (95), 115 (100); HRMS *m*/*z* calcd for C₁₂H₁₆NO₈ 302.0876, found 302.0878. Anal. Calcd for C₁₂H₁₆NO₈: C, 47.84; H, 5.02; N, 4.65. Found: C, 48.13; H, 5.29; N, 4.50.

2,3-O-Benzylidene-4-O-formyl-D-erythrononitrile (19). The product was isolated by chromatography (hexanes-EtOAc, 70:30) as a crystalline solid (64%): mp 78–80 °C (from *n*-hexane-EtOAc); $[\alpha]_D$ –5.1 (*c* 0.82); IR 2109, 1734 cm⁻¹; ¹H NMR (C₆D₆) δ_H 3.67 (1H, ddd, J = 5.3, 6.3, 6.3 Hz), 3.96 (1H, d, J = 6.3, Hz), 4.24 (1H, dd, J = 5.3, 11.9 Hz), 4.33 (1H, dd, J = 6.3, 11.9 Hz), 5.40 (1H, s), 7.16–7.13 (3H, m), 7.42 (1H, s), 7.49–7.47 (2H, m); ¹³C NMR δ_C 61.3 (CH₂), 66.1 (CH), 76.2 (CH), 106.5 (CH), 115.1 (C), 127.0 (2 × CH), 128.6 (2 × CH), 130.4 (CH), 134.5 (C), 159.9 (CH); MS *m*/*z* calcd for C₁₂H₁₁NO₄ 233.0688, found 233.0683. Anal. Calcd for C₁₂H₁₁NO₄: C, 61.80; H, 4.75; N, 6.01. Found: C, 61.95; H, 4.88; N, 6.08.

4-O-(tert-Butyldimethylsilyl)-3-O-formyl-2-O-(methoxymethyl)-D-erythrononitrile (20). The product was isolated by chromatography (hexanes–EtOAc, 90:10) as a syrup (90%) which solidified at low temperature: mp 24–26 °C (from *n*-hexane); $[\alpha]_D + 42.3$ (*c* 0.26); IR 2109, 1733 cm⁻¹; ¹H NMR δ_H 0.08 (6H, s), 0.85 (9H, s), 3.40 (3H, s), 3.79 (1H, dd, J = 5.5, 11.2 Hz), 3.84 (1H, dd, J = 4.5, 11.2 Hz), 4.68 (1H, d, J = 7.0 Hz), 4.74 (1H, d, J = 5.5 Hz), 4.81 (1H, d, J = 7.0 Hz), 4.74 (1H, d, J = 5.5 Hz), 8.10 (1H, s); ¹³C NMR $\delta_C - 5.5$ (2 × CH₃), 18.2 (C), 25.8 (3 × CH₃), 56.5 (CH₃), 60.2 (CH₂), 63.7 (CH), 72.1 (CH), 96.0 (CH₂), 115.9 (C), 159.5 (CH); MS *m/z* calcd for C₁₃H₂₆NO₅Si 304.1580, found 304.1490. Anal. Calcd for C₁₃H₂₅NO₅Si: C, 51.46; H, 8.30; N, 4.62. Found: C, 51.24; H, 8.35; N, 4.73.

General Procedure for the Preparation of Compounds 26–30. A solution of β -hydroxy azide (1 mmol) in CH₂Cl₂ (40 mL) containing DIB (1.2 mmol) and iodine (1 mmol) was irradiated with two 80 W tungsten-filament lamps at the temperature and for the time specified in Table 2. The reaction mixture was then poured into a 10% aqueous Na₂S₂O₃ solution, extracted with CH₂Cl₂, dried (Na₂SO₄), and concentrated in vacuo. Chromatotron chromatography of the residue (hexanes–EtOAc) as specified gave the nitriles.

