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Synthesis of *O*-(2-*O*-sulfo-α-L-idopyranosyluronic acid)-(1 → 3)-2-acetamido-2-deoxy-4-*O*-sulfo-D-galactopyranose trisodium salt, a disaccharide fragment of dermatan sulfate [1]

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Abstract

Benzyl 2-acetamido-2-deoxy-α, and β-D-glucopyranoside were converted in high yield into the corresponding D-*galacto* analogues through a three-step procedure. These later were transformed in a straightforward manner into benzyl 2-acetamido-4-*O*-acetyl-6-*O*-benzyl-2-deoxy-α, and β-D-galactopyranoside, respectively, which served as acceptors in glycosylation reactions with variously activated derivatives of methyl 2-*O*-benzoyl-3-*O*-benzyl-4-*O*-chloroacetyl-L-idopyranuronate. Condensation of the chloride derivative promoted by silver triflate led unexpectedly to the formation of the β-linked disaccharide, whereas the trichloroacetimidoyl derivative afforded the expected α-linked disaccharide in 63% yield. *O*-Dechloroacetylation of this later, followed by 4-methoxybenzylation at O-4 of the uronic acid moiety, saponification of the esters, *O*-sulfonation of the free hydroxyls, and catalytic hydrogenation provided the title disaccharide in high yield, as its sodium salt. © 1998 Elsevier Science Ltd

Keywords: Synthesis; Disaccharide; Dermatan sulfate; L-Iduronic acid; D-Galactosamine

1. Introduction

Dermatan sulfate (DeS) is a linear, *O*-sulfonated glycosaminoglycan, first isolated from pig skin [1], and mainly composed of disaccharide repeating units of 2-acetamido-2-deoxy-D-galactose and L-iduronic acid, namely, [4)-α-L-Ido*p*A-(1 → 3)-β-D-Gal*p*NAc-(1 →]$_n$. Structural studies on DeS from various origins [2] showed differences in the location of the sulfate groups, but the D-galactosamine residues are mainly sulfated at C-4, and the adjacent L-iduronic acid residues can be sulfated or not at C-2 (Fig. 1). This microheterogeneity complicates to a larger extent the biological studies on this polymer. DeS possesses anticoagulant, profibrinolytic, and antithrombotic properties associated with its ability to inhibit thrombin by potentiating of heparin cofactor II (HCII) [3]. This activation of HCII is associated with disulfated sequences, namely, [4)-α-L-Ido*p*A2SO$_3$-(1

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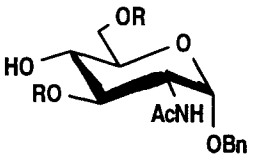
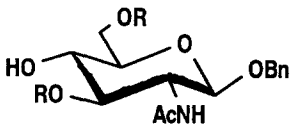
$\rightarrow 3)$-β-D-Gal*p*NAc4SO_3-$(1\rightarrow]_n$, and the active site was first postulated to be an hexasaccharide sequence [4], and more recently, a nonasaccharide [5]. However, all these isolated fragments have a lower activity with respect to the parent polymeric DeS, since longer polyanionic chains are required [3] for the formation of a ternary complex with thrombin. It has also been postulated that DeS should be a potential high-affinity ligand for membrane proteins of NK lymphocytes [6], thus, playing a prominent role in cellular recognition. Some fragments of DeS have been synthesized, such as methyl glycoside derivatives of the basic monosulfated disaccharide (non-sulfated at position 2 of the L-iduronic acid moiety) [7,8], or an hexasaccharide containing three disulfated disaccharide residues [9], but the preparation of the basic disulfated disaccharide has never been reported.

Within the frame of a programme devoted to the synthesis of glycosaminoglycan fragments [10], we now report on for the first time a preparation of the title disulfated disaccharide.



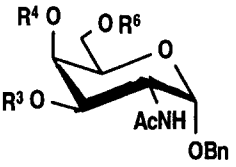
	R
1	H
2	Piv



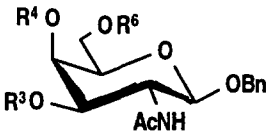
	R
8	H
9	Piv

2. Results and discussion

The preparation of D-galactosamine derivatives which could serve as acceptors was first examined. Since D-galactosamine is a rare, thus, expensive sugar, its derivatives are generally prepared by azidonitration of D-galactal [11], followed by subsequent protection and/or activation. This route was used for the previously reported synthesis of DeS fragments [7–9]. We also demonstrated [12,13] that selective inversion of configuration at C-4 of D-glucosamine derivatives, a route still explored by several groups [14,15], was efficient and well-suited for the preparation of D-galactosamine synthons which could be used for the synthesis of glycosaminoglycan fragments. Thus, we first focused on the preparation of benzyl galactosaminides **3** and **10** from the easily available D-*gluco* analogues.



	R^3	R^4	R^6
3	H	H	H
4	$C(Me)_2$		H
5	$C(Me)_2$		Bn
6	H	H	Bn
7	H	Ac	Bn



	R^3	R^4	R^6
10	H	H	H
11	$C(Me)_2$		H
12	$C(Me)_2$		Bn
13	H	H	Bn
14	*t*-BDMS	Ac	Bn
15	H	Ac	Bn

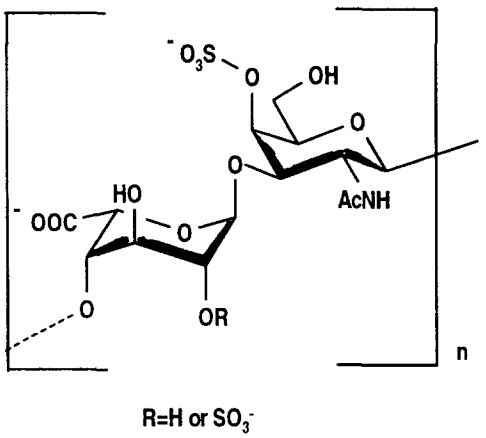


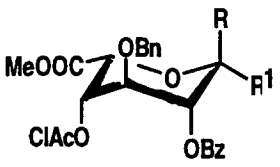
Fig. 1.

