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PII: S0008-6215(11)00207-2
DOI: 10.1016/j.carres.2011.04.027
Reference: CAR 5759

To appear in: *Carbohydrate Research*

Received Date: 3 February 2011
Revised Date: 12 April 2011
Accepted Date: 18 April 2011

Please cite this article as: Csávás, M., Májer, G., Herczeg, M., Remenyik, J., Lázár, L., Mándi, A., Borbás, A., Antus, S., Investigation of glycosylating properties of 1-deoxy-1-ethoxysulfonyl-hept-2-ulopyranosyl derivatives. Synthesis of a new sulfonic acid mimetic of the sialyl Lewis X tetrasaccharide, *Carbohydrate Research* (2011), doi: 10.1016/j.carres.2011.04.027

Investigation of glycosylating properties of 1-deoxy-1-ethoxysulfonyl-hept-2-ulopyranosyl derivatives. Synthesis of a new sulfonic acid mimetic of the sialyl Lewis X tetrasaccharide

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Dedicated to Professor András Lipták on the occasion of his 75th birthday

Abstract

Glycosylation reactions of the ethylthio, bromo, and chloro derivatives of 1-deoxy-1-ethoxysulfonyl-hept-2-ulopyranose were studied applying different acceptors under different conditions. Elimination side-reactions affording exo- and endoglycals occured in all cases, however, with different proportions. Glycosyl chloride donor was applied to glycosylate a trisaccharide acceptor obtaining a new sulfonic acid mimetic of the sialyl Lewis X tetrasaccharide in high yield.

Keywords

Carbohydrate sulfonic acid; Glycosylation; Ketopyranosyl glycosides; Elimination; Sialyl Lewis X mimetic

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1. Introduction

Selectins are carbohydrate-binding transmembrane glycoproteins, and their role is to mediate the first steps of the recruitment of leukocytes from the blood stream in a series of normal and pathologic situations.[1] Control of these processes by inhibiting the adhesion between the calcium-dependent lectin domain of selectins and their carbohydrate ligands has been considered as a new anti-inflammatory and anti-metastatic strategy.[2] Sialyl Lewis X (sLe^x) tetrasaccharide, one of the major natural ligands of selectins serves as a lead-structure for the design of selectin antagonists (Figure 1).[3] The negatively charged carboxylate of sialic acid is crucial in binding to transmembrane proteins, but it can be replaced by other charged moieties. Analogues containing e.g. sulfate ester,[4] phosphate ester[5] or cyclohexyl lactic acid[6] instead of sialic acid proved to be active as selectin antagonists.

Earlier, we described the synthesis of sulfonic acid analogues of the sLe X tetrasaccharide in which the sialic acid is replaced by an anomeric sulfonomethyl-type sugar moiety.[7,8] To install the sulfonomethyl derivative to oligosaccharides ethyl 3,4,5,7-tetra-*O*-benzyl-1-deoxy-1-ethoxysulfonyl-2-thio-α-D-*gluco*-hept-2-ulopyranoside was used as glycosyl donor. However, the yields of glycosylation reactions were moderate since a considerable amount of *exo*-glycal was always formed *via* elimination side-reaction.

Recently, two isosteric sulfonate mimetics of mannose-6-*O*-phosphate prepared by Wadsworth-Horner-Emmons olefination have been published.[9] Both conjugated and

unconjugated mannose-sulfonates displayed better binding affinity to cation-independent mannose-6-phosphate receptor and possessed greater stability in human serum than mannose-6-phosphate.

We have found that sulfonate analogues of idraparinux, a synthetic non-glycosaminoglycan anticoagulant pentasaccharide inhibited efficiently the blood coagulation factor Xa in an *in vitro* assay.[10]

The experimental evidence of biological activity of carbohydrate sulfonic acids inspired us to revisit the synthesis of sulfonic acid mimetic of sialic acid-containing oligosaccharides using anomeric sulfonomethyl-type donors.

Here, we report glycosylation reactions of ethylthio, chloro and bromo derivatives of 3,4,5,7-tetra-*O*-benzyl-1-deoxy-1-ethoxysulfonyl-α-D-*gluco*-hept-2-ulopyranose applying different acceptors and conditions. Efficient synthesis of a new sulfonic acid tetrasaccharide analogue of the sialyl Lewis X is also discussed.

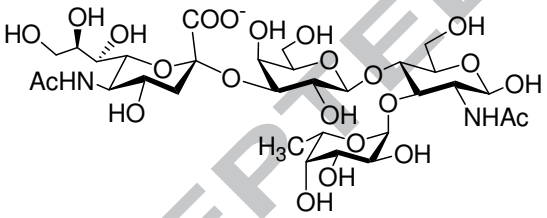
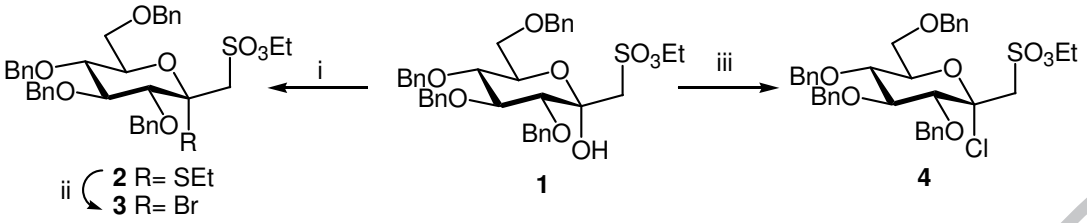


Figure 1. Structure of the sialyl Lewis X tetrasaccharide

2. Results and discussion

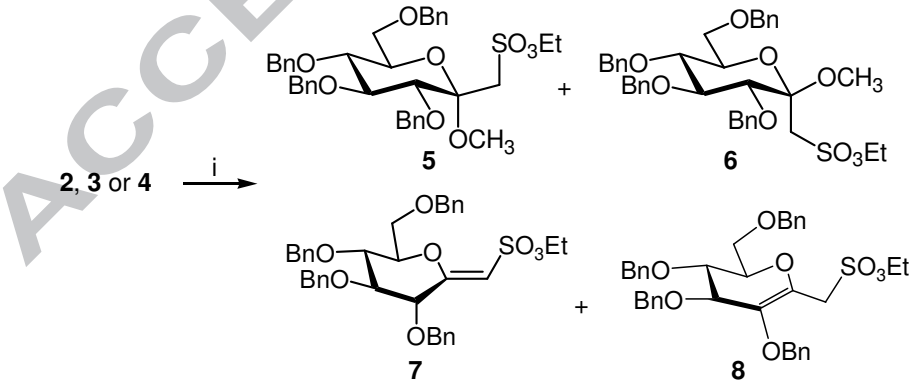
2.1. Glycosylation study

Thioglycoside **2**,[7,8] and the appropriate bromo (**3**) and chloro (**4**) derivatives were planned to be utilized as glycosyl donors. Compound **2** was treated with bromine to produce **3**; the reaction went to completion in ten minutes. The chlorosugar **4** was prepared from the hemiketal **1** using thionyl chloride and pyridine as reagents (Scheme 1).



Scheme 1. Reagents and conditions: i) EtSH, $BF_3{\cdot}Et_2O$, abs CH_2Cl_2, 0 °C, 93% ii) Br_2, abs DCM, 0 °C, 10 min, iii) $SOCl_2$, py, abs CH_2Cl_2, rt, 10 min, 85%.

The obtained **2**-**4** were used as donors to glycosylate methanol (Scheme 2), acceptor **9**[11] containing free hydroxyl group at primary position (Scheme 3), and acceptors **12**[11] and **13**[12] with secondary alcoholic functions (Scheme 4), respectively. NIS-TfOH promoter system was applied at different temperatures to activate the thioglycoside, and MeOTf was also used as a promoter for glycosylation of **12** and **13**.[13] Halide donors, prepared freshly before glycosylations and used without purification, were activated with either AgOTf or $Hg(CN)_2$, and chloro sugar was promoted also with a mixture of $Hg(CN)_2$ and $HgBr_2$. Relative proportions of the products were determined from the crude reaction mixture by HPLC measurements.



Scheme 2. Reagents and conditions: i) MeOH (15 equiv), 3 Å MS, for solvents and promoters see Table 1.