(3*R*)-3-(1-Methylethenyl)-6-oxoheptanenitrile (26). The product was isolated by chromatography (hexanes–EtOAc, 75: 25) as an oil (79%): $[\alpha]_D$ –13 (*c* 0.12); IR 3079, 2243, 1715, 1648, 908 cm⁻¹; ¹H NMR (C₆D₆) δ_H 1.26 (3H, s), 1.28 (1H, dddd, J = 6.0, 8.3, 9.0, 14.1 Hz), 1.39 (1H, dddd, J = 5.0, 6.7, 8.5, 13.9 Hz), 1.53 (1H, dd, J = 6.0, 16.8 Hz), 1.54 (1H, dd, J = 7.6, 16.7 Hz), 1.58 (3H, s), 1.70 (1H, ddd, J = 6.9, 6.9, 8.0 Hz), 1.71 (1H, ddd, J = 6.0, 6.0, 8.5 Hz), 1.87 (1H, dddd, J = 5.1, 7.2, 7.2, 10.0 Hz), 4.56 (1H, br s), 4.68 (1H, dd, J = 1.5, 1.5 Hz); ¹³C NMR (C₆D₆, 125.7 MHz) δ_C 18.1 (CH₃), 21.7 (CH₂),

25.9 (CH₂), 29.4 (CH₃), 40.3 (CH₂), 43.0 (CH), 114.0 (CH₂), 118.1 (C), 144.0 (C), 205.3 (C); MS m/z (rel intens) 165 (M⁺, 6), 150 (7), 147 (12), 132 (6), 125 (15), 122 (57), 108 (59), 58 (100); HRMS m/z calcd for C₁₀H₁₅NO 165.1154, found 165.1124. Anal. Calcd for C₁₀H₁₅NO: C, 72.69; H, 9.15; N, 8.48. Found: C, 72.47; H, 9.31; N, 8.36.

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(1*S*,3*S*)-(3-Acetyl-2,2-dimethylcyclobutyl)acetonitrile (27). The product isolated by chromatography (hexanes– EtOAc, 85:15) has already been partially described.^{2b} In our hands, it was obtained as an oil (82%): $[\alpha]_D -97 (c \ 0.196) (lit.^{2b} [\alpha]_D -215.0)$; IR 2250, 1703, 1185 cm⁻¹; ¹H NMR δ_H 0.94 (3H, s), 1.39 (3H, s), 1.99 (2H, m), 2.06 (3H, s), 2.29 (3H, m), 2.91 (1H, dd, J = 7.7, 9.8 Hz); ¹³C NMR δ_C 16.9 (CH₃), 17.5 (CH₂), 22.8 (CH₂), 30.0 (CH₃), 30.2 (CH₃), 38.1 (CH), 42.9 (C), 53.7 (CH), 118.5 (C), 206.6 (C); MS *m/z* (rel intens) 165 (M⁺, 15), 150 (16), 125 (40), 122 (26), 108 (12), 98 (42), 95 (37), 83 (100), 71 (77), 68 (36); HRMS *m/z* calcd for C₁₀H₁₅NO 165.1154, found 165.1150. Anal. Calcd for C₁₀H₁₅NO: C, 72.69; H, 9.15; N, 8.48. Found: C, 72.57; H, 9.35; N, 8.30.