Treatment of benzyl 2-acetamido-2-deoxy-α-D-glucopyranoside **1** [16] with pivaloyl chloride (2.8 equiv.) in pyridine at 0 °C afforded the 3,6-di-*O*-pivaloyl derivative **2** in 87% yield. Trifluoromethanesulfonylation of **2** with triflic anhydride and pyridine in 1,2-dichloroethane at −15 °C followed by treatment *in situ* with water and heating at 90 °C gave a mixture [13] of 3,4- and 3,6-di-*O*-pivaloyl-D-*galacto* intermediates (not described in Section 3), which was directly *O*-deacylated with methanolic sodium methoxide to afford the known crystalline triol **3** in 83% yield (72% yield from **1**). The physical data for **3** are in agreement with those reported [17] for a compound obtained from 2-acetamido-2-deoxy-D-galactopyranose by Fischer glycosylation with benzyl alcohol, followed by 4,6-*O*-benzylidenation and subsequent hydrolysis of the 4,6-acetal. The route described here, and the overall yield obtained from inexpensive D-glucosamine compares well with those previously reported.

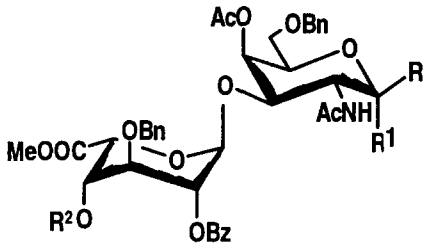
A similar sequence was achieved in the β-D-series starting from benzyl 2-acetamido-2-deoxy-β-D-glucopyranoside **8** [18], *via* the 3,6-di-*O*-pivaloyl derivative **9**, to afford crystalline **10** in 75% yield. The physical data for **10** are in agreement with those reported [19] for a derivative prepared from 2-acetamido-2-deoxy-D-galactose via the intermediate corresponding acetylated methyl oxazoline.

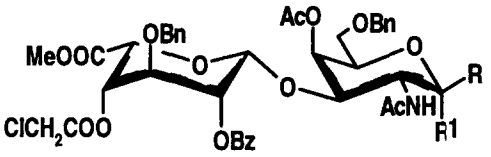
Selective protection at O-4 and 6 was next examined, following the initial strategy for the synthesis of glycosaminoglycan fragments [20] in which the positions to be *O*-sulfonated were first protected by ester groups, while permanent benzyl ethers were used for standing hydroxyls. Treatment of **3** with neat 2,2-dimethoxypropane [21] under acid catalysis gave the thermodynamically favoured 3,4-*O*-isopropylidene derivative **4** in 88% yield, with only traces of the 4,6-isomer. Benzylation of **4** with benzyl bromide and barium hydroxide in *N*,*N*-dimethylformamide gave **5** in 91% yield, which was treated with aqueous acetic acid at 100 °C to afford crystalline **6** in 89% yield (71% from **3**). The physical data for **6** are in agreement with those reported [22] for an amorphous compound obtained by reductive cleavage of the corresponding 4,6-*O*-benzylidene derivative. Selective acylation at O-4 was then achieved through formation of the 3,4-orthoester derivative with trimethyl orthoacetate under acid catalysis followed by its regioselective opening [23] in acidic medium to give crystalline **7** in 85% yield. The signal for H-4 (δ 5.37 ppm) in the ^{1}H NMR spectrum of **7** established clearly the acylation at O-4, as well as the D-*galacto* configuration ($J_{3,4}$ 3.2, $J_{4,5}$ 0.8 Hz).

A similar sequence was attempted in the β-D-series. Treatment of **10**, as described for the preparation of **4**, gave **11** in 76% yield, and benzylation of **11** gave **12** in 85% yield. The *J* values ($J_{2,3}$ 8.5, $J_{3,4}$ 5.5, $J_{4,5}$ 2.0 Hz) observed for **11** and **12** strongly suggested a significant deviation from the expected $^4C_1$ conformation in solution, which was not the case in the α-D-series. Treatment of **12** with aqueous acetic acid at 100 °C, as described for the preparation of **6**, caused extensive hydrolysis of the benzyl glycoside, while a similar treatment at 50 °C afforded cleanly **13**. The *J* values observed for **13** were in agreement with those expected for a derivative retaining the usual $^4C_1$ conformation in solution. Treatment of **13**, as described for the preparation of **7**, gave a complex mixture of acetylated derivatives which could not be easily separated. Careful examination of the reaction showed that the initial formation of the 3,4-orthoester was sluggish, and that this later could not be isolated without extensive degradation. However, treatment of **13** with *tert*-butyldimethylsilyl chloride and imidazole in *N*,*N*-dimethylformamide followed by conventional acetylation afforded **14** in 61% overall yield. *O*-Desilylation of **14** with tetrabutylammonium fluoride in tetrahydrofuran was accompanied by extensive *O*-deacetylation, while treatment with aqueous hydrochloric acid in tetrahydrofuran afforded crystalline **15** in 91% yield. Both derivatives **13** and **14** retained the expected $^4C_1$ conformation, as demonstrated by the *J* values from their ^{1}H NMR spectra. To the best of our knowledge, such a clear-cut difference of behaviour in similar reactions between α- and β-anomers was not observed previously.