The glycosylation results using methanol as an acceptor (Scheme 2) are summarized in Table 1. Each reaction afforded an anomeric mixture of the methyl glycosides **5** and **6**.[13] Using the thioglycoside donor **2** the stereoselectivity was poor in favour of either the α- or the β-anomer depending on the reaction temperature. Reactions applying halide donors **3** and **4** provided the α-isomer **5** as the major product with high stereoselectivity. From the chloro and bromo-sugars the known elimination side-product **7**[7,8] was formed in all cases, and upon AgOTf promotion the endoglycal **8** as another side-product was observed as well.

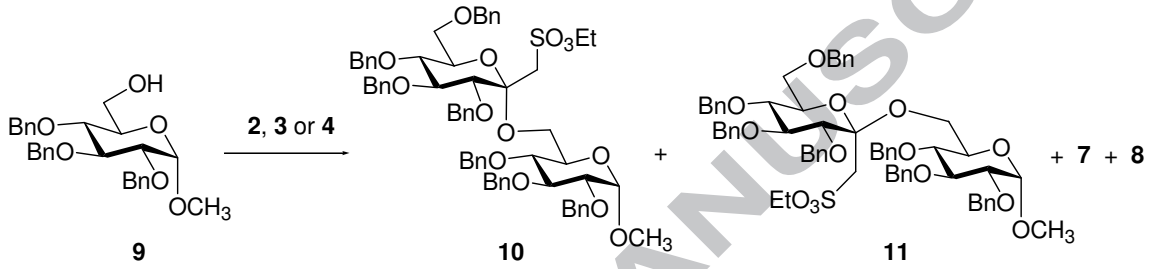
Table 1. Glycosylation of methanol with 1-deoxy-1-ethloxysulfonyl-hept-2-ulopyranosyl donors

Entry	Donor	Promoter[a]	T (°C)	Time	**5** (%)	**6** (%)	**7** (%)	**8** (%)
1	**2**	NIS-TfOH	-60	40 min	43	57	-	-
2	**2**	NIS-TfOH	0	40 min	62	38	-	-
3	**2**	NIS-TfOH	rt	30 min	69	31	-	-
4	**3**	AgOTf	-40 to -10	20 min	81.3	17.6	0.7	0.4
5	**3**	$Hg(CN)_2$	0	20 min	65.2	33.1	1.6	-
6	**4**	AgOTf	-40 to -10	5 h	80.7	12.0	5.4	1.9
7	**4**	$Hg(CN)_2$-$HgBr_2$	0 to rt	5 h	84.9	9.5	5.6	-

[a]Amount of promoters: NIS (1.2 equiv) TfOH (0.4 equiv); $Hg(CN)_2$ (1 equiv); AgOTf (2 equiv); $Hg(CN)_2$-$HgBr_2$ (1.5 equiv-0.5 equiv). Solvents: CH_2Cl_2 for entries 1-3, CH_2Cl_2-toluene for entries 4 and 6, CH_2Cl_2-CH_3CN for entries 5 and 7.

Glycosylation reactions using acceptor **9** possessing a reactive primary hydroxyl (Scheme 3) are summarized in Table 2. In each case a mixture of the stereoisomeric 2,6-linked disaccharides **10** and **11**[11] together with elimination side-product(s) was formed. Reactions using thioglycoside gave the disaccharides with the highest proportion and the highest α-

selectivity; by using chloro- and bromo sugars upon AgOTf promotion at –15 ^{o}C a slightly lower rate of disaccharides and lower stereoselectivity were achieved. For both halide donors the rate of glycosylation decreased using Hg(II) salt instead of Ag(I) salt. Carrying out glycosylation with donor **4** of low reactivity using less powerful activation the glycoside formation decreased dramatically and elimination reactions became the dominant reactions (Entry 7).



Scheme 3. Reagents and conditions: see Table 2.

Table 2. Glycosylation of **9** with 1-deoxy-1-ethoxysulfonyl-hept-2-ulopyranosyl donors

Entry	Donor	Promoter[a]	T (°C)	Time	**10** (%)	**11** (%)	**7** (%)	**8** (%)
1	**2**	NIS-TfOH	-50	1 h	81.6	6.7	11.7	-
2	**2**	NIS-TfOH	-5	30 min	74.4	7.7	17.9	0
3	**3**	AgOTf	-15	7.5 h	63.6	24.0	12.4[b]	
4	**3**	$Hg(CN)_2$	0	3 h	55.2	19.4	25.4[b]	
5	**4**	AgOTf	-15	8 h	71.5	6.3	19.8	2.4
6	**4**	$Hg(CN)_2$-$HgBr_2$	0	18 h	55.8	19.6	24.6[b]	
7	**4**	$Hg(CN)_2$	rt	18 h	11.3	8.5	57.1	23.1

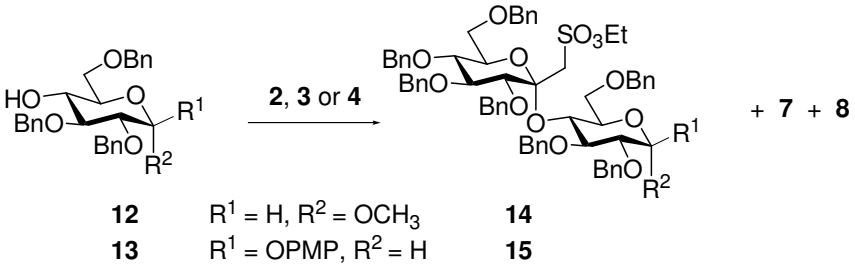
[a]Amount of promoters: NIS (1.2 equiv) TfOH (0.4 equiv); $Hg(CN)_2$ (1 equiv); AgOTf (2 equiv); $Hg(CN)_2$-$HgBr_2$ (1.5 equiv-0.5 equiv). [b]Ratio of **7** and **8** was not determined. Solvents:

CH_2Cl_2 for entries 1-2, CH_2Cl_2-toluene for entries 3 and 5, CH_2Cl_2-CH_3CN for entries 4, 6 and 7.

Glycosylation reactions using acceptor **12** and **13** (Scheme 4) are summarized in Tables 3 and 4. The main features of these reactions were that elimination reactions generally overtook glycoside formation, and the α-linked disaccharides formed exclusively. Configuration of the interglycosidic linkages of **14** and **15** was determined on the basis of the NMR C1–H3 three-bond coupling constant which is dependent on the dihedral angle in a manner similar to $^3J_{H,H}$.[13]

Thioglycoside **2** upon powerful activation using NIS-TfOH was inefficient for glycosylation of the unreactive acceptors **12** and **13**; reactivity of the secondary hydroxyl groups was low at the low temperature of activation (-40 °C), therefore oxocarbenium intermediate formed rapidly from the donor was stabilized *via* elimination (Table 3: entries 1, 2 and Table 4: entry 1). Slow activation process of **2** at room temperature using the mild MeOTf as a promoter gave slightly better results, due to the increasing reactivity of the acceptor at higher temperature (Table 3: entry 3 and Table 4: entry 2). Beside exoglycal **7**, formation of endoglycal **8** from thioglycoside was also observed.

Glycosyl halides proved to be more efficient donors for both acceptors **12** and **13** than the thioglycoside. Interestingly, the outcome of the reactions was greatly influenced by the aglycons of the acceptors (α-methyl for **12** and β-*p*-methoxyphenyl for **13**). For acceptor **12** the more reactive halide donor **3** with the less powerful promoter $Hg(CN)_2$ worked as well than the less reactive halide donor **4** with the more powerful promoter AgOTf (Table 3: entries 5 and 6). For acceptor **13** chlorosugar **4** upon AgOTf promotion worked much better than bromosugar **3** activated by $Hg(CN)_2$ (Table 4: entries 5 and 4).



12 R^1 = H, R^2 = OCH_3 **14**

13 R^1 = OPMP, R^2 = H **15**

Scheme 4. Reagents and conditions: see Table 3 and 4.

Table 3. Glycosylation of **12** with 1-deoxy-1-ethoxysulfonyl-hept-2-ulopyranosyl donors

Entry	Donor	Promoter[a]	T (°C)	Time	**14** (%)	**7** (%)	**8** (%)
1	**2**	NIS-TfOH	-40	30 min	17.4	55.1	27.5
2	**2**	NIS-TfOH	0	2 h	0.6	99.4[b]	
3	**2**	MeOTf	rt	1 day	23.2	76.8[b]	
4	**3**	AgOTf	0	1 h	28.6	40.8	30.6
5	**3**	$Hg(CN)_2$	0	1h	39.6	35.0	25.4
6	**4**	AgOTf	0	1h	40.0	45.2	14.8
7	**4**	$Hg(CN)_2$-$HgBr_2$	0	4 days	11.2	62.0	26.8

[a]Amount of promoters: NIS (1.2 equiv) TfOH (0.4 equiv); MeOTf (6 equiv); AgOTf (2 equiv); $Hg(CN)_2$ (1 equiv); $Hg(CN)_2$-$HgBr_2$ (1.5 equiv-0.5 equiv). [b]Ratio of **7** and **8** was not determined. Solvents: CH_2Cl_2 for entries 1-3, CH_2Cl_2-toluene for entries 4 and 6, CH_2Cl_2-CH_3CN for entries 5 and 7.

