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One-pot synthesis of *C*-glycosylic compounds (*C*-glycosides) from D-glucal, *p*-tolylsulfenyl chloride and aromatic/heteroaromatic compounds in the presence of Lewis acids

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Abstract

In the presence of $Zn(CN)_2$, benzylated 2-thio-2-*S*-(*p*-tolyl)pyranosyl chlorides (**2**) generated in situ from tri-*O*-benzyl-D-glucal and *p*-TolSCl, smoothly react with thiophene, 2-methylthiophene, furan, 2-methylfuran, and *N*-methylpyrrole to give heteroaryl 2-thio-2-*S*-(*p*-tolyl)-*C*-β-D-glucopyranosylic compounds (*C*-glycosides) in good yields. Upon treatment with $SnCl_4$, the reaction of chlorides **2** with thiophene or 1,4-dimethoxybenzene provides the corresponding benzylated *C*-β-D-glucofuranosylic derivatives. Under the same conditions, the use of 2-methylthiophene, furan, 2-methylfuran, or *N*-methylpyrrole yields (2*S*,3*R*,4*R*,5*S*)-1,3,4-tribenzyloxy-6,6-diheteroaryl-5-(*p*-tolylthio)-2-hexanoles. Treatment of **2** and mesitylene with $AgBF_4$ yielded 1,6-anhydro-3,4-di-*O*-benzyl-2-thio-2-*S*-(*p*-tolyl)-β-D-glucose.

Keywords: *C*-glycosylic compounds; *C*-Glycosides; Friedel–Crafts reaction; Pyranosyl chlorides; Heteroaromatic compounds; D-Glucal; Arylsulfenyl chloride

1. Introduction

C-Glycosylic compounds, known also as *C*-glycosides, and particularly aryl *C*-glycosides,‡ have been the subject of considerable study for at least two decades.[1–3] The interest in these compounds stems from an array of physiological activities which they possess.[1,4] There are many synthetic approaches to aryl *C*-glycosides.[1,5] Glycosidation of aromatic compounds in Friedel–Crafts-type reactions is one of them.[6–14] The use of various glycosyl donors has been described, including pyranosyl halides,[6,8] acetates,[6,9] nitrobenzoates,[6] pyridylthio derivatives,[7] and trichloroacetimidates.[10,11] Recently, 5-thio-D-pyranosyl bromides and trichloroacetimidates have also been shown to participate in Friedel–Crafts reactions.[12–14] Most of the glycosyl donors are not very stable in the presence of Lewis acids, so usually only activated aromatic and heteroaromatic compounds capable of reacting under mild conditions (e.g., methoxybenzenes, furan, and thiophene) provide *C*-glycosides in preparative yields. The reaction of organometallic derivatives with glycosylating agents is another common approach to *C*-glycosides.[15–19]

Previously we have shown that in the presence of a Lewis acid, 2-thio-2-*S*-(aryl)pyranosyl chlorides (prepared in situ by the addition of ArSCl to D-glucals) react with nucleophiles of diverse structure, e.g., silyl enol ethers, Grignard reagents, and vinyl ethers.[2a,16] The couplings lead to the highly stereoselective formation of 2-thio-2-*S*-(aryl)-*C*-β-D-glucopyranosylic compounds (Scheme 1). The intermediates of these reactions presumably have an episulfonium-like structure, though the possibility of an oxonium intermediate has not been ruled out by ab initio calculations.[17]

Episulfonium ions have been known to be rather strong alkylating agents and are capable of reacting with activated aromatic compounds (methyl- and

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‡ Hereafter '*C*-glycoside' terminology will be used.

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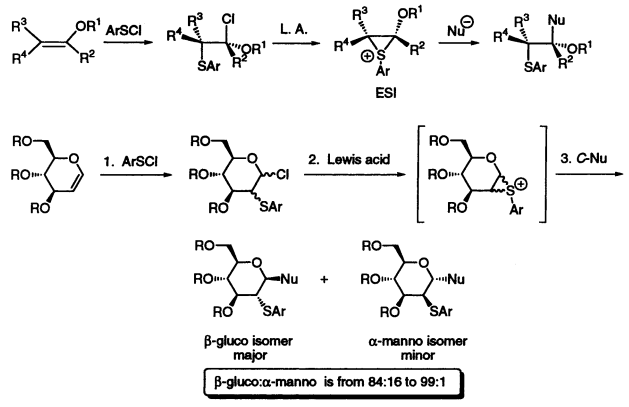
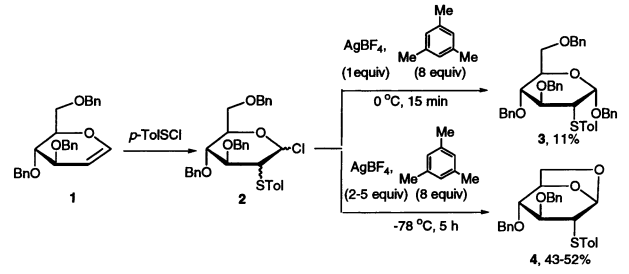
methoxy-substituted benzenes, phenol, *N*,*N*-dimethylaniline, mesitylene, and thiophene) under Friedel–Crafts reaction conditions.[18,19] Thus far, carbohydrate-based episulfonium-like intermediates have not been used in the reactions with aromatic and heteroaromatic compounds. In this paper we disclose our results on the reaction of *p*-TolSCl adducts of tri-*O*-benzyl-D-glucal with a number of aromatic and heteroaromatic compounds.

2. Results and discussion

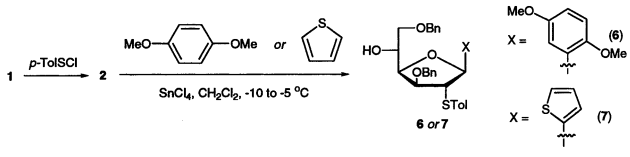
Mesitylene was considered as a good model compound to start with, because it reacted with ArSCl adducts of simple alkenes and the formation of *ortho*-, *meta*- and/or *para*-isomers would be avoided.[18] We found that in the presence of 1 equiv of $SnCl_4$ or $TiCl_4$, a mixture of *p*-TolSCl adducts of tri-*O*-benzyl-D-glucal (**2**, gluco:manno, 88:12[2a]) does not react with mesitylene in the range of -78 to $+20$ °C. The use of 1 equiv of $AgBF_4$, a harder Lewis acid, led to the formation of



Scheme 1.



Scheme 2.



Scheme 3.

benzyl 3,4,6-tri-*O*-benzyl-2-thio-2-*S*-(*p*-tolyl)-α-D-glucopyranoside (**3**, 11%, 15 min at 0 °C); no reaction was observed at -78 °C (1 hour).

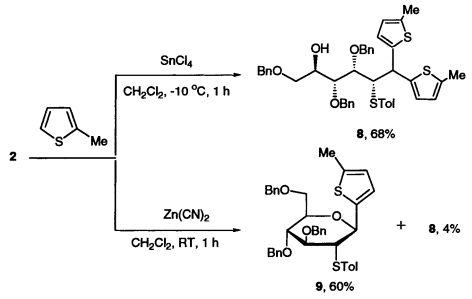
A similar reaction with 2 equiv of $AgBF_4$ surprisingly yielded 43% of 1,6-anhydro derivative **4**. The increased amount of the Lewis acid (5 equiv) provided a slightly higher yield of **4** (52%, Scheme 2). The latter was not formed in the absence of mesitylene. However, compound **4** was isolated (6%) in the room temperature reaction of chlorides **2** with 1,4-dimethoxybenzene in the presence of $SnCl_4$. Apparently, the formation of a weak π-complex of mesitylene or 1,4-dimethoxybenzene with the episulfonium ion changes the reactivity of the latter, and it makes intramolecular attack of the 6-OBn group by the electrophilic center of **2** more favorable compared to the intermolecular one.