3β-Hydroxy-5,6-seco-5-oxocholestane-6-nitrile (28). The product isolated by chromatography (hexanes-EtOAc, 70:30) has already been partially described.^{24a} It was obtained as a crystalline solid (64%): mp 68–69 °C (from *n*-hexane); $[\alpha]_D$ +90.4 (c 0.77, CHCl₃) [lit.^{24a} mp 67–69; $[\alpha]_{\rm D}$ +84.6 (MeOH)]; IR 3621, 3489, 2250, 1703 cm⁻¹; ¹H NMR $\delta_{\rm H}$ 0.66 (3H, s), 0.84 (3H, d, J = 6.7 Hz), 0.85 (3H, d, J = 6.4 Hz), 0.89 (3H, d, J = 6.4 Hz), 0.96 (3H, s), 2.10 (1H, dd, J = 3.9, 17.6 Hz), 2.46 (1H, dd, J = 3.5, 17.5 Hz), 2.49 (1H, ddd, J = 2.8, 2.8, 13.6 Hz), $3.42 (1H, dd, J = 3.9, 14.3 Hz), 4.49 (1H, br s); {}^{13}C NMR (125.7)$ MHz) δ_C 11.8 (CH₃), 17.5 (CH₃), 18.5 (CH₃), 19.1 (CH₂), 22.5 (CH₃), 22.69 (CH₂), 22.74 (CH₃), 23.6 (CH₂), 24.3 (CH₂), 27.6 (CH₂), 27.7 (CH₂), 27.9 (CH), 33.6 (CH₂), 35.6 (2 \times CH), 35.9 (CH₂), 39.3 (CH₂), 39.4 (CH₂), 41.5 (CH), 42.4 (C), 47.2 (CH₂), 52.4 (C), 53.2 (CH), 56.0 (CH), 70.8 (CH), 118.7 (C), 217.9 (C); MS m/z (rel intens) 415 (M⁺, 4), 397 (10), 371 (18), 343 (68), 317 (94), 128 (100); HRMS m/z calcd for C₂₇H₄₅NO₂ 415.3450, found 415.3485. Anal. Calcd for C₂₇H₄₅NO₂: C, 78.02; H, 10.91; N, 3.37. Found: C, 78.09; H, 10.80; N, 3.25.

3β-Acetoxy-5,6-seco-5-oxocholestane-6-nitrile (29). The product isolated by chromatography (hexanes-EtOAc, 93:7) has already been partially described.²⁵ It was obtained as a crystalline solid (88%): mp 95–97 °C (from *n*-hexane); $[\alpha]_D$ +63 (c 0.27) (lit.²⁵ mp 96–97 °C; $[\alpha]_D$ +73.7); IR 2250, 1733, 1703 cm⁻¹; ¹H NMR $\delta_{\rm H}$ 0.67 (3H, s), 0.84 (3H, d, J = 6.7 Hz), 0.85 (3H, d, *J* = 6.4 Hz), 0.90 (3H, d, *J* = 6.4 Hz), 0.99 (3H, s), 2.00 (3H, s), 2.11 (1H, dd, J = 3.8, 17.8 Hz), 2.49 (1H, dd, J = 3.8, 17.8 Hz), 3.49 (1H, dd, J =3.5, 17.8 Hz, 2.57 (1 H, ddd, J = 2.4, 2.4, 15.0 Hz), 3.40 (1 H, 10.0 Hz)dd, J = 4.3, 15.0 Hz), 5.40 (1H, br s); ¹³C NMR (125.7 MHz) δ_C 11.8 (CH₃), 17.5 (CH₃), 18.5 (CH₃), 19.1 (CH₂), 21.2 (CH₃), 22.5 (CH₃), 22.7 (CH₂), 22.8 (CH₃), 23.7 (CH₂), 24.4 (CH₂), 25.0 (CH₂), 27.7 (CH₂), 28.0 (CH), 34.0 (CH₂), 35.6 (CH), 35.7 (CH), 35.9 (CH₂), 39.3 (CH₂), 39.4 (CH₂), 41.5 (CH), 42.4 (C), 43.6 (CH₂), 52.0 (C), 53.2 (CH), 56.0 (CH), 73.2 (CH), 118.6 (C), 179.1 (C), 216.5 (C); MS m/z (rel intens) 457 (M⁺, 18), 397 (47), 369 (71), 110 (100); HRMS *m/z* calcd for C₂₉H₄₇NO₃ 457.3470, found 457.3545. Anal. Calcd for C₂₉H₄₇NO₃: C, 76.10; H, 10.35; N, 3.06. Found: C, 76.15; H, 10.40; N, 3.02.