Table 4. Glycosylation of **13** with 1-deoxy-1-ethoxysulfonyl-hept-2-ulopyranosyl donors

Entry	Donor	Promoter[a]	T (°C)	Time	**15** (%)	**7** (%)	**8** (%)
1	**2**	NIS-TfOH	-40	65 min	12.0	86.1	1.9

2	**2**	MeOTf	RT	1 day	18.5	81.5[b]	
3	**3**	AgOTf	0	2 h	13.5	30.5	56.0
4	**3**	$Hg(CN)_2$	0	2.5 h	16.2	29.3	54.5
5	**4**	AgOTf	0	2 days	63.4	29.1	7.5
6	**4**	$Hg(CN)_2$-$HgBr_2$	0	5 days	16.3	50.7	33.0

[a]Amount of promoters: NIS (1.2 equiv) TfOH (0.4 equiv); MeOTf (6 equiv); AgOTf (2 equiv); $Hg(CN)_2$ (1 equiv); $Hg(CN)_2$-$HgBr_2$ (1.5 equiv-0.5 equiv). [b]Ratio of **7** and **8** was not determined. Solvents: CH_2Cl_2 for entries 1-2, CH_2Cl_2-toluene for entries 3 and 5, CH_2Cl_2-CH_3CN for entries 4 and 6.

Summarising the results, using ketosyl donors carrying a sulfonomethyl moiety at the anomeric position the outcome of glycosylation reactions strongly depends on the reactivity of the acceptor. The oxocarbenium ion formed upon activation can react with the aglycon to form glycoside, or can transform easily to glycal derivatives *via* elimination of the labile proton next to the electron withdrawing sulfonic acid moiety. The ratio of glycosylation and elimination is determined by the relative rate of formation of the oxocarbenium cation, its reaction with the acceptor and the elimination reaction from the oxocarbenium intermediate.

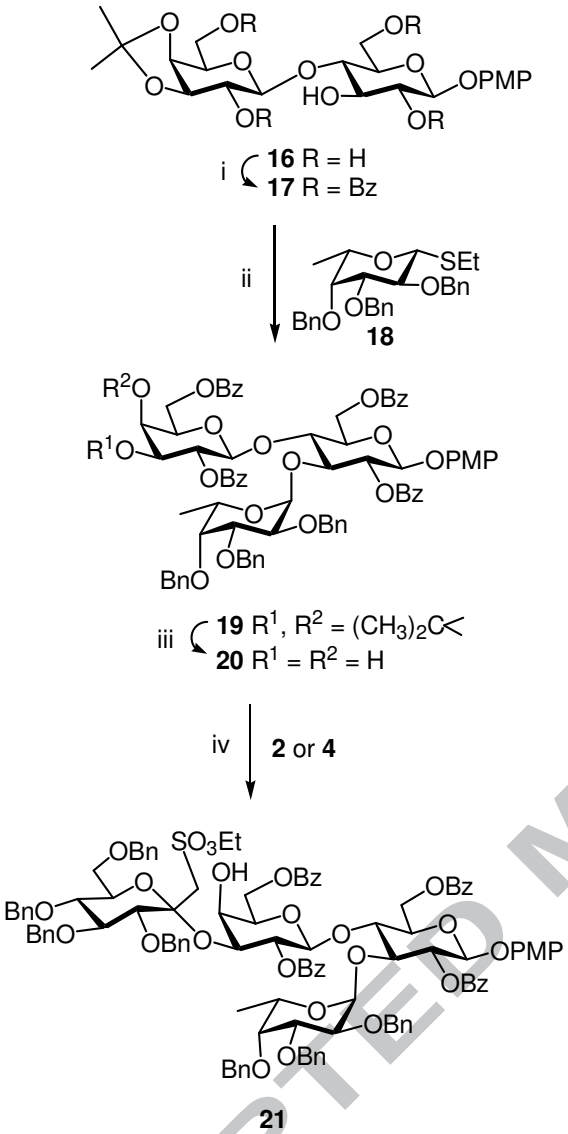
During glycosylation of methanol, the elimination was negligible, independently of the applied donor or promoter, due to the immediate reaction of the oxocarbenium ion with the highly reactive alcohol. In the reactions of acceptor **9** containing a primary hydroxyl, at lower temperature glycoside formation was more favoured. Accordingly, more reactive donor afforded better results.

Acceptors with low reactivity could not be glycosylated at low temperature, therefore application of reactive donors and promoters should be avoided. Increasing the temperature both glycosylation and elimination became faster, and an optimum of their relative rates can

lead to better results. In our case, the chlorosugar with the lowest reactivity proved to be the best donor to glycosylate **12** and **13**.

2.2. Synthesis of a new sialyl Lewis X mimic

Synthesis of tetrasaccharide **21** as a new sulfonic acid analogue of the sialyl Lewis X was carried out as shown on Scheme 5. It is known from SAR study of the sLe^x tetrasaccharide analogues, that 2-acetamido group of its glucosamine residue is not involved in binding to selectins, therefore the cheap and easily available lactose could be used for the synthesis instead of lactosamine. The 3',4'-*O*-isopropylidene derivative of *p*-methoxyphenyl lactoside **16**[14] was converted to crystalline **17** in high yield by the well-established selective benzoylation.[15] Fucosylation of acceptor **17** with ethyl 2,3,4-tri-*O*-benzyl-1-thio-β-L-fucoside **18**[16] upon TMSOTf activation afforded the Lewis X mimetic **19**. Deisopropylidenation of the fully protected trisaccharide using methanolic HCl[17] gave **20** without affecting the highly acid sensitive α-fucosidic linkage. Then the diol was glycosylated with both thioglycoside **2** and chlorosugar **4**, as to consider their capacity in forming a tetrasaccharide. Based on our glycosylation experiments discussed above, higher yield was expected using donor **4**.



Scheme 5. Reagents and conditions: i) BzCl, toluene-py, 0°C, 1.5 h, 69% ii) abs CH_2Cl_2, NIS-TMSOTf, -45°C, 1 h, 94% iii) 1M HCl, MeOH, 50°C, 3 h, 89% iv) (a) donor **4**, AgOTf, abs CH_2Cl_2, 0°C, 12h, 59% for **21**, 28 % for **7** + **8** (b) donor **2**, MeOTf, abs CH_2Cl_2, rt, 33% for **21**, 38% for **7** + **8** (c) donor **2**, NIS-TfOH, abs CH_2Cl_2, rt, 10% for **21**, 42% for **7** + **8**.

In the reactions of thioglycoside **2** elimination took place dominantly, and the desired tetrasaccharide formed only in moderate yields. Glycosylation of **20** with the chloride donor **4** resulted in the target compound **21** in considerably higher yield, according to our expectation.

In conclusion, this investigation of glycosylation reactions of the ethylthio, bromo, and chloro derivatives of 1-deoxy-1-ethoxysulfonyl-hept-2-ulopyranose revealed, that activation methods and reactivity of the donors should be matched to the reactivity of acceptors in order to achieve high yield in glycosylations. Glycosyl chloride donor **4** with moderate reactivity was applied successfully to glycosylate a trisaccharide acceptor affording a new sialyl Lewis X mimetic in acceptable yield. Further exploitation of glycosylation with anomeric sulfonomethyl-containing donors in synthesis of oligosaccharides of potential biological activity is in progress in our laboratory.