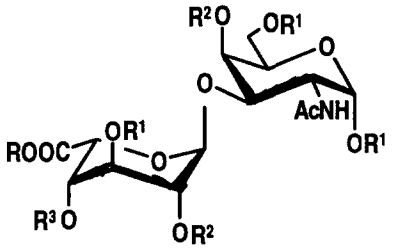
	R	R¹
16	Cl	H
17	H, OC(=NH)CCl$_3$	





	R	R¹	R²
18	H	OBn	ClAc
20	OBn	H	ClAc
22	H	OBn	H
23	H	OBn	MPM

	R	R¹
19	H	OBn
21	OBn	H



	R	R¹	R²	R³
24	H	Bn	H	MPM
25	Na	Bn	SO_3Na	MPM
26	Na	H	SO_3Na	H

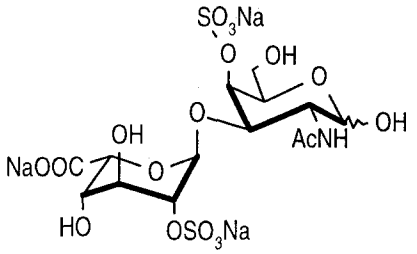
Derivatives of methyl 2-*O*-benzoyl-3-*O*-benzyl-4-*O*-chloroacetyl-L-idopyranuronate, i.e., chloride **16** and trichloroacetimidate **17** [24] were tested as L-iduronic acid donors in glycosylation reactions with acceptors **7** and **15**. Condensation of **17** (mixture of anomers) with **7** (1 equiv.) in dichloromethane at −78 °C, with trimethylsilyl triflate as a catalyst, afforded the expected α-linked disaccharide **18** in 63% yield, along with its β-linked isomer **19** (27%). The same reaction, conducted at 0 °C, gave a ~ 1:1 mixture of isomers with the same overall yield. Variations of the solvent or the catalyst did not significantly improved the selectivity. A similar coupling of **17** with the β-linked acceptor **15** gave a much lower yield (52%) of disaccharides **20** and **21** with the same selectivity. That **19** and **21** were β-anomers rather than *ortho*-esters was evident from their NMR spectra (δ 5.08 and 5.11 for the signals for H-2′, and δ 101.21 and 101.42 for the signals for C-1′, respectively). Such a difference of behaviour between similar, but anomerically different acceptors, was still observed [25], but is difficult to rationalise. Surprisingly, coupling of the more easily available [24] chloride **16** with **7** or **15** in dichloromethane, and silver triflate as a promoter, with or without added base (*sym*-collidine, not described in Section 3), afforded very sluggishly, but exclusively, the β-linked disaccharides **19** and **21** in 70 and 60% yields, respectively. Silver triflate is a soluble catalyst supposed to cause abstraction of the anomeric halogen, but in the case described herein, it seems to react as an insoluble silver salt, i.e., silver silicate [26], through a push–pull-like mechanism in which complete inversion of configuration at C-1 was observed. The presence of a stereocontrolling auxiliary (benzoyl group) at C-2 had apparently no directing effect in this reaction. The low leaving-group character of the anomeric halogen is certainly due, at least partially,

Table 1
^{1}H NMR data for disaccharide derivatives **18–26**[a]

Chemical shifts (δ, ppm)	Compounds								
	18[b]	**19**	**20**	**21**	**22**	**23**	**24**[c]	**25**[c]	**26**[d]
H-1	5.21	4.97	4.90	5.05	5.10	5.04	4.93	4.97	5.22, 4.75
H-2	5.07	4.67	4.68	4.58	4.55	4.51	4.38	4.48	4.35
H-3	4.41	3.96	3.80	3.90	4.03	4.20	3.88	4.32	4.24
H-4	5.89	5.42	5.51	5.46	5.51	5.43	4.09	4.74	4.98, 4.92
H-5	4.31	4.14	3.80	3.55	4.03	3.91	3.90	4.10	3.95, 3.80
H-6a,6b	3.64	3.44	3.55	3.55	3.46	3.37	3.63	3.81	3.80
N*H*	5.97	5.65	5.78	5.64	6.26	5.95	–	–	–
C*H*$_3$CO	1.88	2.06	1.89	1.89	1.98	1.92	1.92	1.97	2.08, 2.07
	1.62	1.61	1.84	1.73	1.97	1.76	–	–	–
H-1′	5.85	5.17	5.65	5.14	5.48	5.31	4.95	5.28	5.38, 5.36
H-2′	4.72	5.08	5.13	5.11	5.50	5.51	4.37	5.17	4.33
H-3′	4.15	3.93	4.27	3.90	4.33	4.19	4.09	4.32	4.39
H-4′	5.92	5.33	5.48	5.38	3.73	4.40	4.50	4.84	4.33
H-5′	5.26	5.15	5.28	5.15	5.14	5.30	4.02	4.54	4.60
COOC*H*$_3$	3.24	3.78	3.67	3.79	3.72	3.73	–	–	–
OC*H*$_3$	–	–	–	–	–	3.63	3.67	3.68	–
COC*H*$_2$Cl	3.76	3.92	4.15	4.01	–	–	–	–	–
Coupling constants (J, in Hz)									
$J_{1,2}$	3.5	3.5	8.5	8.5	3.5	3.5	3.5	3.5	3.5, 8.0
$J_{2,3}$	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.0	10.5
$J_{3,4}$	3.5	3.0	3.5	3.5	3.5	3.5	3.0	3.0	3.0
$J_{4,5}$	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$J_{2,NH}$	9.0	10.0	8.0	8.0	10.0	8.5	–	–	–
$J_{1',2'}$	6.0	1.0	7.5	1.0	6.0	1.5	4.0	3.5	1.0, 1.0
$J_{2',3'}$	6.0	2.5	5.5	2.5	6.0	2.5	5.5	6.5	3.0
$J_{3',4'}$	2.5	2.5	2.5	2.5	3.5	2.5	2.5	3.5	3.0
$J_{4',5'}$	2.5	2.0	2.5	2.0	2.0	1.5	1.5	2.5	2.0

[a]For solutions in $CDCl_3$, unless otherwise stated.
[b]C_6D_6.
[c]CD_3OD.
[d]D_2O, equilibrium.

to the strong electron-withdrawing effect of the 5-carboxymethyl group in **16**, but this phenomenon was not encountered with trichloroacetimidate **17**. These results are in agreement with recent observations [27] showing that trichloroacetimidates appear as best candidates for the activation at the anomeric centre of L-iduronic acid derivatives. *O*-Dechloroacetylation of **18** with thiourea afforded **22** in 75% yield, which is available for further chain extension at the non-reducing end [24].



For the preparation of the target molecule **26**, protection at O-4 of the L-iduronic acid moiety by an hydrogenolyzable group was required. Treatment of **22** with 4-methoxybenzyl trichloroacetimidate, conveniently prepared [28] by phase-transfer catalysis, and triflic acid as a catalyst, afforded **24** in 84% yield. Similar treatment of **22** with benzyl trichloroacetimidate [29] gave a very low yield of benzylated derivative, as reported [30] for a similar reaction on an heparin disaccharide derivative. Saponification of both benzoate and methyl esters was achieved through treatment [31] of **23** with lithium hydroperoxide followed by methanolic sodium hydroxide and acidification to afford the acid **24** in 84% yield. No β-elimination reaction was observed under these conditions. *O*-Sulfonation of **24** with sulfur trioxide–trimethylamine complex in *N*,*N*-dimethylformamide at 50 °C followed by ion-exchange chromatography gave the disulfate **25**, as its sodium salt, in 83% yield. Comparison of the ^{1}H NMR spectra of **25** and **24**, in deuterated methanol, showed the expected [7,32] downfield shifts (-0.65 and -0.80 ppm) of the signals for GalNAc H-4 and IdoA H-2, respectively. Final hydrogenation of **25** with Pd–C in aqueous methanol afforded the target molecule **26** in 97% yield. The NMR data for **26** are in agreement with the postulated structure. The low J values observed for the 2-*O*-sulfonated L-iduronic acid residue (Table 1) indicate that this later retains in solution almost exclusively a $^1C_4$ conformation, which was not the case for its non-sulfated analogue [7].