The formation of 1,6-anhydro-2,3,4-tri-*O*-benzyl-β-D-glucopyranose (30% yield; along with 2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl thiophene, 40% yield) has also been reported in the reaction of 2,3,4,6-tetra-*O*-benzyl-α-D-glucosyl trichloroacetimidate with thiophene in the presence of $ZnCl_2$–Et_2O as a catalyst.[11] More electron-rich and sterically hindered 2-methylthiophene formed only the corresponding *C*-glycoside (59%).[11] This suggests that an increase in steric hindrance at the cationic center after its complexation with an arene is not a major driving force of the intramolecular cyclization.

The structure of **4** was proven by NMR spectroscopy and supported by the absence of an OH absorption band in the IR spectrum; its elemental composition was confirmed by HRMS analysis. Vicinal coupling constant values of the pyranosyl ring protons are close to zero and similar to those of 1,6-anhydro-β-D-glucopyranose (levoglucosan) and its derivatives.[20] The coupling constant values suggest close to planar position of all ring protons and, therefore, confirm axial position of the *p*-TolS group and the gluco configuration of **4**.

Our attempts to use anisole and toluene as nucleophiles at different temperatures in the presence of a variety of Lewis acids were unsuccessful. The major products of these reactions were benzyl 3,4,6-tri-*O*-benzyl-2-thio-2-*S*-(*p*-tolyl)-α-D-glucopyranoside (**3**) and/or 3,4,6-tri-*O*-benzyl-2-thio-2-*S*-(*p*-tolyl)-D-glucopyranose (**5**).

1,4-Dimethoxybenzene was the only arene active enough to be alkylated by 2-thio-2-*S*-(*p*-tolyl)pyranosyl chlorides **2** (Scheme 3). Using $SnCl_4$ as a Lewis acid, 7% of *C*-glycoside **6** has been obtained along with 13% of **3**. Based on the analysis of the NMR spectra, it was concluded that the product is a *C*-β-D-glucofuranosyl derivative. A pyranosyl structure was ruled out because of the low (≤ 3.5 Hz) values of spin–spin coupling constants $J_{1,2}$, $J_{2,3}$ and $J_{3,4}$. The value of $J_{2,3} = 0$ Hz suggests the glucofuranosylic structure. For comparison, the $J_{2,3}$ value in mannofuranosylic derivatives is



Scheme 4.

about 6 Hz.[21] The chemical shift value for H-1, δ 5.19 ppm, is typical for aryl *C*-furanosides and aryl *C*-α-D-pyranosides (compare with δ 4.25–4.85 for aryl *C*-β-D-pyranosides,[7,9–11] including 2-thio-2-*S*-(*p*-tolyl) derivatives[21,16]). The NOESY spectrum of **6** clearly shows an interaction between H-1 and H-4 that is indicative of the β-D-configuration. Though we could not determine the absolute configuration of C-5, it was assumed that the product has the *S* configuration of the starting glucal **1**.

The aforementioned results prompted us to use more reactive aromatic compounds, i.e., thiophene. In the presence of $SnCl_4$, no reaction of thiophene with chlorides **2** was observed in the range of -78 to -20 °C. However, increasing the temperature to -5 °C led to the formation of the compound **7** in 54% yield (Scheme 3). Analysis of the NMR (^1H, ^{13}C, COSY, and NOESY) and HRMS data let us conclude that the product is a *C*-β-D-glucofuranoside. ^1H NMR spectra of **7** and *C*-β-D-glucofuranoside **6** are very similar. The NOESY spectrum shows interactions between H-1 and H-3 as well as between H-1 and H-4. This supports the β-D-configuration and the furanose structure of **7**. The low value of $J_{2,3}$ (1.5 Hz) suggests gluco rather than manno configuration. Finally, there is no NOE signal between H-2 and H-4; that is indicative of *trans* position of these protons and, therefore, the gluco structure. Like in the case of compound **6**, the absolute configuration of C-5 in *C*-glycoside **7** was assumed to be the *S*.

Under similar conditions and using the same catalyst, $SnCl_4$, reaction of **2** with more electron-rich 2-methylthiophene provided compound **8** in a yield of 65% (Scheme 4). The open-chain structure and the presence of two heterocycles in the compound were unambiguously proven by the data obtained from 1D (^1H, ^{13}C, and DEPT) and 2D (COSY, NOESY) NMR spectra. The elemental composition of the product was supported by HRMS data. Compound **8** was also isolated when $TiCl_4$, $FeCl_3$ or $Mg(ClO_4)_2$ were used as a Lewis acid (Table 1).

Replacement of $SnCl_4$ by a milder Lewis acid $Zn(CN)_2$ in the reaction of **2** with methylthiophene afforded *C*-β-D-glucopyranoside **9** in a high yield (Scheme 4). To the best of our knowledge, this Lewis acid has never been employed in Friedel–Crafts reactions and was used once for cholesterol O-rhamnosylation.[21] It is worthy to note that $Hg(CN)_2$ frequently used for O-glycosidation[22] was not active in the reaction studied.

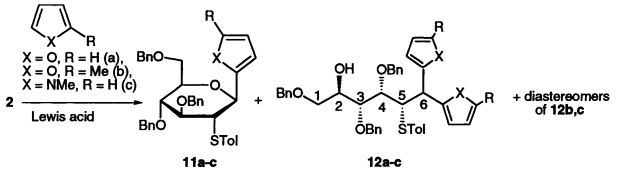
The treatment of a mixture of **2** and 2-methylthiophene with $ZnCl_2$ in CH_2Cl_2 or ether led to the formation of **9** along with a small amount of the corresponding α-D-gluco isomer (**10**).

Table 1
Reactions of *p*-TolSCl adducts of tri-*O*-benzyl-D-glucal (**2**) with 2-methylthiophene.

Lewis acid[a]	Equiv Lewis acid	T (°C)	Time	Solvent	Yield (%)			
					8	**9**	**10**	**3**
$SnCl_4$	1.2	-10 to (-5)	1 h	CH_2Cl_2	65			1
$SnCl_4$	1.2	-40	40 min	CH_2Cl_2	45			
$SnCl_4$	1.2	-40	40 min	$C_2H_4Cl_2$	68			1
$TiCl_4$	1.2	rt	40 min	CH_2Cl_2	11			
$FeCl_3$	1.2	-10 to (-5)[b]	45 min	CH_2Cl_2	22			
$Mg(ClO_4)_2$	4	-10 to (-5)	20 min	CH_2Cl_2	23			
$BF_3{\cdot}Et_2O$	1.3	rt	12 h	CH_2Cl_2		41	10	1
$ZnCl_2$	3.3	rt	45 min	CH_2Cl_2		44	8	
$ZnCl_2$	2	-10 to (-5)	1 h	Et_2O		52	5	30
$ZnCl_2$	4	-10 to (-5)	1 h	MeCN				38
ZnO	10.6	10	30 min	CH_2Cl_2		10		
$Zn(CN)_2$	4	rt	1 h	CH_2Cl_2		60		
$Zn(CN)_2$	4	-10 to (-5)	30 min	$MeNO_2$		25	2	30

[a] No reaction with $Zn(CN)_2$ in MeCN or $Hg(CN)_2$ in CH_2Cl_2 at rt; 6 M $LiClO_4$ in Et_2O (0 °C, 1.5 h) furnishes a complex mixture.