3. Experimental

3.1. General methods

Optical rotations were measured at room temperature with a Perkin-Elmer 241 automatic polarimeter. TLC was performed on Kieselgel 60 F_{254} (Merck) with detection by immersing into 5% ethanolic sulfuric acid soln followed by heating. Column chromatography was performed on Silica gel 60 (Merck 0.063-0.200 mm) and Sephadex LH-20 (Sigma-Aldrich, Bead size 25-100 μ). Organic solutions were dried over $MgSO_4$, and concentrated in vacuum. The ^1H (200, 360, 400 and 500 MHz) and ^{13}C NMR (50.3, 90.54, 100.28, 125.76 MHz) spectra were recorded with Bruker AC-200, Bruker DRX-360, Bruker DRX-400 and Bruker DRX-500 spectrometers. Chemical shifts are referenced to Me_4Si (0.00 ppm for ^1H) or to the residual solvent signals ($CDCl_3$: 77.00 ppm for ^{13}C). MALDI-TOF MS analyses of the compounds were carried out in the positive reflectron mode using a BIFLEX III mass spectrometer (Bruker, Germany) equipped with delayed-ion extraction. The matrix solution was a satd 2,4,6-trihydroxy-acetophenone (THAP) solution in MeCN. A Hewlett-Packard 1090 series II Liquid Chromatograph equipped with a diode array detector (DAD), an

automatic samples and Chem Station were used for the separation experiments. The separation was performed using a Supelcosil Si 5µm column. *n*-Hexane/ethyl-acetate mixture was used as eluent. The effluent was monitored for UV-active groups at 256 nm. The component ratio was given on the basis of the Area% of the HPLC analysis.

3.2. General method A for glycosylation of methanol starting from thioglycoside 2

To a solution of 1 mmol thioglycoside donor (1 equiv) in dry CH_2Cl_2 (15 mL) 3 Å molecular sieves and methanol (15 equiv) were added and it was stirred for 3 h. The reaction mixture was cooled to the appropriate temperature then the solution of NIS (1.2 equiv) and TfOH (0.4 equiv) in dry CH_2Cl_2 and THF (1:1, 2 mL) was added. When TLC showed complete conversion of the donor, the reaction mixture was quenched with Et_3N, the insoluble materials were removed by filtration, the filtrate was diluted with CH_2Cl_2 and washed with water, filtered, dried and concentrated. The ratio of the products was determined from the crude product by HPLC.

3.3. General method B for glycosylation of methanol with halide donor 3 or 4

I) To a solution of methanol (15 equiv) in toluene (2.5 mL) 3 Å molecular sieves and AgOTf (2 equiv) were added and it was stirred for 3 h. The reaction mixture was cooled to the appropriate temperature then the solution of donor (1 equiv) in dry CH_2Cl_2 (2 mL/0.3 mmol) was added. When TLC showed complete conversion of the donor, the insoluble materials were removed by filtration, the filtrate was diluted with CH_2Cl_2, washed with 10% $Na_2S_2O_3$-solution and water, filtered, dried and concentrated. The ratio of the products was determined from the crude product by HPLC.

II) A mixture of methanol (15 equiv) in dry CH_3CN (2.5 mL), powdered 3 Å molecular sieves and $(HgCN)_2$ (1 equiv) or $Hg(CN)_2$ (1.5 equiv) and $HgBr_2$ (0.5 equiv) was stirred for 3 h. The reaction mixture was cooled to 0 °C then the solution of donor (1 equiv) in dry CH_2Cl_2 (2 mL/0.3 mmol) was added. When TLC showed complete conversion of the donor, the insoluble materials were removed by filtration, the filtrate was diluted with CH_2Cl_2, washed with 10% $Na_2S_2O_3$-solution and water, filtered, dried and concentrated. The ratio of the products was determined from the crude product by HPLC.

3.4. General method C for preparation of glycosides 5, 6, 10, 11, 14 and 15 starting from donor 2

To a solution of acceptor (1.5 equiv) and donor (1 equiv) in dry CH_2Cl_2 (15 mL/mmol) 4 Å molecular sieves was added and it was stirred for 3 h. The reaction mixture was cooled to the appropriate temperature then the solution of NIS (1.2 equiv) and TfOH (0.4 equiv) in dry CH_2Cl_2 and THF (1:1, 2 mL) was added. When TLC showed complete conversion of the donor, the reaction was quenched with Et_3N, the insoluble materials were removed by filtration, the filtrate was diluted with CH_2Cl_2, washed with water, filtered, dried and concentrated. The obtained crude product was used for HPLC measurements.

3.5. General method D for preparation of glycosides 14 and 15 starting from donor 2 using MeOTf

To a solution of acceptor (1.5 equiv) and donor (1 equiv) in dry CH_2Cl_2 (15 mL/mmol) 4 Å powdered molecular sieves was added and it was stirred for 3 h, then MeOTf (6 equiv) was added. When TLC showed complete conversion of the donor, the reaction was quenched with

Et_3N, the insoluble materials were removed by filtration, the filtrate was diluted with CH_2Cl_2, washed with water, filtered, dried and concentrated. The ratio of the products was determined from the crude product by HPLC.

3.6. General method E for preparation of glycosides 5, 6, 10, 11, 14 and 15 with halide donors 3 and 4

I) To a solution of acceptor (1.5 equiv) in toluene (2.5 mL) 4 Å molecular sieves and AgOTf (2 equiv) were added and it was stirred for 3 h. The reaction mixture was cooled to the appropriate temperature then the solution of donor (1 equiv) in dry CH_2Cl_2 (2 mL/0.3 mmol) was added. When TLC showed complete conversion of the donor, the insoluble materials were removed by filtration, the filtrate was diluted with CH_2Cl_2, washed with 10% $Na_2S_2O_3$-solution and water, filtered, dried and concentrated. The ratio of the products was determined from the crude product by HPLC.

II) A mixture of acceptor (1.5 equiv) in dry CH_3CN (2.5 mL), powdered 4 Å molecular sieves and $(HgCN)_2$ (1 equiv) or $Hg(CN)_2$ (1.5 equiv) and $HgBr_2$ (0.5 equiv) was stirred for 3 h. The reaction mixture was cooled to 0°C then the solution of donor (1 equiv) in dry CH_2Cl_2 (2 mL/0.3 mmol) was added. When TLC showed complete conversion of the donor, the insoluble materials were removed by filtration, the filtrate was diluted with CH_2Cl_2, washed with 10% $Na_2S_2O_3$-solution and water, filtered, dried and concentrated. The ratio of the products was determined from the crude product by HPLC.

3.7. 3,4,5,7-Tetra-*O*-benzyl-1-deoxy-1-ethoxysulfonyl-α-D-*gluco*-hept-2-ulopyranosyl-bromide (3)

To a stirred solution of **2** (212 mg, 0.30 mmol) in abs dichloromethane (2 mL), 15 μL (0.30

mmol, 1.0 equiv) bromine was added and it was cooled to 0 °C. The reaction mixture was concentrated after 10 min and the residue was coevaporated 3 times with toluene. The obtained syrupy crude product (218 mg) was used for further reaction without purification. R_f 0.75 (98:2 CH_2Cl_2-acetone).

3.8. 3,4,5,7-Tetra-*O*-benzyl-1,2-dideoxy-1-ethoxysulfonyl-α-D-*gluco*-hept-2-ulopyranosyl-chloride (4)

Compound **1** (700 mg, 0.99 mmol) was dissolved in 5 mL abs dichloromethane and 55 μL (0.99 mmol, 1.0 equiv) pyridine and 85 μL (1.09 mmol, 1.1 equiv) $SOCl_2$ were added at room temperature. After 10 min the reaction mixture was diluted with CH_2Cl_2, washed twice with 1M aq HCl, 1M aq $NaHCO_3$ and water, then it was dried, filtered, evaporated and purified by column chromatography, to give **4** (625 mg, 85%). For glycosylation, the syrupy crude product was used without purification. R_f 0.81 (*n*-hexane-EtOAc 7:3); ^{1}H NMR (200 MHz, $CDCl_3$): δ 7.38-7.12 (m, 20H, Ph), 5.04 (m, 7H, *J* 11.9 Hz, C*H*$_2$Ph), 4.59 (d, 1H, *J* 9.2 Hz), 4.50 (d, 1H, *J* 12.1 Hz, C*H*$_2$Ph), 4.28-4.13 (m, 3H, $SO_3CH_2CH_3$), 4.13-4.06 (m, 1H), 3.80 (d, 1H, *J* 15.1 Hz, H-1a), 3.82-3.72 (m, 3H), 3.69 (d, 1H, *J* 15.1 Hz, H-1b), 1.22 (t, 3H, *J* 7.1 Hz, $SO_3CH_2CH_3$); ^{13}C NMR (50 MHz, $CDCl_3$) δ 138.1, 137.9 (4C, C_q, Ph), 128.5-125.6 (20C, Ph), 104.3 (C-2), 83.6, 79.8, 76.7, (C-3, C-4, C-5), 75.6, 75.2, 75.1, 73.3 (4C, *C*H_2Ph), 68.0 (2C, C-7, $SO_3CH_2CH_3$), 57.9 (C-1), 15.0 ($SO_3CH_2CH_3$); MALDI-TOF m/z Calcd for $C_{37}H_{41}ClNaO_8S^+$ $[M+Na]^+$: 703.21, Found: 703.21.