In conclusion, a convenient preparation of D-galactosamine acceptors from inexpensive D-glucosamine was reported. Coupling of the α-linked acceptor **7** with trichloroacetimidate **17** followed by *O*-sulfonation and deprotection allowed the preparation of the title disaccharide in a straightforward manner. Unexpected behaviour of chloride **16** in glycosylation reaction promoted by silver triflate was highlighted. The target molecule **26** is currently being evaluated in biological assays.

3. Experimental

General methods.—Melting points were determined in capillary tubes with a Büchi apparatus and are uncorrected. Optical rotations were measured at 20–25 °C with Perkin-Elmer 141 or 241 polarimeters. ^{1}H and ^{13}C spectra were recorded with Bruker DPX-250 or AM-300 spectrometers at 250 or 300 MHz, and 63 or 75.4 MHz, respectively, with Me_4Si as internal standard, unless otherwise stated. Assignments were based on homonuclear decoupling experiments, and homo- and hetero-nuclear correlations. Unprimed numbers refer to the 'reducing' unit, and primed numbers to the 'non-reducing' unit. C.i. (ammonia)-mass spectra were recorded with a Nermag R 10-10 spectrometer. The purity of the products was determined by TLC on Silica Gel F_{254} (E. Merck), with detection by charring with H_2SO_4. Flash-column chromatography was performed on Silica Gel (E. Merck, 40–63 μm). Elemental analyses were performed by the Service Central de Microanalyse du CNRS (Vernaison, France).

*Benzyl 2-acetamido-2-deoxy-3,6-di-*O*-pivaloyl-α-*D*-glucopyranoside* (**2**).—Pivaloyl chloride (10.25 mL, 84 mmol) was added dropwise at 0 °C to a soln of benzyl 2-acetamido-2-deoxy-α-D-glucopyranoside **1** [16] (9.37 g, 30 mmol) in CH_2Cl_2 (50 mL) and pyridine (80 mL), and the mixture was stirred at 0 °C for 2 h, diluted with CH_2Cl_2 (200 mL), washed with saturated aq $NaHCO_3$, with water, dried ($MgSO_4$), and concentrated. The residue was eluted from a column (3 × 15 cm) of silica gel with 1:1 heptane–EtOAc to give **2** as a foam (12.5 g, 87%); $[\alpha]_D$ +71° (*c* 1, $CHCl_3$); ^{1}H NMR ($CDCl_3$): δ 7.34 (m, 5 H, Ph), 5.70 (d, 1 H, J 10.0 Hz, NH), 5.12 (dd, 1 H, $J_{2,3}$ 10.5, $J_{3,4}$ 9.0 Hz, H-3), 4.88 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1), 4.61 (ABq, 2 H, OCH_2Ph), 4.42 (dd, 1 H, $J_{5,6a}$ 4.5, $J_{6a,6b}$ 12.5 Hz, H-6a), 4.30 (m, 2 H, H-2,6b), 3.90 (m, 1 H, H-5), 3.54 (m, 1 H, $J_{4,5}$ 9.0, $J_{4,OH}$ 4.5 Hz, H-4), 2.86 (d, 1 H, *H*O-4), 1.88 (s, 3 H, NAc),

and 1.23, 1.15 (2 s, 18 H, $C(CH_3)_3$); MS: *m/z* 480, $[M + H]^+$. Anal. Calcd. for $C_{25}H_{37}NO_8$: C, 62.61; H, 7.78; N, 2.92. Found: C, 62.73; H, 7.79; N, 2.75.

Benzyl 2-acetamido-2-deoxy-α-D-galactopyranoside (**3**).—Trifluoromethanesulfonic anhydride (5.8 mL, 34 mmol) was added dropwise at −15 °C, under Ar, to a soln of **2** (12.5 g, 26 mmol) in dry 1,2-dichloroethane (150 mL) and dry pyridine (12.5 mL), and the mixture was stirred for 2 h at this temperature, then allowed to attain room temperature. Water (10 mL) was added, and the mixture was stirred for 2 h at 90 °C, then cooled, diluted with CH_2Cl_2 (200 mL), washed with saturated aq $NaHCO_3$, with water, dried ($MgSO_4$), and concentrated. A soln of the residue in MeOH (150 mL) was treated with methanolic NaOMe (1 M, 10 mL) for 18 h at room temperature, then deionized with Amberlite IR-120 [H^+] resin, filtered, and concentrated. The residue was crystallised from 2-propanol to give **3** (6.72 g, 83%); mp 203–205 °C, lit. 203–205 °C [17]; $[\alpha]_D$ +210° (*c* 1, H_2O), lit. +204° (*c* 0.98, H_2O).

Benzyl 2-acetamido-2-deoxy-3,4-O-isopropylidene-α-D-galactopyranoside (**4**).—A mixture of **3** (622 mg, 2 mmol) and (±)-camphor–10-sulfonic acid (40 mg) in 2,2-dimethoxypropane (20 mL) was stirred for 48 h at room temperature. Et_3N (0.14 mL) was added, and the mixture was concentrated. A soln of the residue in 10:1 MeOH–water (22 mL) was stirred for 2 h at 65 °C, then cooled, and concentrated. The residue was eluted from a column (50 g) of silica gel with EtOAc containing 0.1% of Et_3N to give sirupy **4** (623 mg, 88%); $[\alpha]_D$ +193° (*c* 1, MeOH); ^1H NMR ($CDCl_3$): δ 7.30 (m, 5 H, Ph), 5.95 (d, 1 H, *J* 8.5 Hz, NH), 4.92 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1), 4.57 (ABq, 2 H, OCH_2Ph), 4.30–3.90 (m, 6 H, H-2,3,4,5,6a,6b), 2.80 (t, 1 H, *J* 6.0 Hz, *HO*-6), 1.97 (s, 3 H, NAc), and 1.55, 1.32 (2 s, 6 H, $C(Me)_2$). Anal. Calcd. for $C_{18}H_{25}NO_6$: C, 61.52; H, 7.17; N, 3.98. Found: C, 61.42; H, 7.09; N, 3.75.