[b] Complex mixture at 0 °C.

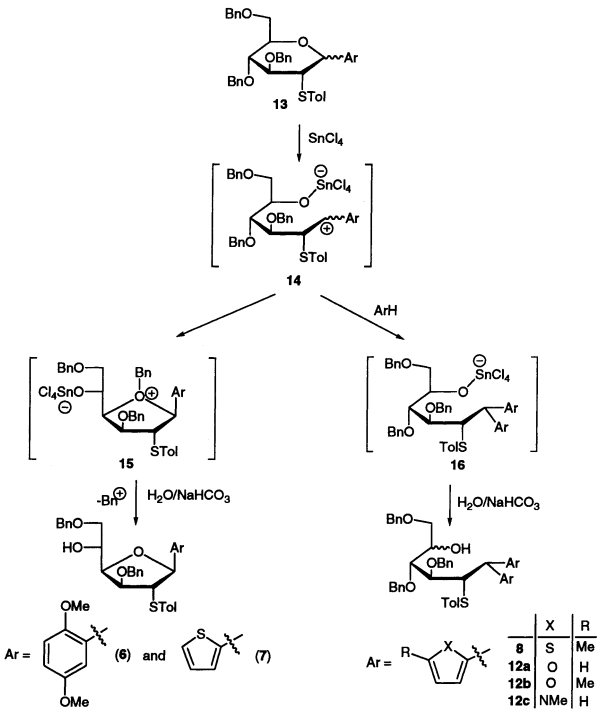


Scheme 5.

Reactions of **2** with furan (a) and 2-methylfuran (b) provided the results similar to those obtained for 2-methylthiophene (Scheme 5 and Table 2). *C*-β-D-Glucopyranosides **11a**,**b** were synthesized selectively employing $Zn(CN)_2$ as a Lewis acid. Using $SnCl_4$, the major products were compounds of the open-chain structure **12a**,**b**. Di(methylfuryl) derivative **12b** was prepared selectively (in 44% yield) when adducts **2** in chlorobenzene were treated with $SnCl_4$, followed by the addition of 2-methylfuran. The NMR and HRMS data for **12a**,**b** confirmed the presence of two heterocycles in each compound. Overall, the NMR spectra of **12a**,**b** and the other open-chain product **8** are very similar.

Reaction of chlorides **2** with 1-methylpyrrole (c) was somewhat more complicated and furnished a mixture of *C*-β-D-glucopyranoside **11c**, di(1-methylpyrryl) derivative **12c** and two diastereomers of the latter **12c′** and **12c″**, regardless the Lewis acid used (Scheme 5, Table 2). The ^1H NMR spectra of compound **12c** and its two isomers have a doublet assigned to the OH group split by the proton at C-2. Thus, the position of the OH group in products **12c**, **12c′** and **12c″** is the same, and therefore the latter compounds are diastereomers, which differ by the absolute configuration at C-2 and/or C-5.

We suggest that the formation of the open-chain products **8** and **12a**–**c** and furanoside derivatives **6** and **7** is a result of ring-opening of the corresponding *C*-glucopyranosides, e.g., **11a**–**c**, in the presence of a Lewis acid (Scheme 6). In accord with the proposed mechanism, treatment of *C*-glucopyranoside **9** (an analog of **13** shown in Scheme 6) with $SnCl_4$ and 2-methylthiophene provided compound **8** in 10% yield. The absence of open-chain products in the reactions with 1,4-dimethoxybenzene and thiophene can be explained by their lower nucleophilicity compared to the other heterocycles. The epimerization at C-5 is likely to occur upon quenching of intermediate **16** with aq $NaHCO_3$ solution (Scheme 6). The formation of C-2 epimers is a result of the reaction of heteroaromatic compounds with two isomeric episulfonium ion intermediates (see Scheme 1).[2a]



Scheme 6.

The observed formation of monodeprotected open-chain diaryl *C*-glucosides is rather unique and is believed to be caused by the presence of the *p*-TolS group that is capable of stabilizing the carbocation in the intermediate **14**. The only reported synthesis of deprotected 1-deoxy-1,1-diphenyl-D-glucitol from benzene and tetraacetylglucosyl chloride required 6 equiv of $AlCl_3$ and reflux for 8 hours.[23] For comparison, the Friedel–Crafts reaction of 2,3,4-tri-*O*-acetyl-5-thio-α-D-xylopyranosyl bromide and thiophene using $ZnCl_2$ as a Lewis acid led to (3*S*,4*S*)-diacetoxy-(2*R*)-[di-(2-thienyl)methyl]tetrahydrothiophene in 35% yield.[12]

Table 2
Reactions of *p*-TolSCl adducts of D-glucal (**2**) with furan, 2-methylfuran and 1-methylpyrrole

Conditions	11			12		
	a	b	c	a	b	c
$SnCl_4$ (1.2 equiv), CH_2Cl_2, −10 °C, 30 min	0	0	10	38	39	30 (11, 18)[a]
$Zn(CN)_2$ (3 equiv), CH_2Cl_2, rt, 3 h	16	24	33	0	38 (10)[a]	5 (2)[a]

[a] Yields of the corresponding diastereomers are given in parentheses. The stereochemistry of the diastereomers was not determined.

3. Conclusions

A number of novel compounds have been synthesized starting with simple and readily available reagents (tri-*O*-benzyl-D-glucal, *p*-TolSCl, 1,4-dimethoxybenzene and aromatic heterocycles) and using convenient one-pot procedures under Friedel–Crafts reaction conditions: (i) heteroaryl 2-thio-2-*S*-(*p*-tolyl)-*C*-β-D-glucopyranosides (**9** and **11a**–**c**) with $Zn(CN)_2$ as a catalyst; (ii) promising building blocks for synthesis of oligosaccharides, monodeprotected *C*-glycosides: 3,6-di-*O*-benzyl-2-thio-2-*S*-(*p*-tolyl)-β-D-glucofuranosyl arenes (**6** and **7**) and (2*S*,3*R*,4*R*,5*S*)-1,3,4-tribenzyloxy-6,6-diheteroaryl-5-(*p*-tolylthio)-2-hexanols (**8**, **12a**–**c**) with $SnCl_4$ as a catalyst; and (iii) the versatile building block 1,6-anhydro-3,4-di-*O*-benzyl-2-thio-2-*S*-(*p*-tolyl)-β-D-glucose (**4**) with $AgBF_4$–mesitylene as a catalyst. Some of the synthesized compounds can be transformed to other *C*-glycosides of biological relevance using oxidative cleavage.[9,11,15c,24]

4. Experimental

Instrumentation and materials.—^{1}H and ^{13}C NMR spectra (500 or 300 MHz and 125 or 75 MHz, respectively) of all compounds were recorded in $CDCl_3$ using Me_4Si as the internal standard unless stated otherwise. Coupling constants, *J*, are given in Hz. IR spectra were recorded on an ATI Mattson Genesis Series FTIR instrument. Optical rotations were measured on a Rudolph Autopol III automatic polarimeter. HRMS were recorded at the University of California, Riverside, using VG-ZAB (FAB) or VG-7070 (CI/NH_3) mass spectrometers.