3.9. 2,6-Anhydro-3,4,5,7-tetra-*O*-benzyl-1-ethoxysulfonyl-D-*gluco*-hept-2-enitol (8)

Isolated as a colourless syrup (14%) from the reaction of **4** and **9** according to general method **E**, II, using $Hg(CN)_2$ as a promoter. $[\alpha]_D$ -4.3 (*c* 0.07, $CHCl_3$); R_f 0.60 (99:1 CH_2Cl_2-acetone);

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.34-7.25 (m, 20H, Ph), 4.85-4.48 (m, 8H, CH_2Ph), 4.39 (d, 1H, *J* 4.2 Hz, H-4), 4.27-4.21 (m, 3H, H-6, $SO_3CH_2CH_3$), 4.06-3.97 (m, 3H, H-5, C-1-CH_2), 3.83-3.75 (m, 2H, C-7a,b), 1.25 (t, 3H, *J* 7.1 Hz, $SO_3CH_2CH_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.9, 137.7, 137.6, 136.9 (4C, C_q, Ph), 136.1, 135.7 (C-2 and C-3), 128.4-127.6 (20C, Ph), 76.5 (C-6), 73.5 (C-4), 72.6 (C-5), 73.6, 73.4, 72.5, 70.4 (4C, 4 x CH_2Ph), 67.9 ($SO_3CH_2CH_3$), 67.8 (C-7), 49.7 (C-1), 15.0 ($SO_3CH_2CH_3$); Anal. Calcd for: $C_{37}H_{40}O_8S$ (644.77): C, 68.92; H, 6.25; S, 4.97. Found: C, 68.79; H, 6.29; S, 5.00.

3.10. Methyl 2,3,6-tri-*O*-benzyl-4-*O*-(3,4,5,7-tetra-*O*-benzyl-1-deoxy-1-ethoxysulfonyl-α-D-*gluco*-hept-2-ulopyranosyl)-β-D-glucopyranoside (14)

Compound **14** was prepared from donor **2** and acceptor **12** by method **C** and donor **3** or **4** and acceptor **12** by method **E** (see Table 3). $[\alpha]_D$ +33.1 (*c* 0.19, $CHCl_3$); R_f 0.69 (98:2 CH_2Cl_2-acetone); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33-7.14 (m, 35H, Ph), 4.95-4.84 (m, 5H, CH_2Ph), 4.77 (d, 1H, *J* 11.1 Hz, CH_2Ph), 4.66 (d, 1H, *J* 11.2 Hz, CH_2Ph), 4.60-4.57 (m, 5H, H-1, CH_2Ph), 4.51-4.42 (m, 3H, CH_2Ph), 4.21-4.14 (m, 4H, H-1'a, H-5', H-6', H-7'a), 4.05 (t, 1H, *J* 9.0 Hz, H-4), 4.00 (dd, 1H, *J* 10.0 Hz, *J* 5.0 Hz, H-3'), 3.91-3.89 (m, 1H, H-3), 3.86 (q, 2H, *J* 7.0 Hz, $SO_3CH_2CH_3$), 3.73-3.70 (m, 3H, H-1'b, H-5, H-6a), 3.67-3.62 (m, 2H, H-4', H-6b), 3.55 (d, 1H, *J* 11.3 Hz, H-7'b), 3.45 (dd, 1H, $J_{1,2}$ 3.3 Hz, $J_{2,3}$ 9.5 Hz, H-2), 3.36 (s, 3H, OCH_3), 1.08 (t, 3H, *J* 7.05 Hz, $SO_3CH_2CH_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 139.1-137.8 (7C, C_q, Ph), 128.6-126.8 (35C, Ph), 99.9 (C-2'), 97.3 (C-1), 82.4 (C-5'), 81.0 (C-3), 80.4 (C-6'), 79.4 (C-2), 78.5 (C-4'), 73.2 (C-4), 73.0 (C-3'), 70.3 (C-5), 75.4, 75.3, 75.2, 73.3, 73.2, 73.1 (7C, CH_2Ph), 69.5 (C-7'), 68.9 (C-6), 66.7 ($SO_3CH_2CH_3$), 55.4 (OCH_3), 51.5 (C-1', $^3J_{C1',H3'} \leq 1$ Hz), 14.8 ($SO_3CH_2CH_3$); Anal. Calcd for: $C_{65}H_{72}O_{14}S$ (1109.32): C, 70.38; H, 6.54; S, 2.89. Found: C, 69.96; H, 6.33; S, 2.76.

3.11. 4-Methoxyphenyl 2,3,6-tri-*O*-benzyl-4-*O*-(3,4,5,7-tetra-*O*-benzyl-1-deoxy-1-ethoxysulfonyl-α-D-*gluco*-hept-2-ulopyranosyl)-β-D-glucopyranoside (15)

Compound **15** was prepared from donor **2** and acceptor **13** by method **C** and from donor **3** or **4** and acceptor **13** by method **E** (see Table 4). $[\alpha]_D$ +9.8 (*c* 0.17, $CHCl_3$); R_f 0.85 (97:3 CH_2Cl_2-acetone); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34-7.16 (m, 35H, Ph), 6.98, 6.79 (2 x d, 4H, PMP), 5. 07 (d, 1H, *J* 6.3 Hz), 4.98-4.41 (m, 14H, C*H*$_2$Ph), 4.23 (d, 1H, *J* 9.6 Hz), 4.17-4.11 (m, 3H), 3.96-3.89 (m, 5H), 3.75 (s, 3H, OC*H*$_3$), 3.71-3.59 (m, 7H), 1.10 (t, 3H, *J* 7.1 Hz, $SO_3CH_2CH_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 155.1, 151.2 (2C, C_q, PMP), 138.4-138.0 (7C, C_q, Ph), 128.3-127.1 (35C, Ph), 118.1, 114.5 (4C, PMP), 102.0 (C-1), 100.1 (C-2'), 82.5, 80.5, 80.1, 78.3, 76.6, 73.3, 73.2 (skeleton carbons) 75.3, 75.2, 75.0, 74.6, 74.1, 73.4, 73.3 (6C, *C*H$_2$Ph), 70.1, 68.9 (C-6 and C-7'), 67.0 ($SO_3CH_2CH_3$), 55.5 (O*C*H$_3$), 51.8 (C-1', $^3J_{C1',H3'}$ ≤ 1 Hz), 14.9 ($SO_3CH_2CH_3$); Anal. Calcd for $C_{71}H_{76}O_{15}S$ (1200.49): C, 70.98; H, 6.38; S, 2.67. Found: C, 71.04; H, 6.43; S, 2.59.

3.12. 4-Methoxyphenyl 3,4-*O*-isopropylidene-2,6-di-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-2,6-di-*O*-benzoyl-β-D-glucopyranoside (17)

A stirred solution of **16** (970 mg, 2 mmol) in 15 mL of dry pyridin and 20 mL of dry toluene was cooled to 0 °C and BzCl (1.85 ml, 16 mmol, 8 equiv) was added dropwise. After 90 min MeOH was added and the reaction mixture was concentrated. It was then diluted with EtOAc, washed with satd aq $NaHCO_3$ and water, dried, filtered and evaporated. The crude product was recrystallized from EtOAc-*n*-hexane to yield **17** (1.25 g, 69%). Mp 225-227°C, $[\alpha]_D$ +7.6 (c 0.54, $CHCl_3$); R_f 0.73 (95:5 CH_2Cl_2-acetone); ^{1}H NMR (200 MHz, DMSO-d_6) δ 8.09-7.29

(m, 20H, Ph), 6.82, 6.59 (2 x d, 4H, PMP), 5.46 (t, 1H, *J* 8.5 Hz),5.38 (t, 1H, *J* 7.6 Hz), 4.7 (d, 1H, $J_{1,2}$ 8.0 Hz,), 4.87 (d, 1H, *J* 10.8 Hz), 4.69-4.66 (m, 2H), 4.47-4.28 (m, 6H), 4.06 (t, 1H, *J* 9.2 Hz), 3.84-3.75 (m, 2H), 3.65 (s, 3H, OCH_3), 1.64, 1.35 (2 x s, 6H, C(CH_3)$_2$); ^{13}C NMR (50 MHz, DMSO) δ 166.5, 165.4, 165.2 (4C, *C*O), 155.4, 151.0 (2C, C_q, PMP), 133.3-128.4 (24C, Ph), 118.7, 114.2 (4C, PMP), 111.2 (*C*(CH$_3$)$_2$), 101.4 (C-1), 100.5 (C-1'), 82.4, 76.9, 73.5, 73.4, 72.9, 72.7, 72.1, 72.0 (skeleton carbons), 63.6, 62.7 (C-6 and C-6'), 55.4 (O*C*H$_3$), 27.5, 26.2 (C(*C*H$_3$)$_2$); Anal. Calcd for $C_{50}H_{48}O_{16}$ (904.29): C, 66.36; H, 5.35. Found: C, 66.37; H, 5.34.