3β-Acetoxy-16,17-seco-17,20-dioxopregn-5-ene-16-nitrile (30). The product was isolated by chromatography (benzene–EtOAc, 93:7) as light yellow crystals (51%): mp 121–122 °C (from *n*-hexane–acetone); $[\alpha]_D$ –58.7 (*c* 1.46); IR 2248, 1722 cm⁻¹; ¹H NMR (400 MHz) δ 1.03 (3H, s), 1.33 (3H, s), 2.02 (3H, s), 2.34 (3H, s), 2.59 (1H, m), 2.37 (1H, m); ¹³C NMR (100.4 MHz) δ 14.3 (CH₃), 18.0 (CH₂), 19.1 (CH₃), 19.2 (CH₂), 21.3 (CH₃), 26.8 (CH₃), 27.5 (CH₂), 31.3 (CH₂), 31.8 (CH), 35.5 (CH₂), 36.6 (CH₂), 36.7 (C), 37.7 (CH₂), 41.9 (CH), 48.4 (CH), 50.1 (C), 73.4 (CH), 118.7 (C), 121.0 (CH), 139.3 (C), 170.4 (C), 200.6 (C), 206.2 (C); MS *m/z* (rel intens) 342 (M⁺ – COCH₃, 1), 325 (11), 254 (100), 213 (10); HRMS *m/z* calcd for C₂₁H₂₈-NO₃ 342.2069, found 342.2071. Anal. Calcd for C₂₃H₃₁NO₄: C, 71.66; H, 8.11; N, 3.63. Found: C, 71.84; H, 8.10; N, 3.63.

5-O-Benzyl-4-O-formyl-2,3-O-isopropylidene-D-lyxononitrile (34). A solution of β -hydroxy azide 33^{18f} (100.1 mg, 0.30 mmol) in CH₂Cl₂ (6 mL) was treated with DIB (115.5 mg, 0.36 mmol) and iodine (75.9 mg, 0.30 mmol). The reaction mixture was stirred at 20 °C for 1 h, then poured into a 10% aqueous Na₂S₂O₃ solution, and extracted with CH₂Cl₂. The organic layer was dried over anhydrous Na₂SO₄ and concentrated under reduced pressure. The residue was purified by column chromatography (hexanes-EtOAc, 80:20) to give the nitrile **34** (78.3 mg, 0.26 mmol, 86%) as an oil: $[\alpha]_{D}$ +10.1 (c 1.10); IR 2103, 1732 cm⁻¹; ¹H NMR $\delta_{\rm H}$ 1.39 (3H, s), 1.59 (3H, s), 3.66 (1H, dd, J = 5.5, 10.8 Hz), 3.77 (1H, dd, J = 4.3, 10.8 Hz), 4.45 (1H, dd, J = 5.2, 8.1 Hz), 4.56 (2H, m), 4.75 (1H, d, J =5.2 Hz), 5.46 (1H, ddd, J = 4.3, 5.5, 8.1 Hz), 7.32–7.37 (3H, m), 7.37–7.40 (2H, m), 8.12 (1H, s); ¹³C NMR (125.7 MHz) $\delta_{\rm C}$ 25.7 (CH₃), 26.8 (CH₃), 65.4 (CH), 67.8 (CH₂), 70.8 (CH), 73.7 (CH₂), 76.5 (CH), 112.4 (C), 116.3 (C), 128.1 (3 × CH), 128.4 $(2 \times CH)$, 136.8 (C), 159.6 (CH); MS m/z (rel intens) 305 (M⁺, <1), 198 (1), 91 (100); HRMS m/z calcd for $C_{16}H_{19}NO_5$, 305.1263, found 305.1256. Anal. Calcd for C₁₆H₁₉NO₅: C, 62.94; H, 6.27; N, 4.59. Found: C, 62.86; H, 6.11; N, 4.73.