Benzyl 2-acetamido-6-O-benzyl-2-deoxy-3,4-O-isopropylidene-α-D-galactopyranoside (**5**).—Benzyl bromide (0.36 mmol, 3 mmol) was added to a mixture of **4** (0.6 g, 1.7 mmol), barium oxide (2.1 g, 13.5 mmol), and barium hydroxide, 8 water (0.47 g, 1.7 mmol) in dry DMF (15 mL), and the mixture was stirred for 20 h at room temperature. MeOH (2 mL) was added, and the mixture was stirred for 2 h, then diluted with EtOAc (100 mL), and filtered through a pad of Celite. The filtrate was washed with cold aq 5% acetic acid, water, saturated aq $NaHCO_3$, and water, dried ($MgSO_4$), and concentrated. The residue was eluted from a column (40 g) of silica gel with 3:1 EtOAc–heptane containing 0.2% of Et_3N to give sirupy **5** (684 mg, 91%); $[\alpha]_D$ +136° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.30 (m, 10 H, 2 Ph), 5.61 (d, 1 H, *J* 9.0 Hz, NH), 4.88 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1), 4.62, 4.58 (2 ABq, 4 H, 2 OCH_2Ph), 4.28 (m, 1 H, $J_{2,3}$ 9.0 Hz, H-2), 4.20 (m, 2 H, H-4,5), 4.06 (dd, 1 H, $J_{3,4}$ 4.0 Hz, H-3), 3.78 (m, 2 H, H-6a,6b), 1.96 (s, 3 H, NAc), and 1.54, 1.30 (2 s, 6 H, $C(Me)_2$). Anal. Calcd. for $C_{25}H_{31}NO_6$: C, 68.00; H, 7.07; N, 3.17. Found: C, 68.07; H, 7.01; N, 3.11.

Benzyl 2-acetamido-6-O-benzyl-2-deoxy-α-D-galactopyranoside (**6**).—A soln of **5** (600 mg, 1.36 mmol) in 4:1 acetic acid–water (20 mL) was stirred for 30 min at 100 °C, then cooled, concentrated, and evaporated with water (3 × 10 mL). The residue was crystallised from EtOH to give **6** (484 mg, 89%); mp 183–184 °C; $[\alpha]_D$ +151° (*c* 1, Me_2SO); lit. +145.1° (*c* 1.2, Me_2SO) [22]; ^1H NMR [$(CD_3)_2SO$]: δ 7.70 (d, 1 H, *J* 8.5 Hz, NH), 7.30 (m, 10 H, 2 Ph), 4.71 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1), 4.67 (d, 1 H, *J* 4.5 Hz, *HO*-4), 4.51 (ABq, 2 H, OCH_2Ph), 4.48 (s, 2 H, OCH_2Ph), 4.46 (d, 1 H, *J* 6.5 Hz, *HO*-3), 4.04 (m, 1 H, $J_{2,3}$ 11.0 Hz, H-2), 3.87 (m, 1 H, H-5), 3.72 (m, 1 H, $J_{3,4}$ 3.5, $J_{4,5}$ 1.0 Hz, H-4), 3.68 (m, 1 H, H-3), 3.59 (dd, 1 H, $J_{5,6a}$ 5.0, $J_{6a,6b}$ 11.0 Hz, H-6a), 3.51 (dd, 1 H, $J_{5,6b}$ 7.0 Hz, H-6b), and 1.82 (s, 3 H, NAc); MS: *m/z* 402, $[M + H]^+$.

Benzyl 2-acetamido-4-O-acetyl-6-O-benzyl-2-deoxy-α-D-galactopyranoside (**7**).—A mixture of **6** (401 mg, 1 mmol), trimethyl orthoacetate (2 mL), and (±)-camphor–10-sulfonic acid (40 mg) in dry toluene (20 mL) was stirred for 1 h at room temperature. Triethylamine (0.8 mL) was added, and the mixture was diluted with toluene (30 mL), washed with saturated aq $NaHCO_3$, and water, dried ($MgSO_4$), and concentrated. A soln of the residue in 4:1 acetic acid–water (20 mL) was stirred for 10 min at room temperature, concentrated, and evaporated with water (3 × 10 mL). The residue was crystallised from EtOAc–heptane to give **7** (380 mg, 85%); mp 146–147 °C; $[\alpha]_D$ +94° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.30 (m, 10 H, 2 Ph), 5.81 (d, 1 H, *J* 8.5 Hz, NH), 5.37 (dd, 1 H, $J_{3,4}$ 3.2, $J_{4,5}$ 0.8 Hz, H-4), 4.96 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1), 4.62, 4.53 (2 ABq, 4 H, 2 OCH_2Ph), 4.34 (m, 1 H, $J_{2,3}$ 10.2 Hz, H-2), 4.12 (m, 1 H, $J_{5,6a} = J_{5,6b} = 5.8$ Hz, H-5), 3.94 (m, 1 H, $J_{3,OH}$ 5.6 Hz, H-3), 3.53 (m, 2 H, H-6a,6b), 3.25 (d, 1 H, *HO*-3), 2.11 (s, 3 H, OAc), and 1.96 (s, 3 H, NAc); ^{13}C ($CDCl_3$): δ 172.10, 170.91 (2 C=O), 137.77–125.87 (12 C, aromatic C), 96.61 (C-1), 73.59 (C-4), 70.28, 69.68, 68.90, 68.71 (C-3,5,6, 2 CH_2Ph), 50.82 (C-2), and 22.27, 20.88 (2 CH_3CO); MS: *m/z* 444,

$[M + H]^+$. Anal. Calcd. for $C_{24}H_{29}NO_7$: C, 65.00; H, 6.59; N, 3.16. Found: C, 65.08; H, 6.44; N, 3.11.

Benzyl 2-acetamido-2-deoxy-3,6-di-O-pivaloyl-β-D-glucopyranoside (**9**).—Benzyl 2-acetamido-2-deoxy-β-D-glucopyranoside **8** [18] (5.0 g, 16.1 mmol) was treated as described for the preparation of **2** to give sirupy **9** (7.34 g, 95%); $[\alpha]_D$ −75° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.30 (m, 5 H, Ph), 5.59 (d, 1 H, *J* 9.5 Hz, NH), 4.99 (dd, 1 H, $J_{2,3}$ 10.5, $J_{3,4}$ 9.0 Hz, H-3), 4.72 (ABq, 2 H, OCH_2Ph), 4.46 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 4.40 (m, 2 H, H-6a,6b), 4.02 (m, 1 H, H-2), 3.51 (m, 2 H, H-4,5), 3.03 (bs, 1 H, *HO*-4), 1.88 (s, 3 H, NAc), and 1.25, 1.16 (2 s, 18 H, $C(Me)_3$); MS: *m/z* 480, $[M + H]^+$. Anal. Calcd. for $C_{25}H_{37}NO_8$: C, 62.61; H, 7.78; N, 2.92. Found: C, 62.49; H, 7.84; N, 2.69.