3.13. 4-Methoxyphenyl 2,6-di-*O*-benzoyl-3,4-*O*-isopropylidene-β-D-galactopyranosyl-(1→4)-2,6-di-*O*-benzoyl-3-*O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-β-D-glucopyranoside (19)

To a stirred solution of acceptor **17** (1.1 g, 1.22 mmol) and donor **18** (0.875 g, 1.83 mmol) in dry CH_2Cl_2 (20 mL) 4 Å molecular sieves was added. After stirring for 1 h the mixture was cooled to -45 °C and NIS (36 mg, 1.3 equiv) and TMSOTf (66 µL, 0.3 equiv) dissolved in CH_2Cl_2:THF (1:1, 5 mL) were added. After 1 h the reaction was quenched with pyridine (0.5 mL), diluted with CH_2Cl_2 and filtered through Celite. The filtrate was washed with 10% aq $Na_2S_2O_3$ and water, dried and concentrated. The crude product was purified by column chromatography (99:1 CH_2Cl_2-acetone) to yield **19** (1.51 g, 94%) as a colourless syrup. $[\alpha]_D$ +13.56 (c 0.649, $CHCl_3$); R_f 0.42 (*n*-hexane-EtOAc 7:3); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.12-6.90 (m, 35H, Ph), 6.65, 6.47 (2 x d, 4H, PMP), 5.58 (t, 1H, *J* 8.8 Hz), 5.38 (d, 1H, $J_{1",2"}$ 3.5 Hz, H-1"), 5.19 (t, 1H, *J* 8.0 Hz), 4.90-4.69 (m, 6H), 4.61-4.44 (m, 4H), 4.33-4.18 (m, 6H), 4.11-4.02 (m, 2H), 3.90-3.89 (m, 2H), 3.73 (s, 1H), 3.58-3.54 (m, 1H), 3.53 (s, 3H, OCH_3), 1.43, 1.24 (2 x s, 6H, C(CH_3)$_2$), 1.20 (d, 3H, H-6"); ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.3,

165.8, 164.6, 164.4 (4C, *C*O), 155.4, 151.0 (2C, C_q, PMP), 139.0. 138.5, 138.0 (3C, C_q, Ph), 133.3-126.7 (39C, Ph), 118.6, 114.2 (4C, PMP), 110.7 ($C(CH_3)_2$), 100.8 (C-1), 100.3 (C-1'), 97.3 (C-1"), 79.0, 78.1, 75.5, 73.9, 73.4, 73.2, 73.1, 71.3, 66.4 (skeleton carbons), 74.5, 72.5 (3C, CH_2Ph), 62.5 (C-6 and C-6'), 55.3 (OCH_3), 27.6, 26.2 ($C(CH_3)_2$), 16.8 (C-6"). Anal. Calcd for $C_{77}H_{76}O_{20}$ (1320.49): C, 69.99; H, 5.80. Found: C, 66.97; H, 5.78.

3.14. 4-Methoxyphenyl 2,6-di-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-2,6-di-*O*-benzoyl-3-*O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-β-D-glucopyranoside (20)

A solution of **19** (1.3 g, 0.19 mmol) in MeOH (25 mL) was treated with 2.5 mL 1M aq HCl at 50 °C for 3 h. The mixture was concentrated, diluted with CH_2Cl_2, washed with satd aq $NaHCO_3$ and water, dried, filtered and evaporated. The crude product was purified by column chromatography (9:1 CH_2Cl_2-EtOAc) to yield **20** (1.1 g, 89%) as a colourless syrup. $[\alpha]_D$ -11.6 (c 0.96, $CHCl_3$); R_f 0.52 (9:1 CH_2Cl_2-EtOAc); ^{1}H NMR (200 MHz, $CDCl_3$) δ 8.12-6.98 (m, 35H, Ph), 6.81-6.52 (m, 4H, PMP), 5.69 (t, 1H, *J* 9.0 Hz, H-2), 5.40 (d, 1H, $J_{1",2"}$ 3.5 Hz, H-1"), 5.25 (t, 1H, *J* 9.0 Hz, H-2'), 4.89-4.53 (m, 11H), 4.39-4.07 (m, 6H), 3.99-3.53 (m, 7H), 3.63 (s, 3H, OCH_3), 1.32 (d, 3H, H-6"); ^{13}C NMR (50 MHz, $CDCl_3$) δ 166.5, 166.2, 166.0, 164.5 (4C, *C*O), 155.3, 151.1 (2C, C_q, PMP), 139.1-126.7 (35C, Ph), 118.6, 114.2 (4C, PMP), 100.9 (C-1), 100.1 (C-1'), 97.6 (C-1"), 78.9, 78.3, 75.4, 74.4, 73.5, 71.8, 67.7, 66.5 (skeleton carbons), 75.1, 72.6 (3C, CH_2Ph), 62.9, 61.7 (C-6 and C-6'), 55.4 (OCH_3), 16.5 (C-6"). Anal. Calcd for $C_{74}H_{72}O_{20}$ (1280.46): C, 69.36; H, 5.66. Found: C, 66.34; H, 5.65.

3.15. 4-Methoxyphenyl 3,4,5,7-tetra-*O*-benzyl-1-deoxy-1-ethoxysulfonyl-α-D-*gluco*-hept-2-ulopyranosyl-(1→3)-2,6-di-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-2,6-di-*O*-benzoyl-3-*O*-(2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl)-β-D-glucopyranoside (21)

To a stirred solution of acceptor **20** (750 mg, 0.57 mmol) and donor **4** (267 mg, 0.38 mmol) in dry CH_2Cl_2 (10 mL) 4 Å molecular sieves was added. After stirring for 1 h the mixture was cooled to 0 °C and AgOTf (74 mg, 2 equiv) dissolved in toluene (2 mL) was added. The mixture was kept at 0 °C overnight. Insoluble materials were removed by filtration, the filtrate was diluted with CH_2Cl_2, washed with 10% aq $Na_2S_2O_3$ and water, dried, filtered and concentrated. The crude product was purified by column chromatography (6:4 *n*-hexane-EtOAc) to yield **21** (710 mg, 59%) as a colourless syrup.

Compound **21** was also prepared from acceptor **20** (250 mg, 0.19 mmol, 1.5 equiv) and donor **2** (92 mg, 0.13 mmol, 1 equiv) in dry CH_2Cl_2 (10 mL) by method **D** using MeOTf (86 µL, 0.78 mmol, 6 equiv). The crude product was purified by column chromatography (9:1 toluene-acetone) to yield **21** (82 mg, 33%) as a colourless syrup.