All reactions were carried out under an atmosphere of dry nitrogen using oven-dried or flame-dried glassware and freshly distilled and dried solvents. Analytical TLC was performed on Whatman PE Sil G/UV plates. R_f data are given for 2:1 hexane–Et_2O. Flash chromatography was carried out using Natland Silica Gel 60 (230–400 mesh).

p-Tolylsulfenyl chloride (*p*-TolSCl) was synthesized from *p*-methyl thiophenol using SO_2Cl_2.[25] Other chemicals were commercially available (Aldrich Chemical Co.).

Benzyl 3,4,6-tri-O-*benzyl-2-thio-2*-S-(p-*tolyl*)-α-D-*glucopyranose* (**3**).—The compound was a side product in the majority of the reactions. R_f 0.57; $[\alpha]_D^{20}$ +160° (*c* 0.26, CH_2Cl_2); ^{1}H NMR (500 MHz): δ 2.31 (s, 3 H, CH_3), 3.34 (dd, 1 H, $J_{1,2}$ 3.0, $J_{2,3}$ 11.0, H-2), 3.61 (dd, 1 H, $J_{5,6}$ 2.0, $J_{6a,6b}$ 10.5, H-6a), 3.70 (dd, 1 H, $J_{3,4}$ 9.0, $J_{4,5}$ 10.0, H-4), 3.73 (dd, 1 H, $J_{5,6b}$ 3.5, $J_{6a,6b}$ 10.5, H-6b), 3.88 (ddd, 1 H, $J_{5,6}$ 2.0, $J_{5,6b}$ 3.5, $J_{4,5}$ 10.0, H-5), 4.00 (dd, 1 H, $J_{3,4}$ 9.0, $J_{2,3}$ 11.0, H-3), 4.47 and 5.01 (two d, 2 H, *J* 10.5, CH_2Ph), 4.49 and 4.62 (two d, 2 H, *J* 12.5, CH_2Ph), 4.56 and 4.71 (two d, 2 H, *J* 12.0, CH_2Ph), 4.80 (m, 2 H, CH_2Ph), 5.04 (d, 1 H, $J_{1,2}$ 3.0, H-1), 7.30 (m, 24 H, H-Ar); ^{13}C NMR (125 MHz): 21.0 (*C*H_3), 55.3 (C-2), 68.5 (C-6), 69,8, 73.5, 75.1 and 76.0 (4 *C*H_2Ph), 71.1 (C-5), 79.3 (C-4), 82.2 (C-3), 99.0 (C-1), 127.5, 127.6, 127.7, 127.8, 128.0, 128.2, 128.3, 128.4, 129.4, 129.6, 130.2, 131.3, 132.6,136.5, 137.2, 138.0, 138.2 (C-Ar): HRMS: Calcd for $C_{41}H_{42}NaO_5S$ 669.2651; Found $(MNa)^+$ *m*/*z* 669.2658.

1,6-Anhydro-3,4-di-O-*benzyl-2-thio-2*-S-(p-*tolyl*)-β-D-*glucose* (**4**).—A solution of **1** (104 mg, 0.250 mmol) in CH_2Cl_2 (10 mL) and a 1.0 M solution of *p*-TolSCl (0.25 mL, 0.25 mmol) was stirred at rt for 10 min (the color changed from yellow to colorless). The mixture was cooled to −78 °C, and mesitylene (240 mg, 2.00 mmol) was added, followed by $AgBF_4$ (97 mg, 0.50 mmol). After 5 h, the mixture was poured into a chilled and vigorously stirred mixture of 5% aq $NaHCO_3$ (5 mL) and CH_2Cl_2 (15 mL), extracted with CH_2Cl_2 (2 × 15 mL), and dried over K_2CO_3. After evaporation of the solvent, the mixture was separated using column chromatography (25:10:1 hexane–CH_2Cl_2–Et_2O). Yield 49 mg (43%). Under the same conditions and using 5 equiv $AgBF_4$, compound **4** was obtained in 52% yield. R_f 0.25; ^{1}H NMR (500 MHz): δ 2.34 (s, 3 H, CH_3), 3.27 (s, 1 H, H-2), 3.38 (s, 1 H, H-4), 3.72 and 4.08 (two m, 2 H, H-6), 3.77 (s, 1 H, H-3), 4.28 and 4.64 (two d, 2 H, *J* 12.1, CH_2Ph), 4.47 (m, 2 H, CH_2Ph), 4.60 (m, 1 H, H-5), 5.60 (s, 1 H, H-1), 7.15 and 7.30 (two m, 14 H, H-Ar); ^{13}C NMR (125 MHz): δ 21.1 (*C*H_3), 50.4 (C-2), 65.3 (C-6), 71.1 and 71.6 (2 *C*H_2Ph), 74.8 (C-5), 76.0 (C-3), 76.3 (C-4), 101.4 (C-1), 127.8, 127.9, 128.4, 128.5, 129.8, 130.0, 131.2, 132.4 137.6, 137.7, 137.7 (C-Ar): HRMS: Calcd for $C_{27}H_{29}O_4S$ 449.1786; Found $(MH)^+$ *m*/*z* 449.1807.

2-[3,6-Di-O-*benzyl-2-thio-2*-S-(p-*tolyl*)-β-D-*glucofuranosyl]-1,4-dimethoxybenzene* (**6**).—A solution of **1** (104 mg, 0.250 mmol) in CH_2Cl_2 (10 mL) and a 1.0 M solution of *p*-TolSCl (0.25 mL, 0.25 mmol) was stirred at rt for 10 min (the color changed from yellow to colorless). The mixture was cooled to −10 °C and 1,4-dimethoxybenzene (138 mg, 1.00 mmol) was added, followed by a 1.0 M solution of $SnCl_4$ (0.3 mL, 0.3 mmol). After 40 min, the mixture was poured into a chilled and vigorously stirred mixture of 5% aq $NaHCO_3$ (5 mL) and CH_2Cl_2 (15 mL), extracted with CH_2Cl_2 (2 × 15 mL), and dried over K_2CO_3. After solvent removal, the mixture was separated using gradient elution column chromatography (3:1:0.05 to 3:1:1 hexane–CH_2Cl_2–Et_2O) and additional purification on a TLC plate (1:1 hexane–Et_2O); yield 11 mg (7%) of **6** and 18 mg 13% of **5**. R_f 0.57; $[\alpha]_D^{20}$ −5.8° (*c* 0.20, CH_2Cl_2); ^{1}H NMR (500 MHz): δ 2.34 (s, 3 H, CH_3), 2.82 (d, 1 H, $J_{5,OH}$ 4.8, OH), 3.65 (s, 3 H, OCH_3), 3.68 (m, 2 H, H-6a, H-2), 3.77 (s, 3 H, OCH_3), 3.78 (m, 1 H, H-6b), 4.03 and 4.19 (two d, 2 H, *J* 11.6, CH_2Ph), 4.08

(d, 1 H, $J_{2,3}$ 0, $J_{3,4}$ 3.5, H-3), 4.25 (dd, 1 H, $J_{4,5}$ 7.5, H-4), 4.36 (m, 1 H, H-5), 4.54 and 4.59 (two d, 2 H, J 11.8, CH_2Ph), 5.21 (d, 1 H, $J_{1,2}$ 3.5, H-1), 6.78–7.30 (m, 17 H, H-Ar); ^{13}C NMR (125 MHz): δ 21.1 (CH_3), 55.6 and 56.2 (2 OCH_3 groups), 58.5, 69.0, 70.8, 72.3, 73.6, 79.7, 80.9 and 85.0 (OCH and OCH_2), 111.6, 112.8, 113.7, 127.6, 127.7, 127.8, 127.9, 128.3, 128.4, 128.5, 129.8, 130.8, 131.0, 133.4, 137.5, 138.0, 138.1, 150.6 and 153.8 (C-Ar): HRMS: Calcd for $C_{35}H_{38}NaO_6S$ 609.2287; Found $(MNa)^+$ m/z 609.2275.