5-O-Benzyl-2,3-O-isopropylidene-D-lyxononitrile (35). A solution of 34 (188.6 mg, 0.62 mmol) in MeOH was treated at 0 °C with camphorsulfonic acid (28.3 mg, 15%) and stirred at this temperature for 5 min. The stirring was continued for 2 h at rt, and then the reaction mixture was poured into a saturated aqueous solution of NaHCO₃ and extracted with EtOAc. The organic layer was washed with brine, dried over anhydrous Na₂SO₄, and concentrated under reduced pressure. The residue was purified by column chromatography (nhexanes-EtOAc, 85:15) to give 35 (120.6 mg, 0.44 mmol, 70%) as an oil: $[\alpha]_{\rm D}$ +12.0 (c 0.74); IR 3692, 3599 cm⁻¹; ¹H NMR $\delta_{\rm H}$ 1.50 (3H, s), 1.68 (3H, s), 3.61 (1H, dd, J = 5.5, 9.7 Hz), 3.71 (1H, dd, J = 4.0, 9.7 Hz), 4.24 (1H, d, J = 4.6 Hz), 4.26 (1H, d, J = 4.6 Hz), 4.26 (1H, d, J = 4.0 Hz)dd, J = 4.0, 5.5 Hz), 4.60 (2H, m), 4.74 (1H, d, J = 4.6 Hz), 7.23–7.33 (5H, m); ¹³C NMR (125.7 MHz) $\delta_{\rm C}$ 25.8 (CH₃), 27.0 (CH₃), 65.6 (CH), 69.8 (CH), 70.2 (CH₂), 73.7 (CH₂), 79.1 (CH), 111.9 (C), 116.6 (C), 127.8 (2 \times CH), 128.0 (CH), 128.5 (2 \times CH), 137.2 (C); MS $m\!/\!z$ (rel intens) 277 (M^+, <1), 262 (1), 91 (100); HRMS m/z calcd for C15H19NO4, 277.1314, found 277.1287. Anal. Calcd for C₁₅H₁₉NO₄: C, 64.97; H, 6.91; N, 5.05. Found: C, 65.22; H, 6.55; N, 4.95.

5-O-Benzyl-2, 3-O-is opropylide ne-4-O-(methyl sulfonyl)-D-lyxononitrile (36). A solution of 35 (120.6 mg, 0.44 mmol) and Et₃N (90 µL, 66.0 mg, 0.65 mmol) in dry CH₂Cl₂ (3 mL) was treated with MsCl (67 μ L, 0.87 mmol) under N₂ at 0 °C. The reaction mixture was then stirred at rt for 1 h and concentrated under reduced pressure. The residue was purified by column chromatography (benzene-EtOAc, 93:7) to give 36 (109.9 mg, 0.31 mmol, 71%) as an oil: $[\alpha]_{D} + 8.0$ (c 0.29); IR 1365 cm⁻¹; ¹H NMR $\delta_{\rm H}$ 1.39 (3H, s), 1.59 (3H, s), 3.11 (3H, s), 3.76 (1H, dd, J = 6.1, 11.2 Hz), 3.86 (1H, dd, J = 4.6, 11.2 Hz), 4.40 (1H, dd, J = 5.1, 8.7 Hz), 4.57 (2H, s), 4.74 (1H, d, J= 5.0 Hz), 4.98 (1H, ddd, J = 4.8, 5.7, 8.6 Hz), 7.32-7.40 (5H, m); ${}^{13}C$ NMR (125.7 MHz) δ_C 25.9 (CH₃), 26.9 (CH₃), 38.3 (CH₃), 65.4 (CH), 68.7 (CH₂), 73.9 (CH₂), 76.9 (CH), 78.9 (CH), 112.4 (C), 116.2 (C), 127.9 (2 \times CH), 128.2 (CH), 129.6 (2 \times CH), 136.5 (C); MS m/z (rel intens) 355 (M⁺, 8), 340 (2), 91 (100); HRMS m/z calcd for C₁₆H₂₁NO₆S, 355.1090, found 355.1054. Anal. Calcd for C₁₆H₂₁NO₆S: C, 54.07; H, 5.96; N, 3.94; S, 9.00. Found: C, 54.19; H, 6.05; N, 3.99; S, 8.91.