Compound **21** was also prepared from acceptor **20** (250 mg, 0.19 mmol, 1.5 equiv) and donor **2** (92 mg, 0.13 mmol, 1 equiv) in dry CH_2Cl_2 (10 mL) by method **C** using NIS (35 mg, 1.2 equiv) and TfOH (4.7 µL, 0.05 mmol, 0.4 equiv). The crude product was purified by column chromatography (9:1 toluene-acetone) to yield **21** (25 mg, 10%) as a colourless syrup. $[\alpha]_D$ +24.4 (c 0.38 $CHCl_3$); R_f 0.37 (9:1 toluene-acetone); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15-7.00 (m, 55H, Ph), 6.74, 6.55 (2 x d, 4H, PMP), 5.61 (t, 1H, $J_{2,3}$ 8.2 Hz, H-1), 5.47 (t, 1H, $J_{2',3'}$ 8.9 Hz, H-1'), 5.41 (d, 1H, $J_{1'',2''}$ 3.5 Hz, H-1''), 4.98-4.17 (m, 28H, 7 x C*H*$_2$Ph, H-5'', H-1, H-1', H-6a,b, H-6'a,b, H-4'', H-7'''a,b, H-6''', H-3, H-4''', H-3''), 4.11-3.98 (m, 4H, H-4, H-3', $SO_3CH_2CH_3$), 3.95-3.84 (m, 2H, H-2'', H-5'''), 3.78-3.57 (m, 4H, H-4', H-3''', H-5, H-5'), 3.64 (s, 3H, OC*H*$_3$), 3.28 (s, 1H, H-4'-O*H*), 3.15-3.04 (m, 2H, H-1'''a,b), 1.40 (d, 3H, $J_{5'',6''}$ 6.5 Hz, H-6''), 1.10 (t, 3H, *J* 7.0 Hz, $SO_3CH_2CH_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3,

165.9, 164.4 (4C, *C*O), 155.4, 151.1 (2C, C_q, PMP), 139.3-137.3 (7C, C_q, Ph), 129.8-126.7 (55C, Ph), 118.7, 114.2 (4C, PMP), 100.1, 100.4, 97.7 (C-1, C-1', C-1"), 99.8 (C-2'"), 82.8, 82.4, 80.9, 78.9, 78.8, 77.9, 75.6, 74.5, 74.4, 73.5, 72.8, 71.9, 71.5, 70.6, 67.8, 66.6, (skeleton carbons), 75.2, 75.1, 74.9, 73.4, 73.1, 72.6, 72.3 (7C, *C*H_2Ph), 68.4, 68.1 (C-6''', $SO_3CH_2CH_3$), 62.6, 62.2 (C-6, C-6'), 55.4 (OCH_3), 53.3 (C-1''', $^3J_{C1''',H3'''} \leq 1$ Hz), 16.5 (C-6"), 15.0 ($SO_3CH_2CH_3$). MALDI-TOF m/z Calcd for $C_{111}H_{112}NaO_{28}S$ $[M+Na]^+$: 1947.70, Found: 1948.25. Anal. Calcd for $C_{111}H_{112}O_{28}S$ (1924.71): C, 69.22; H, 5.86; S, 1.66. Found: C, 69.21; H, 5.84; S, 1.64.

Acknowledgements:

This work was supported by the TÁMOP 4.2.1/B-09/1/KONV-2010-0007 project. The project was co-financed by the European Union and the European Social Fund. Financial support of the Hungarian Research Fund (K 62802) is also acknowledged.

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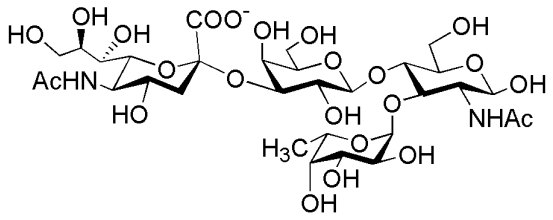
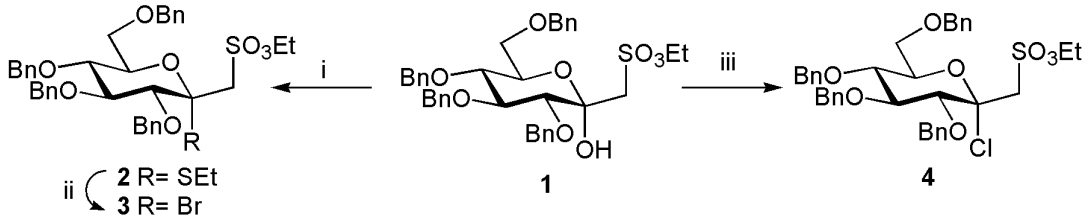
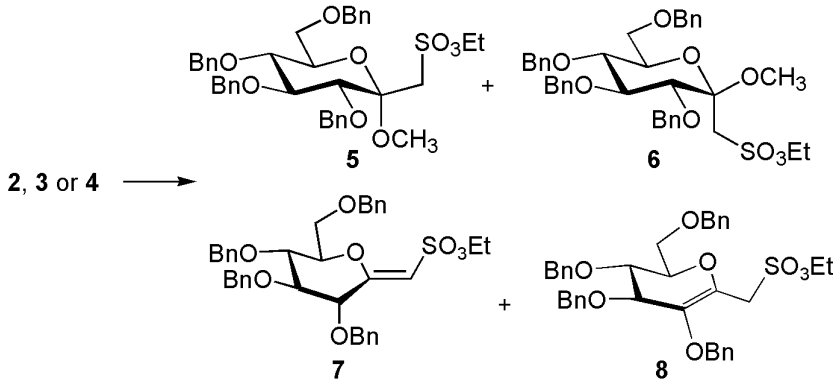
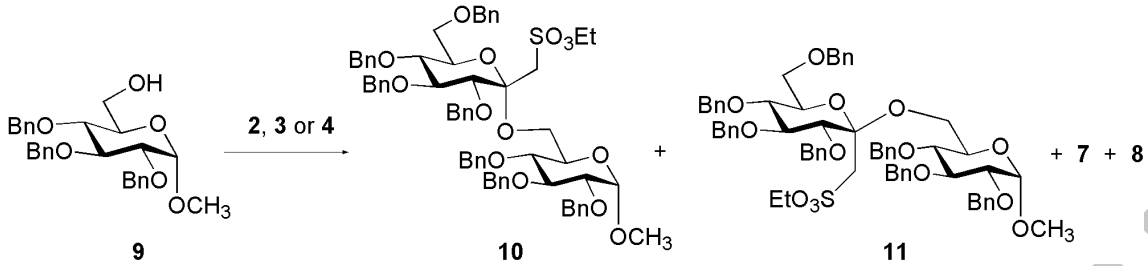
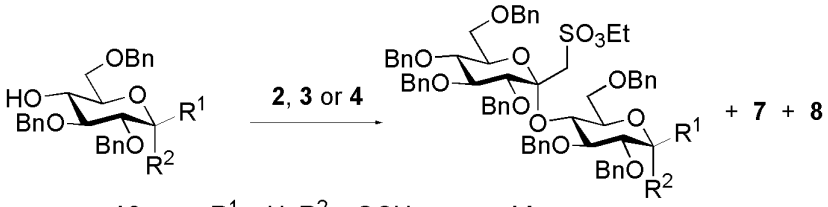








9 **10** **11**



12 R^1 = H, R^2 = OCH_3 **14**

13 R^1 = OPMP, R^2 = H **15**

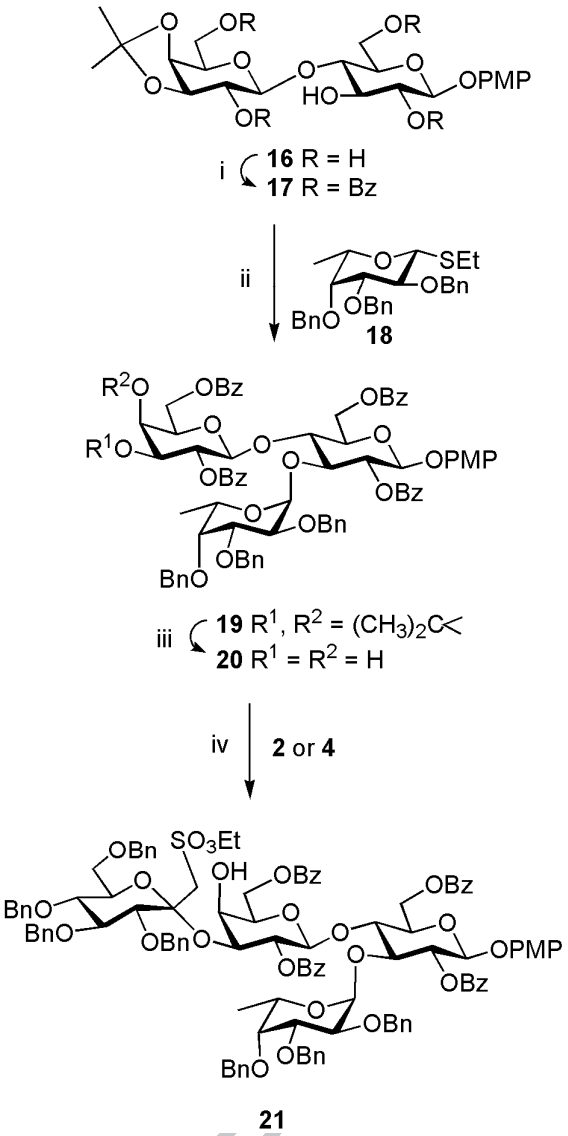


Table 1. Glycosylation of methanol with 1-deoxy-1-ethloxysulfonyl-hept-2-ulopyranosyl donors