*2-[3,4-Di-*O*-benzyl-2-thio-2-*S*-(*p*-tolyl)-β-*D*-gluco-furanosyl]thiophene* (**7**).—A solution of **1** (104 mg, 0.250 mmol) in CH_2Cl_2 (10 mL) and a 1.0 M solution of *p*-TolSCl (0.25 mL, 0.25 mmol) was stirred at rt for 10 min (the color changed from yellow to colorless). The mixture was cooled to −10 °C, and thiophene (21 mg, 0.25 mmol) was added, followed by a 1.0 M solution of $SnCl_4$ (0.3 mL, 0.3 mmol). The mixture was stirred for 25 min at −10 °C and 10 min at 0 °C, then it was poured into a chilled and vigorously stirred mixture of 5% aq $NaHCO_3$ (5 mL) and CH_2Cl_2 (15 mL), extracted with CH_2Cl_2 (2 × 15 mL), and dried over K_2CO_3. After evaporation of the solvent, the mixture was separated using column chromatography (2:1:0.1 hexane–CH_2Cl_2–Et_2O) and preparative TLC (35:1 $CHCl_3$–Et_2O). Yield 72 mg (54%) along with 32 mg (20%) of **3**. R_f 0.25; $[\alpha]_D^{20}$ −17° (*c* 0.20, CH_2Cl_2); ^{1}H NMR (500 MHz): δ 2.33 (s, 3 H, CH_3), 2.73 (s, 1 H, OH), 3.63 (dd, 1 H, $J_{5,6}$ 6.3, $J_{6a,6b}$ 3.8, H-6a), 3.67 (dd, 1 H, $J_{1,2}$ 5.5, $J_{2,3}$ 1.5, H-2), 3.73 (dd, 1 H, $J_{5,6b}$ 9.9, H-6b), 4.09 (dd, 1 H, $J_{3,4}$ 4.1, H-4), 4.14 (dd, 1 H, H-3), 4.16 and 4.42 (two d, 2 H, J 11.8, CH_2Ph), 4.29 (m, 1 H, H-5), 4.53 and 4.57 (s, 2 H, J 11.8, CH_2Ph), 4.97 (d, 1 H, H-1), 6.93 (dd, 1 H, $J_{3',4'}$ 3.4, $J_{3',5'}$ 5.1, H-4′ of Th), 6.99 (m, 1 H, H-3′ of Th), 7.30 (m, 15 H, 2 Ph, *p*-Tol, H-5′ of Th); ^{13}C NMR (125 MHz): δ 21.2 (CH_3), 60.0 (C-2), 68.7 (C-5), 71.2 and 73.5 (2 CH_2Ph groups), 72.0 (C-6), 81.1 (C-4), 81.6 (C-1), 84.9 (C-3), 125.2 (C-4′), 126.5 (C-3′), 125.6, 127.7, 127.8, 128.4, 130.0, 130.1 and 133.8 (CH-Ar), 130.03, 137.5, 138.2, 138.5 and 144.2 (C-Ar). HRMS: Calcd for $C_{31}H_{33}O_4S_2$ 533.1863, Found $(MH)^+$ m/z 533.1863.

*(2*S*,3*R*,4*R*,5*S*)-1,3,4-Tribenzyloxy-6,6-di-[2-(5-methyl)thienyl]-5-(*p*-tolylthio)-2-hexanol* (**8**).—The compound was prepared in 65% yield under the conditions similar to those described for **7** (after addition of 2-methylthiophene, the reaction mixture was stirred for 1 h at −10 °C). R_f 0.31; IR (neat): 3477 cm^{-1} (OH); $[\alpha]_D^{20}$ −7.9° (*c* 0.63, CH_2Cl_2); ^{1}H NMR (500 MHz): δ 2.33 (s, 3 H, CH_3), 2.36 and 2.42 (two s, 6 H, 2 $ThCH_3$), 2.90 (br. s, 1 H, OH), 3.68 (m, 2 H, H-1), 4.00 (m, 2 H, H-4 and H-5), 4.07 (m, 1 H, H-2), 4.29 (t, 1 H, $J_{2,3} = J_{3,4}$ 6.7, H-3), 4.51 and 4.86 (two d, 2 H, J 11.6, CH_2Ph), 4.58 (m, 2 H, CH_2Ph), 4.70 and 4.84 (two d, 2 H, J 11.3, CH_2Ph), 4.79 (d, 1 H, $J_{5,6}$ 7.6, H-6), 6.48 and 6.52 (m, 2 H, H-4′ of two Th), 6.62 and 6.73 (two d, 2 H, $J_{3',4'}$ 3.4, H-3′ of Th), 6.95 and 7.12 (m, 4 H, *p*-Tol), 7.40 (m, 15 H, 3 Ph); ^{13}C NMR (125 MHz): δ 15.1 and 15.2 (2 ThCH_3 groups), 21.0 (ArCH_3), 46.8 (C-6), 60.9 (C-2), 71.3 (C-1), 71.9 and 81.2 (C-4 and C-5), 73.6, 74.5 and 74.9 (3 CH_2Ph groups), 80.3 (C-3), 125.2 (C-4′), 126.5 (C-3′), 125.6, 127.7, 127.8, 128.4, 130.0, 130.1 and 133.8 (CH-Ar), 130.05, 137.5, 138.2, 138.5 and 144.2 (C-Ar). HRMS: Calcd for $C_{44}H_{46}O_4S_3$ 734.2558; Found: M^+ m/z 734.2629.