Benzyl 2-acetamido-2-deoxy-β-D-galactopyranoside (**10**).—Compound **9** (1.34 g, 2.8 mmol) was treated as described for the preparation of **3**. Crystallisation of the residue from 2-propanol gave **10** (653 mg, 75%); mp 195–197 °C, lit. 210–212 °C (from MeOH–Et_2O) [19]; $[\alpha]_D$ −7° (*c* 1, H_2O), lit. −3.4° (*c* 0.5, H_2O) [19]; ^1H NMR [$(CD_3)_2SO + D_2O$]: δ 7.32 (m, 5 H, Ph), 4.87 (ABq, 2 H, OCH_2Ph), 4.28 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 3.74 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-2), 3.60 (dd, 1 H, $J_{3,4}$ 3.5, $J_{4,5}$ 1.0 Hz, H-4), 3.49 (m, 2 H, H-6a,6b), 3.38 (dd, 1 H, H-3), 3.28 (m, 1 H, H-5), and 1.76 (s, 3 H, NAc); MS: *m/z* 312, $[M + H]^+$.

Benzyl 2-acetamido-2-deoxy-3,4-O-isopropylidene-β-D-galactopyranoside (**11**).—Compound **10** (2.96 g, 9.5 mmol) was treated as described for the preparation of **4**. The residue was eluted from a column (100 g) of silica gel with 10:1 CH_2Cl_2–MeOH containing 0.2% of Et_3N to give **11** (2.53 g, 76%); mp 178–180 °C (from EtOAc–heptane); $[\alpha]_D$ −5° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.30 (m, 5 H, Ph), 6.24 (d, 1 H, *J* 7.5 Hz, NH), 4.98 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 4.72 (ABq, 2 H, OCH_2Ph), 4.65 (dd, 1 H, $J_{2,3}$ 8.5, $J_{3,4}$ 5.5 Hz, H-3), 4.14 (dd, 1 H, $J_{4,5}$ 2.0 Hz, H-4), 4.0–3.80 (m, 3 H, H-5,6a,6b), 3.20 (m, 1 H, H-2), 2.56 (bs, 1 H, *HO*-6), 1.94 (s, 3 H, NAc), and 1.52, 1.32 (2 s, 6 H, $C(Me)_2$); MS: *m/z* 352, $[M + H]^+$. Anal. Calcd. for $C_{18}H_{25}NO_6$: C, 61.52; H, 7.17; N, 3.99. Found: C, 61.33; H, 7.29; N, 4.08.

Benzyl 2-acetamido-6-O-benzyl-2-deoxy-3,4-O-isopropylidene-β-D-galactopyranoside (**12**).—Compound **11** (2.53 g, 7.2 mmol) was treated as described for the preparation of **5** to give **12** (2.69 g, 85%); mp 95–97 °C (from heptane–EtOAc); $[\alpha]_D$ −26° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.34 (m, 10 H, 2 Ph), 6.16 (d, 1 H, *J* 7.5 Hz, NH), 5.01 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 4.75, 4.65 (2 ABq, 4 H, 2 OCH_2Ph), 4.68 (dd, 1 H, $J_{2,3}$ 8.5, $J_{3,4}$ 5.5 Hz, H-3), 4.19 (dd, 1 H, $J_{4,5}$ 2.0 Hz, H-4), 4.08 (m, 1 H, $J_{5,6a} = J_{5,6b} = 5.5$ Hz, H-5), 3.85 (m, 2 H, H-6a,6b), 3.23 (m, 1 H, H-2), 1.90 (s, 3 H, NAc), and 1.52, 1.31 (2 s, 6 H, $C(Me)_2$); MS: *m/z* 442, $[M + H]^+$. Anal. Calcd. for $C_{25}H_{31}NO_6$: C, 68.01; H, 7.08; N, 3.17. Found: C, 68.26; H, 7.21; N, 2.96.

Benzyl 2-acetamido-6-O-benzyl-2-deoxy-β-D-galactopyranoside (**13**).—A soln of **12** (1.44 g, 3.26 mmol) in 4:1 acetic acid–water (25 mL) was stirred at 50 °C for 40 min, cooled, and concentrated to give **13** as a white powder which could not be induced to crystallise (1.28 g, 98%); $[\alpha]_D$ −56° (*c* 0.5, MeOH); ^1H NMR [$(CD_3)_2SO + D_2O$]: δ 7.30 (m, 10 H, 2 Ph), 4.58, 4.50 (2 ABq, 4 H, 2 OCH_2Ph), 4.34 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 4.08 (dd, 1 H, $J_{3,4}$ 3.0, $J_{4,5}$ 1.0 Hz, H-4), 3.78 (m, 2 H, H-2,3), 3.58 (dd, 1 H, $J_{5,6a}$ 3.5, $J_{6a,6b}$ 11.5 Hz, H-6a), 3.56 (m, 1 H $J_{5,6b}$ 3.5 Hz, H-5), 3.42 (dd, 1 H, H-6b), and 1.82 (s, 3 H, NAc); MS: *m/z* 402, $[M + H]^+$. Anal. Calcd. for $C_{22}H_{27}NO_6$: C, 65.82; H, 6.78; N, 3.49. Found: C, 65.72; H, 6.91; N, 3.52.

Benzyl 2-acetamido-4-O-acetyl-6-O-benzyl-2-deoxy-3-O-tert-butyldimethylsilyl-β-D-galactopyranoside (**14**).—A mixture of **13** (355 mg, 0.88 mmol), *tert*-butyldimethylsilyl chloride (0.26 g, 1.77 mmol), and imidazole (0.24 g, 3.54 mmol) in dry DMF (5 mL) was stirred at 80 °C for 2 h, then cooled. The mixture was diluted with EtOAc (30 mL), washed with saturated ammonium chloride, with water, dried ($MgSO_4$), and concentrated. The residue was eluted from a column (20 g) of silica gel with 1:1 EtOAc–heptane to give a fraction (344 mg, 76%) which was dissolved in pyridine (5 mL). Ac_2O (2.5 mL) and DMAP (20 mg) were added, and the mixture was stirred for 2 h at room temperature, then concentrated. The residue was eluted from a column (30 g) of silica gel with 1:1 EtOAc–heptane to give sirupy **14** (297 mg, 61% from **13**); $[\alpha]_D$ −32° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.32 (m, 10 H, 2 Ph), 5.49 (d, 1 H, *J* 8.0 Hz, NH), 5.31 (dd, 1 H, $J_{3,4}$ 3.5, $J_{4,5}$ 1.0 Hz, H-4), 5.11 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 4.77, 4.56 (2 ABq, 4 H, 2 OCH_2Ph), 4.38 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-3), 3.86 (m, 1 H, $J_{5,6a} = J_{5,6b} = 6.0$ Hz, H-5), 3.61 (dd, 1 H, $J_{6a,6b}$ 10.0 Hz, H-6a), 3.55 (dd, 1 H, H-6b), 3.42 (m, 1 H, H-2), 2.07, 1.88 (2 s, 6 H, 2 Ac), 0.82 (s, 9 H, $C(CH_3)_3$), and 0.07, 0.02 (2 s, 6 H, $SiCH_3$); MS: *m/z* 588, $[M + H]^+$. Anal. Calcd. for $C_{30}H_{43}NO_7Si$: C, 64.60; H, 7.77; N, 2.51. Found: C, 64.51; H, 7.70; N, 2.62.