1,4-Anhydro-5-O-benzyl-4-[*(tert-butoxycarbonyl)amino*]-**1,4-dideoxy-2,3-O-isopropylidene-L-ribitol (37).** To a stirred solution of **36** (55.7 mg, 0.16 mmol) in THF (6 mL) at 0 °C under N₂ was added LiAlH₄ in Et₂O (1 M) (2.8 mL, 2.82 mmol) dropwise. The mixture was stirred for 1 h, and the excess reagent was carefully destroyed by dropwise addition of a saturated aqueous solution of Na₂SO₄ at 0 °C. After 30 min Boc₂O (0.18 mL, 171.2 mg, 0.78 mmol) was added and stirring continued at rt for 30 min. The reaction mixture was poured into water and extracted with EtOAc. The organic layer was washed with brine, dried over anhydrous Na₂SO₄, and concentrated under reduced pressure. The residue was purified by column chromatography (hexanes–EtOAc, 85:15) to give the iminosugar **37** (40.2 mg, 0.11 mmol, 69%) as an oil: $[\alpha]_D$ +63.0 (*c* 0.35); IR 1687 cm⁻¹; ¹H NMR (65 °C) δ_H 1.34 (3H, s), 1.48 (12H, s), 3.53 (1H, dd, J = 12.3, 5.3 Hz), 3.61 (1H, m), 3.66–3.83 (2H, m), 4.17 (1H, m), 4.52 (2H, s), 4.71 (1H, d, J = 6.0 Hz), 4.75 (1H, dd, J = 5.7, 5.5 Hz), 7.26–7.32 (3H, m), 7.36–7.38 (2H, m); ¹³C NMR (125.7 MHz, 65 °C) δ_C 25.2 (CH₃), 27.1 (CH₃), 28.5 (3 × CH₃), 53.4 (CH₂), 63.5 (CH), 70.4 (CH₂), 73.5 (CH₂), 79.3 (C), 79.7 (CH), 83.2 (CH), 111.5 (C), 127.4 (2 × CH), 127.7 (CH), 128.5 (2 × CH), 138.1 (C), 154.3 (C); MS *m/z* (rel intens) 363 (M⁺, <1), 348 (2), 262 (6), 142 (100); HRMS *m/z* calcd for C₂₀H₂₉NO₅, 363.2046, found 363.2088. Anal. Calcd for C₂₀H₂₉NO₅: C, 66.09; H, 8.04, N; 3.85. Found: C, 66.20; H, 8.10, N; 3.91.

Phenyl 2-Azido-2-deoxy-3,4-O-isopropylidene-6-O-(methylsulfonyl)-1-seleno-α-D-galactopyranoside (40). To a solution of β -phenylseleno azide **39** (656.8 mg, 1.71 mmol) and Et₃N (0.35 mL, 258.5 mg, 2.6 mmol) in dry CH₂Cl₂ (17 mL) at 0 °C under N₂ was added MsCl (0.26 mL, 391.0 mg, 3.41 mmol). The reaction mixture was stirred at rt for 1 h and concentrated under reduced pressure. The residue was purified by column chromatography (hexanes-EtOAc, 60:40) to give **40** (669.7 mg, 1.45 mmol, 85%) as an oil: $[\alpha]_D$ +198.5 (*c* 0.95); IR 2114 cm⁻¹; ¹H NMR $\delta_{\rm H}$ 1.36 (3H, s), 1.52 (3H, s), 2.80 (3H, s), 4.01 (1H, dd, J = 5.2, 7.3 Hz), 4.25 (1H, d, J = 2.5, 5.8 Hz), 4.31 (1H, dd, *J* = 6.1, 7.0 Hz), 4.41 (1H, dd, *J* = 4.8, 11.5 Hz), 4.44 (1H, dd, J = 7.6, 11.5 Hz), 4.72 (1H, ddd, J = 2.6, 4.7, 7.3 Hz), 5.83 (1H, d, J = 5.2 Hz), 7.31 (3H, m), 7.61 (2H, m); ¹³C NMR (125.7 MHz) $\delta_{\rm C}$ 26.0 (CH₃), 27.8 (CH₃), 37.5 (CH₃), 62.0 (CH), 68.4 (CH₂), 68.6 (CH), 72.2 (CH), 75.0 (CH), 82.8 (CH), 110.7 (C), 127.8 (C), 128.2 (CH), 129.3 (2 \times CH), 134.7 (2 \times CH); MS m/z (rel intens) 463/461 (M⁺, 12/7), 436/434 (5/3), 306 (40), 251 (100); HRMS m/z calcd for $\rm C_{16}H_{21}N_{3}O_{6}S^{80}Se$ 463.0316, found 463.0341. Anal. Calcd for C₁₆H₂₁N₃O₆SSe: C, 41.56; H, 4.58; N, 9.09; S, 6.93. Found: C, 41.73; H, 4.49; N, 9.26; S, 6.73.