*2-Methyl-5-[3,4,6-tri-*O*-benzyl-2-thio-2-*S*-(*p*-tolyl)-β-*D*-glucopyranosyl]thiophene* (**9**) *and 2-methyl-5-[3,4,6-tri-*O*-benzyl-2-thio-2-*S*-(*p*-tolyl)-α-*D*-glucopyranosyl]-thiophene* (**10**).—The compounds were obtained from 2-methylthiophene (3 mmol) and $ZnCl_2$ using the conditions given in Table 1. The isomers were separated using column chromatography (1:1 hexane–CH_2Cl_2). Yield 70 mg (44%) of **6b** and 12 mg (8%) of **7b**. Data for **9**: R_f 0.56; $[\alpha]_D^{20}$ −21.6° (*c* 1.20, CH_2Cl_2); ^{1}H NMR (300 MHz): δ 2.35 and 2.46 (two s, 6 H, $ThCH_3$ and $ArCH_3$), 3.28 (t, 1 H, $J_{1,2} = J_{2,3}$ 10.6, H-2), 3.80 (m, 5 H, H-3, 4, 5, and 6), 4.57 (d, 1 H, H-1), 4.60 and 4.71 (two d, 2 H, J 12.0, CH_2Ph), 4.74 and 4.95 (two d, 2 H, J 10.9, CH_2Ph), 5.02 and 5.21 (two d, 2 H, J 10.3, CH_2Ph), 6.62 (m, 1 H, H-4′ of Th), 6.94 (d, 1 H, $J_{3',4'}$ 3.4, H-3′ of Th), 7.09 (m, 4 H, *p*-Tol), 7.40 (m, 15 H, 3 Ph). ^{13}C NMR (75 MHz): δ 15.3 ($ThCH_3$), 21.0 ($ArCH_3$), 59.6, 69.0, 73.4, 75.0, 76.0, 78.9, 79.3, 79.5, and 84.6 (CH and CH_2), 124.1, 126.9, 127.4, 127.6, 127.7, 127.8, 127.9, 128.3, 128.4, 129.2, 133.2, 137.1, 138.3, 138.4, 139.9, and 142.6 (C-Ar). HRMS: Calcd for $C_{39}H_{40}O_4S_2$ 636.2368; Found: M^+ m/z 636.2356. Data for **10**: R_f 0.65; $[\alpha]_D^{20}$ +300° (*c* 0.10, CH_2Cl_2); ^{1}H NMR (300 MHz): δ 2.31 (s, 6 H, $ThCH_3$, $ArCH_3$), 3.61 (dd, 1 H, $J_{5,6}$ 1.8, $J_{6,6'}$ 10.7, H-6), 3.72 (dd, 1 H, $J_{1,2}$ 4.9, $J_{2,3}$ 11.2, H-2), 3.73 (t, 1 H, $J_{3,4} = J_{4,5}$ 8.7, H-4), 3.80 (dd, 1 H, $J_{5,6'}$ 3.7, H-6′), 3.89 (dd, 1 H, H-3), 4.43 (m, 1 H, H-5), 4.22 and 4.59 (two d, 2 H, J 12.0, CH_2Ph), 4.52 and 4.84 (two d, 2 H, J 10.8, CH_2Ph), 4.86 and 5.04 (two d, 2 H, J 10.3, CH_2Ph), 5.46 (d, 1 H, H-1), 7.25 (m, 21 H, H-Ar); ^{13}C NMR (75 MHz): δ 21.4 ($ArCH_3$ and $ThCH_3$), 55.8, 68.9, 72.5, 73.8, 75.5, 76.4, 79.9, 82.7, and 90.0 (CH and CH_2), 128.0, 128.2, 128.3, 128.5, 128.7, 128.8, 130.1, 132.5, 132.7, 137.6, and 138.5 (C-Ar). HRMS: Calcd for $C_{34}H_{35}O_4S$ $[M - CH_3C_4H_2S]^+$ 539.2256; Found $[M - CH_3C_4H_2S]^+$, m/z 539.2238.

*2-[3,4,6-Tri-*O*-benzyl-2-thio-2-*S*-(*p*-tolyl)-β-*D*-gluco-pyranosyl]furan* (**11a**).—The compound was obtained from furan (4 equiv) and $Zn(CN)_2$ (3 equiv) using the conditions indicated in Table 2. The reaction mixture was black in color. The product was isolated using gradient elution column chromatography (3:1:0.1 to 3:1:0.6 hexane–CH_2Cl_2–Et_2O). Yield 25 mg (16%) of **11a** and 38 mg (29%) of **5**. R_f 0.53; ^{1}H NMR (300 MHz): δ 2.30 (s, 3 H, ArCH_3), 3.49 (t, 1 H, $J_{1,2} = J_{2,3}$ 10.8, H-2), 3.53 (m, 1 H, H-5), 3.66 and 3.72 (two m, 4

H, H-3, H-4, and H-6), 4.38 (d, 1 H, H-1), 4.50 and 4.58 (two d, 2 H, *J* 12.2, C*H*$_2$Ph), 4.61 and 4.86 (two d, 2 H, *J* 10.6, C*H*$_2$Ph), 4.95 and 5.15 (two d, 2 H, *J* 10.4, C*H*$_2$Ph), 6.28 and 6.32 (m, 2 H, β-H of Fur), 7.05 (m, 4 H, *p*-Tol), 7.30 (m, 16 H, 3 Ph and α-H of Fur). HRMS: Calcd for $C_{38}H_{38}O_5S$ 606.2440; Found M^+ *m*/*z* 606.2436.

3,4,6-Tri-O-*benzyl-1-deoxy-1,1-di*-C-*(2-furyl)-2-thio-2*-S-*(*p-*tolyl)*-D-*glucitol [(2*S,*3*R,*4*R,*5*S)*-1,3,4-tribenzyloxy-6,6-di-(2-furyl)-5-(*p-*tolylthio)-2-hexanol]* (**12a**).—The compound was synthesized from furan (4 equiv) and $SnCl_4$ (1.2 equiv) under the conditions indicated in Table 2. The reaction mixture color quickly changed from orange to black. The product was isolated using column chromatography (2:1:0.1 hexane–CH_2Cl_2–Et_2O). Yield 38%. R_f 0.28; IR (neat): 3477 cm^{-1} (OH); ^{1}H NMR (500 MHz): δ 2.26 (s, 3 H, ArC*H*$_3$), 2.68 (d, 1 H, $J_{2,OH}$ 4.4, OH), 3.52 and 3.56 (two dd, 2 H, $J_{1,1'}$ 9.5, $J_{1,2}$ 3.5, $J_{1',2}$ 6, H-1,1′), 3.73 (dd, 1 H, $J_{3,4}$ 7.0, $J_{4,5}$ 2.2, H-4), 3.99 (m, 1 H, H-2), 4.09 (dd, 1 H, $J_{5,6}$ 9.8, H-5), 4.26 (t, 1 H, $J_{2,3}$ 7.0, H-3), 4.49 and 4.87 (two d, 2 H, 11.4, C*H*$_2$Ph), 4.53 (s, 2 H, CH_2OCH_2Ph), 4.60 (d, 1 H, H-6), 4.67 and 4.78 (two d, 2 H, 11.2, C*H*$_2$Ph), 6.05, 6.22, and 6.26 (three m, 1 H, 2 H, and 1 H, β-H of Fur), 6.94 (m, 2 H, *p*-Tol), 7.12 (m, 2 H, *p*-Tol and 1 H, α-H of Fur), 7.35 (m, 15 H, 3 Ph and 1 H, α-H of Fur). HRMS: Calcd for $C_{42}H_{43}O_6S$ 675.2780; Found $(MH)^+$ *m*/*z* 675.2788.