Benzyl 2-acetamido-4-O-acetyl-6-O-benzyl-2-deoxy-

β-D-galactopyranoside (**15**).—HCl (1 M, 10 mL) was added to a soln of **14** (0.5 g, 0.9 mmol) in THF (20 mL), and the mixture was stirred for 36 h at room temperature, then concentrated. The residue was eluted from a column (40 g) of silica gel with 10:1 CH_2Cl_2–MeOH to give **15** (360 mg, 91%); mp 171–173 °C (from CH_2Cl_2–heptane); $[\alpha]_D$ −77° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.32 (m, 10 H, 2 Ph), 5.59 (d, 1 H, *J* 5.5 Hz, NH), 5.38 (dd, 1 H, $J_{3,4}$ 3.5, $J_{4,5}$ 1.0 Hz, H-4), 4.83, 4.56 (2 ABq, 4 H, 2 OCH_2Ph), 4.51 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 3.91 (m, 1 H, $J_{2,3}$ 10.5, $J_{3,OH}$ 2.0 Hz, H-3), 3.80 (m, 3 H, H-2,5, HO-3), 3.64 (dd, 1 H, $J_{5,6a}$ 6.0, $J_{6a,6b}$ 12.0 Hz, H-6a), 3.59 (dd, 1 H, $J_{5,6b}$ 6.0 Hz, H-6b), and 2.10, 1.94 (2 s, 6 H, 2 Ac); ^{13}C ($CDCl_3$): δ 172.64, 170.80 (2 C=O), 137.74–127.85 (12 C, aromatic C), 99.03 (C-1), 76.51 (C-4), 73.59, 73.10, 71.86, 70.73, 69.26 (5 C, C-3,5,6, 2 CH_2Ph), 55.77 (C-2), and 23.47, 20.88 (2 CH_3CO); MS: *m/z* 444, $[M + H]^+$. Anal. Calcd. for $C_{24}H_{29}NO_7$: C, 65.00; H, 6.59; N, 3.16. Found: C, 64.94; H, 6.59; N, 2.91.

Benzyl O-(methyl 2-O-benzoyl-3-O-benzyl-4-O-chloroacetyl-α, and β-L-idopyranosyluronate)-(1 → 3)-2-acetamido-4-O-acetyl-6-O-benzyl-2-deoxy-α-D-galactopyranoside (**18**) and (**19**).—A mixture of **17** (57 mg, 92 μmol), **7** (40 mg, 92 μmol), and 4 Å powdered molecular sieves (50 mg) in dry CH_2Cl_2 (1 mL) was stirred for 40 min at room temperature, then cooled to −78 °C. Trimethylsilyl triflate in dry toluene (1 M, 13 μL, 13 μmol) was added at this temperature, and the mixture was allowed to attain room temperature. Et_3N (8 μL) was added, and the mixture was diluted with CH_2Cl_2 (5 mL), filtered, and concentrated. The residue was eluted from a column (12 g) of silica gel with 12:1 CH_2Cl_2–acetone to give first the β-linked isomer **19** (15 mg, 27%); $[\alpha]_D$ +56° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): see Table 1; ^{13}C ($CDCl_3$): δ 101.21 (C-1′), 96.54 (C-1); MS: *m/z* 904, $[M + H]^+$ for ^{35}Cl. Anal. Calcd. for $C_{47}H_{50}ClNO_{15}$: C, 62.43; H, 5.57; N, 1.55. Found: C, 62.20; H, 5.46; N, 1.73.

Next eluted was **18** (35 mg, 63%); $[\alpha]_D$ +68° (*c* 1, $CHCl_3$); ^1H NMR (C_6D_6): see Table 1; ^{13}C ($CDCl_3$): δ 170.92, 170.20, 169.67, 167.28, 167.04 (5 C=O), 137.49–127.15 (20 C, aromatic C), 96.83 (C-1), 93.43 (C-1′), 74.77, 71.96, 71.85, 70.29, 69.81, 69.37, 66.83, 66.45 (10 C, C-3,4,5, C-2′,3′,4′,5′, 3 OCH_2Ph), 60.16 (C-6), 52.54 ($COOCH_3$), 48.49 (C-2), 40.22 ($COCH_2Cl$), and 23.11, 20.81 (2 CH_3CO); MS: *m/z* 904, $[M + H]^+$ for ^{35}Cl. Anal. Calcd. for $C_{47}H_{50}ClNO_{15}$: C, 62.43; H, 5.57; N, 1.55. Found: C, 62.49; H, 5.74; N, 1.43.

Benzyl O-(methyl 2-O-benzoyl-3-O-benzyl-4-O-chloroacetyl-α, and β-L-idopyranosyluronate)-(1 → 3)-2-acetamido-4-O-acetyl-6-O-benzyl-2-deoxy-β-D-galactopyranoside (**20**) and (**21**).—A mixture of **17** (42 mg, 68 μmol) and **15** (30 mg, 68 μmol) was treated as described for the preparation of **18** to give first the β-linked isomer **21** (10 mg, 16%); $[\alpha]_D$ −30° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): see Table 1; ^{13}C ($CDCl_3$): δ 101.42 (C-1′), 99.45 (C-1); MS: *m/z* 904, $[M + H]^+$ for ^{35}Cl. Anal. Calcd. for $C_{47}H_{50}ClNO_{15}$: C, 62.43; H, 5.57; N, 1.55. Found: C, 62.25; H, 5.61; N, 1.42.