2-Azido-2-deoxy-3,4-O-isopropylidene-6-O-(methylsulfonyl)-D-galactopyranose (41). A solution of 40 (412.2 mg, 0.89 mmol) in THF-H₂O (1:1, 9 mL) at 0 °C was treated with N-iodosuccinimide (1.0 g, 4.45 mmol). The reaction mixture was stirred for 30 min, poured into an aqueous solution of K2- CO_3 , and extracted with EtOAc. The organic layer was washed with brine, dried over Na₂SO₄, and concentrated under reduced pressure. The residue was purified by column chromatography (hexanes-EtOAc, 1:1) to give 41 (251.1 mg, 0.78 mmol, 87%) as an anomeric mixture ($\alpha:\beta = 2:1$), crystalline solid: $[\alpha]_D$ +83.5 (c 0.71, MeOH); IR 3593, 3473, 2117 cm⁻¹; ¹H NMR (major isomer) $\delta_{\rm H}$ 1.35 (3H, s), 1.51 (3H, s), 3.07 (3H, s), 3.46 (1H, dd, J = 3.3, 7.9 Hz), 4.22 (1H, dd, J = 2.6, 5.6 Hz), 4.44-4.47 (3H, m), 4.57 (1H, ddd, J = 2.6, 4.2, 7.4 Hz), 5.31 (1H, d, J = 3.3 Hz); ¹³C NMR (100.6 MHz) (major isomer) $\delta_{\rm C}$ 26.1 (CH₃), 28.0 (CH₃), 37.5 (CH₃), 61.3 (CH), 66.2 (CH), 69.0 (CH₂), 72.2 (CH), 73.6 (CH), 91.7 (CH), 110.4 (C); ¹H NMR (500 MHz) (minor isomer) $\delta_{\rm H}$ 1.34 (3H, s), 1.55 (3H, s), 3.08 (3H, s), 3.40 (1H, dd, J = 7.9, 7.9 Hz), 4.05 (1H, dd, J = 7.7, 5.4 Hz), 4.11 (1H, dd, J = 5.6, 2.3 Hz), 4.14 (1H, ddd, J = 7.1, 4.8, 2.3 Hz),4.41 (1H, dd, J = 11.0, 7.7 Hz), 4.44 - 4.47 (1H, m), 4.63 (1H, m)d, J = 8.1 Hz); ¹³C NMR (100.6 MHz) (minor isomer) $\delta_{\rm C}$ 26.1 (CH₃), 28.0 (CH₃), 37.5 (CH₃), 65.7 (CH), 68.7 (CH₂), 71.0 (CH), 72.2 (CH), 77.0 (CH), 95.5 (CH), 111.1 (C); MS *m/z* (rel intens) $308 (M^+ - CH_3, 10), 280 (9), 68 (100); HRMS m/z calcd for$ $C_9H_{14}N_3O_7S$, 308.0552, found 308.0562. Anal. Calcd for C10H17N3O7S: C, 37.15; H, 5.30; N, 13.00; S, 9.90. Found: C, 37.17; H, 5.15; N, 13.02; S, 9.92.