2-Methyl-5-[3,4,6-tri-O-*benzyl-2-thio-2*-S-*(*p-*tolyl)-β-*D-*glucopyranosyl]furan* (**11b**).—The compound was obtained from 2-methylfuran (12 equiv) and $Zn(CN)_2$ (3 equiv) under the conditions indicated in Table 2. The product was isolated using gradient elution column chromatography (100:120:0.5 to 50:75:0.5 hexane–CH_2Cl_2–Et_2O). Yield 24% along with 38% of **12b**, 16% of **3**, and 10% of **5**. R_f 0.51; $[\alpha]_D^{20}$ +0.22° (*c* 0.23, CH_2Cl_2); ^{1}H NMR (300 MHz): δ 2.03 and 2.31 (two s, 6 H, FurC*H*$_3$, ArC*H*$_3$), 3.21 (t, 1 H, $J_{1,2} = J_{2,3}$ 10.6, H-2), 3.75 (m, 5 H, H-3, 4, 5, and 6), 4.32 (d, 1 H, H-1), 4.80 (m, 6 H, three groups C*H*$_2$Ph), 5.84 (m, 1 H, H-4 of Fur), 6.23 (d, 1 H, $J_{3,4}$ 3.1, H-3 of Fur), 7.06 (m, 4 H, *p*-Tol), 7.30 (m, 15 H, 3 Ph); ^{13}C NMR (75 MHz): δ 13.7 (Fur*C*H$_3$), 21.4 (Ar*C*H$_3$), 56.2, 56.8, 69.0, 73.8, 75.3, 76.9, 79.5, 83.0, and 85.0 (CH and CH_2), 102.7 and 106.6 (β-C of Fur), 128.0, 128.1, 128.2, 128.3, 128.4, 128.6, 128.7, 128.8, 129.6, 129.9, 133.2, 133.9, and 138.6 (C-Ar), 149.4 and 152.2 (α-C of Fur). HRMS: Calcd for $C_{39}H_{40}NaO_5S$ 643.2494; Found $(MNa)^+$ *m*/*z* 643.2494.

3,4,6-Tri-O-*benzyl-1-deoxy-1,1-di*-C-*(5-methylfuran-2-yl)-2-thio-2*-S-*(*p-*tolyl)*-D-*glucitol [(2*S,*3*R,*4*R,*5*S)*-1,3,4-tribenzyloxy-6,6-di-[2-(5-methyl)furyl]-5-(*p-*tolylthio)-2-hexanol]* (**12b**) *and its diastereomer* (**12b′**).—The compounds synthesized from 2-methylfuran (12 equiv) and $SnCl_4$ (1.2 equiv) under the conditions indicated in Table 2. The isomers were isolated using column chromatography (1:1.5 hexane–CH_2Cl_2). Yield 39% of **12b** and 8% of **12b′**. Data for **12b**: $[\alpha]_D^{20}$ −4.2° (*c* 2.1, CH_2Cl_2); R_f 0.42; IR (neat): 3472 cm^{-1} (OH); ^{1}H NMR (300 MHz): δ 2.01, 2.20, 2.32 (three s, 9 H, ArC*H*$_3$ and 2 FurC*H*$_3$ groups), 2.74 (d, 1 H, $J_{2,OH}$ 4.4, OH), 3.60 and 3.65 (two dd, 2 H, $J_{1,1'}$ 9.7, $J_{1,2}$ 3.8, $J_{2,1'}$ 6, H-1,1′), 3.79 (dd, 1 H, $J_{4,5}$ 2.2, $J_{3,4}$ 7.0, H-4), 4.03 (dd, 1 H, $J_{5,6}$ 9.9, H-5), 4.06 (m, 1 H, H-2), 4.28 (t, 1 H, $J_{2,3}$ 7.0, H-3), 4.46 (d, 1 H, H-6), 4.52 and 4.57 (two d, 2 H, *J* 11.8, CH_2OCH_2Ph), 4.55 and 4.88 (two d, 2 H, *J* 11.3, C*H*$_2$Ph), 4.68 and 4.79 (two d, 2 H, *J* 11.2, C*H*$_2$Ph), 5.78 and 5.83 (m, 2 H, H-4 of two FurCH_3 groups), 5.94 and 6.10 (two d, 2 H, $J_{3,4}$ 3.0, H-3 of two FurCH_3 groups), 7.04 (m, 4 H, *p*-Tol), 7.30 (m, 15 H, 3 Ph); ^{13}C NMR (125 MHz): δ 13.5 and 13.8 (two Fur*C*H$_3$ groups), 21.2 (Ar*C*H$_3$), 43.8, 53.7, 57.5, 71.1, 71.9, 73.6, 74.5, 74.8, and 80.3 (CH and CH_2), 106.3, 106.7, 108.2, and 108.9 (C-3 and C-4 of two FurCH_3 groups), 127.5, 127.6, 127.8, 127.9, 128.1, 128.4, 128.5, 128.7, 129.4, 132.2, 136.4, 138.3, 138.7, 139.1 (C-Ar), 150.7, 150.9, 151.5, and 152.0 (C-2 and C-5 of two groups FurCH_3). HRMS: Calcd for $C_{44}H_{46}NaO_6S$ 725.2913; Found $(MNa)^+$ *m*/*z* 725.2909. Data for **12b′**: R_f 0.35; $[\alpha]_D^{20}$ +180° (*c* 0.14, CH_2Cl_2); IR (neat): 3477 cm^{-1} (OH); ^{1}H NMR (500 MHz): δ 2.11, 2.13 and 2.14 (three s, 9 H, ArC*H*$_3$ and 2 groups FurC*H*$_3$), 2.61 (d, 1 H, $J_{2,OH}$ 4.4, OH), 3.49 (m, 2 H, H-1,1′), 3.83 (m, 1 H, H-3), 3.91 (m, 2 H, H-2 and H-4), 4.06 (m, 1 H, H-5), 3.97 and 4.18 (two d, 2 H, *J* 11.5, C*H*$_2$Ph), 4.35 and 4.41 (two d, 2 H, *J* 11.5, C*H*$_2$Ph), 4.43 and 4.57 (two d, 2 H, *J* 11.5, C*H*$_2$Ph), 4.86 (d, 1 H, *J* 5, H-6), 5.75 and 5.85 (m, 2 H, H-4 of two FurCH_3 group), 5.90 and 6.26 (two d, 2 H, $J_{3,4}$ 2.7, H-3 of two FurCH_3 group), 6.86 (m, 4 H, *p*-Tol), 7.20 (m, 15 H, 3 Ph); ^{13}C NMR (125 MHz): δ 13.93 and 13.96 (two Fur*C*H$_3$ groups), 21.4 (Ar*C*H$_3$), 40.6, 56.7, 71.0, 71.6. 73.4, 73.7, 73.9, 74.8, 79.3, and 81.2 (CH and CH_2), 106.7, 106.8, 109.3, and 109.5 (C-3 and C-4 of two FurCH_3 groups), 127.6, 127.8, 128.2, 128.4, 128.6, 128.8, 129.8, 132.4, 137.0, 138.4, 139.0, 139.1, 151.0, 152.8, and 158.9 (C-Ar and C-2 and C-4 of two FurCH_3 groups). HRMS: Calcd for $C_{44}H_{46}NaO_6S$ 725.2913, Found $(MNa)^+$ *m*/*z* 725.2901.