Next eluted was **20** (23 mg, 36%); $[\alpha]_D$ −17° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): see Table 1; ^{13}C ($CDCl_3$): δ 99.27 (C-1), 93.61 (C-1′); MS: *m/z* 904, $[M + H]^+$ for ^{35}Cl. Anal. Calcd. for $C_{47}H_{50}ClNO_{15}$: C, 62.43; H, 5.57; N, 1.55. Found: C, 62.57; H, 5.60; N, 1.41.

Benzyl O-(methyl 2-O-benzoyl-3-O-benzyl-α-L-idopyranosyluronate)-(1 → 3)-2-acetamido-4-O-acetyl-6-O-benzyl-2-deoxy-α-D-galactopyranoside (**22**).—A mixture of **18** (91 mg, 0.1 mmol) and thiourea (24 mg, 0.3 mmol) in 1:1 pyridine–EtOH (3 mL) was stirred for 24 h at 80 °C, then cooled, and concentrated. The residue was taken up in CH_2Cl_2 (20 mL), washed with water, dried ($MgSO_4$), and concentrated. The residue was eluted from a column (6 g) of silica gel with 10:1 CH_2Cl_2–acetone to give **22** (63 mg, 75%); $[\alpha]_D$ +45° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): see Table 1; MS: *m/z* 828, $[M + H]^+$. Anal. Calcd. for $C_{45}H_{49}NO_{14}$: C, 65.29; H, 5.96; N, 1.69. Found: C, 65.40; H, 5.88; N, 1.65.

Benzyl O-[methyl 2-O-benzoyl-3-O-benzyl-4-O-(4-methoxybenzyl)-α-L-idopyranosyluronate]-(1 → 3)-2-acetamido-4-O-acetyl-6-O-benzyl-2-deoxy-α-D-galactopyranoside (**23**).—Triflic acid in CH_2Cl_2 (0.01 M, 1 mL) was added at 0 °C, under Ar, to a soln of **22** (83 mg, 0.1 mmol) and 4-methoxybenzyl trichloroacetimidate [28] (84 mg, 0.3 mmol) in dry CH_2Cl_2 (2 mL), and the mixture was stirred for 2 h at room temperature. Et_3N (50 μL) was added, and the mixture was concentrated. The residue was eluted from a column (8 g) of silica gel with 3:2 heptane–EtOAc to give **23** (80 mg, 84%); $[\alpha]_D$ +62° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$): see Table 1; MS: *m/z* 966, $[M + NH_6]^+$. Anal. Calcd. for $C_{53}H_{57}NO_{15}$: C, 67.15; H, 6.06; N, 1.48. Found: C, 67.22; H, 6.20; N, 1.51.

Benzyl O-[3-O-benzyl-4-O-(4-methoxybenzyl)-α-L-idopyranosyluronic acid]-(1 → 3)-2-acetamido-6-O-benzyl-2-deoxy-α-D-galactopyranoside (**24**).—A soln of **23** (40 mg, 42 μmol) in THF (4 mL) was treated

at −5 °C with 30% H_2O_2 (0.5 mL) and lithium hydroxide (1 M, 1 mL), and the mixture was stirred for 2 h at this temperature and for 16 h at room temperature, then cooled to 0 °C. MeOH (3 mL) and NaOH (4 M, 1 mL) were then added, and the mixture was stirred for 6 h at room temperature, then acidified to pH 2 with HCl (1 M), and extracted with EtOAc (5 × 10 mL). The organic layers were washed with water, dried ($MgSO_4$), and concentrated. The residue was eluted from a column (3 g) of silica gel with 15:1 CH_2Cl_2–MeOH to give **24** (28 mg, 84%); $[\alpha]_D$ +87° (*c* 1, $CHCl_3$); ^1H NMR (CD_3OD): see Table 1; MS: *m/z* 788, $[M+H]^+$. Anal. Calcd. for $C_{53}H_{57}NO_{15}$: C, 65.55; H, 6.27; N, 1.78. Found: C, 65.48; H, 6.30; N, 1.75.

Benzyl O-[3-O-benzyl-4-O-(4-methoxybenzyl)-2-O-sulfo-α-L-idopyranosyluronic acid]-(1 → 3)-2-acetamido-6-O-benzyl-2-deoxy-4-O-sulfo-α-D-galactopyranoside, trisodium salt (**25**).—A mixture of **24** (52 mg, 60 μmol) and sulfur trioxide–trimethylamine complex (102 mg, 0.73 mmol) in dry DMF (2 mL) was stirred at 50 °C for 3 d, then cooled, and concentrated. The residue was eluted from a column (6 g) of silica gel with 6:1 CH_2Cl_2–MeOH, then from a column (1 × 15 cm) of Sephadex SP-C25 (Na^+) with 9:1 MeOH–water to give **25** (50 mg, 83%); $[\alpha]_D$ +54° (*c* 1, MeOH); ^1H NMR (CD_3OD): see Table 1. Anal. Calcd. for $C_{43}H_{46}NNa_3O_{19}S_2 \cdot H_2O$: C, 50.05; H, 4.69; N, 1.36. Found: C, 49.80; H, 4.75; N, 1.21.

O-(2-O-sulfo-α-L-idopyranosyluronic acid)-(1 → 3)-2-acetamido-2-deoxy-4-O-sulfo-α-D-galactopyranose, trisodium salt (**26**).—A soln of **25** (48 mg, 46 μmol) in 1:1 MeOH–water (1 mL) was hydrogenated in the presence of 10% Pd–C (50 mg) for 24 h at room temperature. The mixture was directly eluted from a column (1 × 5 cm) of 1:1 charcoal–Celite with 1:1 MeOH–water, then freeze-dried to give **26** (28 mg, 97%); $[\alpha]_D$ +7° (*c* 1, equil., water); ^1H NMR (D_2O, 27 °C, internal H_2O, δ_H 4.754): see Table 1; ^{13}C (D_2O, internal MeOH, δ_C 49.40): δ 178.82, 178.54, 174.13, 173.63 (C=O), 97.65, 96.48 (C-1′), 92.27 (C-1β), 88.97 (C-1α), 82.35, 82.20 (C-3), 76.33, 76.29, 76.25, 75.47 (C-4,2′), 72.45, 72.15, 71.65, 70.32, 70.24, 70.04, 69.90, 69.38 (C-5,3′,4′,5′), 61.53, 60.90 (C-6), 52.10, 51.15 (C-2), and 23.43, 22.16 (CH_3CO). Anal. Calcd. for $C_{14}H_{16}NNa_3O_{18}S_2$: C, 27.15; H, 2.60; N, 2.26. Found: C, 26.90; H, 2.80; N, 2.05.

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