4-O-Formyl-2,3-O-isopropylidene-5-O-(methylsulfonyl)-D-lyxononitrile (42). A solution of β -hydroxy azide 41 (140.5 mg, 0.43 mmol) in CH₂Cl₂ (9 mL) was treated with DIB (172.3 mg, 0.53 mmol) and I₂ (113.3 mg, 0.45 mmol). The reaction mixture was stirred at 0–5 °C for 2.5 h under irradiation with two 80 W tungsten-filament lamps, then poured into a 10% aqueous Na₂S₂O₃ solution, and extracted with CH₂Cl₂. The organic layer was dried over anhydrous Na₂SO₄ and concentrated under reduced pressure. The residue was purified by column chromatography (hexanes–EtOAc, 70:30) to give nitrile **42** (90.0 mg, 0.31 mmol, 71%): mp 57–59 °C (from *n*-hexane–EtOAc); [α]_D +0.7 (*c* 2.27); IR 2100, 1737 cm⁻¹; ¹H NMR (C₆D₆) δ _H 0.93 (3H, s), 1.32 (3H, s), 2.10 (3H, s), 3.82 (1H, dd, *J* = 5.9, 6.0 Hz), 3.91 (1H, dd, *J* = 4.9, 11.6 Hz), 3.98 (1H, dd, *J* = 4.9, 5.0, 6.0 Hz), 7.47 (1H, s); ¹³C NMR (100.6 MHz) $\delta_{\rm C}$ 25.6 (CH₃), 26.6 (CH₃), 37.7 (CH₃), 64.8 (CH), 66.3 (CH₂), 68.8 (CH), 75.1 (CH), 113.1 (C), 116.0 (C), 159.5 (CH); MS *m/z* (rel intens) 278 (M⁺ – CH₃, 100), 126 (43); HRMS *m/z* calcd for C₉H₁₂NO₇S, 278.0334, found 278.0329. Anal. Calcd for C₁₀H₁₅NO₇S: C, 40.95; H, 5.15; N, 4.78; S, 10.93. Found: C, 41.12; H, 5.35; N, 4.90; S, 10.92.

1,5-Anhydro-5-[(*tert*-butoxycarbonyl)amino]-1,5dideoxy-2,3-O-isopropylidene-D-lyxitol (43). To a stirred solution of 42 (70.5 mg, 0.24 mmol) in THF (9 mL) at 0 °C under N₂ was added LiAlH₄ in Et₂O (1 M) (2.8 mL, 2.82 mmol) dropwise. The mixture was stirred for 1 h, and the excess reagent was carefully destroyed by dropwise addition of a saturated aqueous solution of Na₂SO₄ at 0 °C. After 30 min at 0-10 °C, Boc₂O (0.28 mL, 262.6 mg, 1.2 mmol) was added and stirring continued for 30 min. The reaction mixture was poured into water and extracted with EtOAc. The organic layer was washed with brine, dried over anhydrous Na₂SO₄, and concentrated under reduced pressure. The residue was purified by column chromatography (hexanes-EtOAc, 1:1) to give the iminosugar **43** (40.6 mg, 0.15 mmol, 62%) as an oil: $[\alpha]_{\rm D}$ +3.9 (c 0.76); IR 3608, 3448, 1682 cm⁻¹; ¹H NMR (65 °C) $\delta_{\rm H}$ 1.35 (3H, s), 1.46 (9H), 1.47 (3H, s), 1.95 (1H, s), 3.30 (1H, dd, J = 13.6, 5.8 Hz), 3.50 (1H, dd, J = 14.3, 3.9 Hz), 3.61 (1H, dd, J = 13.6, 3.4 Hz), 3.78 (1H, dd, J = 4.2, 14.3 Hz), 3.95 (1H, dd, J = 3.4, 4.6, 5.8 Hz), 4.07 (1H, dd, J = 4.2, 6.4 Hz), 4.31 (1H, dd, J = 4.0, 4.1, 6.5 Hz); ¹³C NMR (125.7 MHz, 65 °C) $\delta_{\rm C}$ 25.3 (CH₃), 27.5 (CH₃), 28.5 (3 × CH₃), 43.3 (CH₂), 45.1 (CH₂), 68.2 (CH), 72.1 (CH), 76.5 (CH), 80.0 (C), 109.3 (C), 155.8 (C); MS *m/z* calcd for C₁₃H₂₃NO₅, 273.1576, found 273.1592. Anal. Calcd C₁₃H₂₃NO₅: C, 57.13; H, 8.48; N, 5.12. Found: C, 57.19; H, 8.22, N; 5.04.

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Supporting Information Available: Detailed experimental procedures and spectral and analytical data for compounds **3**, **5**, **6**, **8**, **10–14**, and **25**. This material is available free of charge via the Internet at http://pubs.acs.org.

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