1-Methyl-2-[3,4,6-tri-O-*benzyl-2-thio-2*-S-*(*p-*tolylthio)-β-*D-*glucopyranosyl]pyrrole* (**11c**).—The compound was one of the products obtained under the conditions described below (see experimental for **12c**); mp 97–98 °C (EtOH), R_f 0.47; $[\alpha]_D^{20}$ −0.52° (*c* 0.15); ^{1}H NMR (300 MHz): δ 2.29 (s, 3 H, ArC*H*$_3$), 3.35 (t, 1 H, $J_{2,3}$ 10.3, H-2), 3.45 (s, 3 H, NCH_3), 3.53 and 3.72 (two m, 1 H and 4 H, H-3,4,5, and 6,6′), 4.30 (d, 1 H, $J_{1,2}$ 11.0, H-1), 4.47 and 4.54 (two d, 2 H, *J* 12.0, C*H*$_2$Ph), 4.63 and 4.88 (two d, 2 H, *J* 10.8, C*H*$_2$Ph), 4.96 and 5.18 (two d, 2 H, *J* 10.1, C*H*$_2$Ph), 6.00, 6.05, and 6.48 (m, 3 H, pyrrole), 6.99 (m, 4 H, *p*-Tol), 7.30 (m, 15 H, C-Ar); ^{13}C NMR (83.3 MHz): δ 21.5 (Ar*C*H$_3$), 34.6 (NCH_3), 56.8, 69.7, 73.8, 75.5, 76.2, 76.8,

79.3, 80.2, and 85.6 (CH and CH_2), 107.2 and 110.0 (β-C of pyrrole), 123.4, 127.9, 128.0, 128.1, 128.2, 128.3, 128.6, 128.7, 128.8, 128.9, 129.4, 129.8, 134.2, 137.9, 138.6, 138.7, and 138.8 (C-Ar). HRMS: Calcd for $C_{39}H_{41}NNaO_4S$ 642.2654; Found $(MNa)^+$ m/z 642.2668.

*3,4,6-Tri-*O*-benzyl-1-deoxy-1,1-di-*C*-(1-methylpyrrol-2-yl)-2-thio-2-*S*-(*p*-tolyl)-*D*-glucitol [(2*S*,3*R*,4*R*,5*S*)-1,3,4-tribenzyloxy-6,6-di-[2-(1-methyl)pyrrolyl]-5-(*p*-tolylthio)-2-hexanol* (**12c**)*] and its two diastereomers* (**12c′** and **12c″**).—The addition of $SnCl_4$ (1.2 equiv) to the mixture of **2** and 1-methylpyrrole (12.0 equiv) resulted in a thick orange jelly, which dissolved after several minutes giving a dark solution. After quenching, the mixture was separated using gradient elution column chromatography (100:130:0.5 to 50:100:0.5 hexane–CH_2Cl_2–Et_2O). Yield 30% of **12c**, 11% of **12c′**, 18% of **12c″**, and 10% of **11c**. Data for **12c**: R_f 0.40; IR (neat): 3484 cm^{-1} (OH); ^1H NMR (500 MHz): δ 2.26 (s, 3 H, ArCH_3), 2.70 (d, 1 H, $J_{2,OH}$ 5.0, OH), 3.41 (s, 6 H, 2 groups NCH_3), 3.55 (m, 2 H, H-1,1′), 3.75 (d, 1 H, $J_{5,6}$ 9.5, $J_{4,5}$ 0, H-5), 3.94 (m, 1 H, H-2), 3.96 (d, 1 H, $J_{3,4}$ 7.5, H-4), 4.17 (t, 1 H, $J_{2,3}$ 7.5, H-3), 4.23 (d, 1 H, H-6), 4.44 and 4.83 (two d, 2 H, J 12.0, CH_2Ph), 4.50 (s, 1 H, CH_2Ph), 4.61 and 4.66 (two d, 2 H, J 11.0, CH_2Ph), 5.84, 5.92, and 6.08 (three m, 1 H, 2 H, and 1 H, β-H of pyrrole), 6.34 and 6.37 (two m, 1 H each, α-H of pyrrole), 6.95 (m, 4 H, *p*-Tol), 7.30 (m, 15 H, H-Ar); ^{13}C NMR (125 MHz): δ 21.1 (ArCH_3), 34.1 and 35.9 (two NCH_3 groups), 38.9, 60.2, 71.0, 71.6, 73.3, 74.27, 74.34, 80.4, and 80.7 (CH and CH_2), 106.4, 106.7, 107.8, 119.9, 120.2, 121.7, 127.3, 127.4, 127.5, 127.7, 127.8, 128.1, 128.2, 128.4, 129.1, 132.9, 135.1, 138.2, 139.3 (C-Ar). HRMS: Calcd for $C_{44}H_{48}N_2NaO_4S$ 723.3232; Found $(MNa)^+$ m/z 723.3245. Data for **11c′**: R_f 0.29; IR (neat): 3483 cm^{-1} (OH); ^1H NMR (300 MHz): δ 2.26 (s, 3 H, ArCH_3), 3.20 and 3.42 (s, 6 H, 2 NCH_3 groups), 2.72 (d, 1 H, $J_{2,OH}$ 3.6, OH), 3.63 (m, 2 H, H-1,1′), 3.85 (dd, 1 H, $J_{5,6}$ 9.5, $J_{4,5}$ 2.3, H-5), 3.98 (m, 1 H, H-2), 4.11 (dd, 1 H, $J_{3,4}$ 7.0, H-4), 4.23 (m, 2 H, H-3,6), 4.24 and 4.78 (two d, 2 H, J 12.1, CH_2Ph), 4.53 (s, 2 H, CH_2OCH_2Ph), 4.64 and 4.73 (two d, 2 H, J 11.1, CH_2Ph), 5.94, 6.00, and 6.25 (three m, 1 H, 2 H and 1 H, β-H of pyrrole), 6.32 and 6.40 (two m, 1 H each, α-H of pyrrole), 6.93 (m, 4 H, *p*-Tol), 7.30 (m, 15 H, H-Ar). HRMS: Calcd for $C_{44}H_{48}N_2NaO_4S$ 723.3232; Found $(MNa)^+$ m/z 723.3191. Data for **12c″**: R_f 0.22; IR (film): OH 3483 cm^{-1}; ^1H NMR (300 MHz): δ 2.27 (s, 3 H, ArCH_3), 3.43 (s, 6 H, 2 NCH_3 groups), 2.72 (d, 1 H, $J_{2,OH}$ 3.0, OH), 3.53 (dd, 1 H, $J_{1,1'}$ 9.8, $J_{1,2}$ 3.0, H-1), 3.60 (dd, 1 H, $J_{1',2}$ 6.2, H-1′), 3.76 (dd, 1 H, $J_{5,6}$ 9.7, $J_{4,5}$ 2.1, H-5), 3.95 (m, 1 H, H-2), 3.97 (dd, 1 H, $J_{3,4}$ 7.1, H-4), 4.18 (t, 1 H, $J_{2,3}$ 7.1, H-3), 4.25 (d, 1 H, H-6), 4.45 and 4.85 (two d, 2 H, J 11.7, CH_2Ph), 4.52 (s, 2 H, CH_2OCH_2Ph), 4.62 and 4.68 (two d, 2 H, J 11.2, CH_2Ph), 5.85, 5.93, 6.09, 6.36, and 6.39 (m, 6 H, pyrrole), 6.40 (m, 2 H, H_α), 6.90 and 7.03 (m, 4 H, *p*-Tol), 7.30 (m, 15 H, H-Ar); ^{13}C NMR (75 MHz): δ 21.0 (ArCH_3), 34.1, 35.9 (NCH_3), 38.9, 60.2, 71.0, 71.6, 73.3, 74.2, 74.3, 80.4, and 80.7 (CH and CH_2), 106.4, 106.7, 107.8, 119.9, 120.2, 121.6, 124.7, 127.3, 127.4, 127.5, 127.7, 127.8, 128.1, 128.2, 128.3, 128.4, 129.0, 132.8, and 132.9 (β-C of pyrrole and C-Ar), 135.1, 138.2, 138.5, and 139.3 (α-C of pyrrole). HRMS: Calcd for $C_{44}H_{48}N_2NaO_4S$ 723.3232; Found $(MNa)^+$ m/z 723.3201.

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