Donor	Promoter[a]	T (°C)	Time	**5** (%)	**6** (%)	**7** (%)	**8** (%)
2	NIS-TfOH	-60	40 min	43	57	-	-
2	NIS-TfOH	0	40 min	62	38	-	-
2	NIS-TfOH	rt	30 min	69	31	-	-
3	AgOTf	-40 to -10	20 min	81.3	17.6	0.7	0.4
3	$Hg(CN)_2$	0	20 min	65.2	33.1	1.6	-
4	AgOTf	-40 to -10	5 h	80.7	12.0	5.4	1.9
4	$Hg(CN)_2$-$HgBr_2$	0 to rt	5 h	84.9	9.5	5.6	-

[a]Amount of promoters: NIS (1.2 equiv) TfOH (0.4 equiv); $Hg(CN)_2$ (1 equiv); AgOTf (2 equiv); $Hg(CN)_2$ (1.5 equiv) $HgBr_2$ (0.5 equiv).

Table 2. Glycosylation of **9** with 1-deoxy-1-ethoxysulfonyl-hept-2-ulopyranosyl donors

Donor	Promoter[a]	T (°C)	Time	**10** (%)	**11** (%)	**7** (%)	**8** (%)
2	NIS-TfOH	-50	1 h	81.6	6.7	11.7	-
2	NIS-TfOH	-5	30 min	74.4	7.7		
3	AgOTf	-15	7.5 h	63.6	24.0	12.4[b]	
3	$Hg(CN)_2$	0	3 h	55.2	19.4	25.4[b]	
4	AgOTf	-15	8 h	71.5	6.3	19.8	2.4
4	$Hg(CN)_2$-$HgBr_2$	0	18 h	55.8	19.6	24.6[b]	
4	$Hg(CN)_2$	rt	18 h	11.3	8.5	57.1	23.1

[a]Amount of promoters: NIS (1.2 equiv) TfOH (0.4 equiv); $Hg(CN)_2$ (1 equiv); AgOTf (2 equiv); $Hg(CN)_2$ (1.5 equiv) $HgBr_2$ (0.5 equiv); [b]Ratio of **7** and **8** was not determined.

Table 3. Glycosylation of **12** with 1-deoxy-1-ethoxysulfonyl-hept-2-ulopyranosyl donors

Donor	Promoter[a]	T (°C)	Time	**14** (%)	**7** (%)	**8** (%)
2	NIS-TfOH	-40	30 min	17.4	55.1	27.5
2	NIS-TfOH	0	2 h	0.6	99.4[b]	
2	MeOTf	rt	1 day	23.2	76.8[b]	
3	AgOTf	0	1 h	28.6	40.8	30.6
3	$Hg(CN)_2$	0	1h	39.6	35.0	25.4
4	AgOTf	0	1h	40.0	45.2	14.8
4	$Hg(CN)_2$-$HgBr_2$	0	4 days	11.2	62.0	26.8

[a]Amount of promoters: NIS (1.2 equiv) TfOH (0.4 equiv); MeOTf (6 equiv); AgOTf (2 equiv); $Hg(CN)_2$ (1 equiv); $Hg(CN)_2$ (1.5 equiv) $HgBr_2$ (0.5 equiv). [b]Ratio of **7** and **8** was not determined.

Table 4. Glycosylation of **13** with 1-deoxy-1-ethoxysulfonyl-hept-2-ulopyranosyl donors

Donor	Promoter[a]	T (°C)	Time	**15** (%)	**7** (%)	**8** (%)
2	NIS-TfOH	-40	65 min	12.0	86.1	1.9
2	MeOTf	RT	1 day	18.5	81.5[b]	
3	AgOTf	0	2 h	13.5	30.5	56.0
3	$Hg(CN)_2$	0	2.5 h	16.2	29.3	54.5
4	AgOTf	0	2 days	63.4	29.1	7.5
4	$Hg(CN)_2$-$HgBr_2$	0	5 days	16.3	50.7	33.0

[a]Amount of promoters: NIS (1.2 equiv) TfOH (0.4 equiv); MeOTf (6 equiv); AgOTf (2 equiv); $Hg(CN)_2$ (1 equiv); $Hg(CN)_2$ (1.5 equiv) $HgBr_2$ (0.5 equiv). [b]Ratio of **7** and **8** was not determined.

Investigation of glycosylating properties of 1-deoxy-1-ethoxysulfonyl-hept-2-ulopyranosyl derivatives. Synthesis of a new sulfonic acid mimetic of the sialyl Lewis X tetrasaccharide

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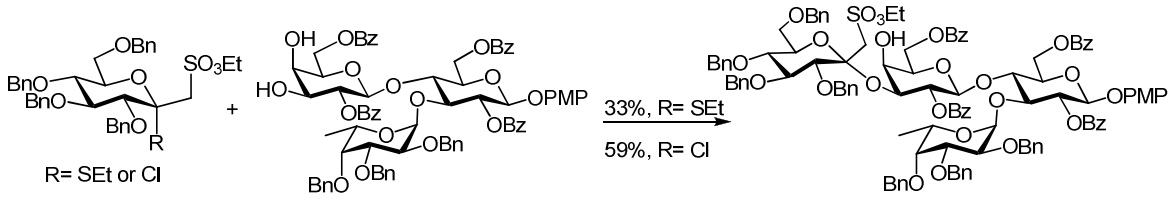
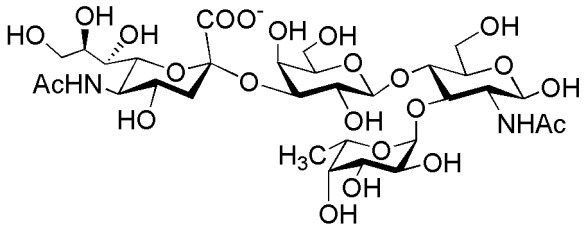
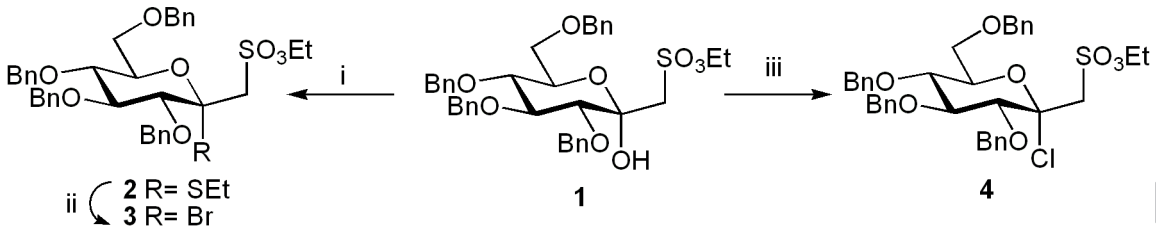
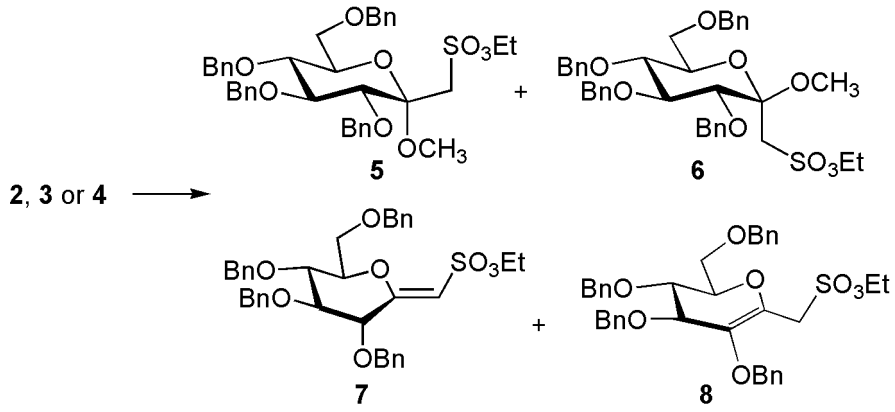
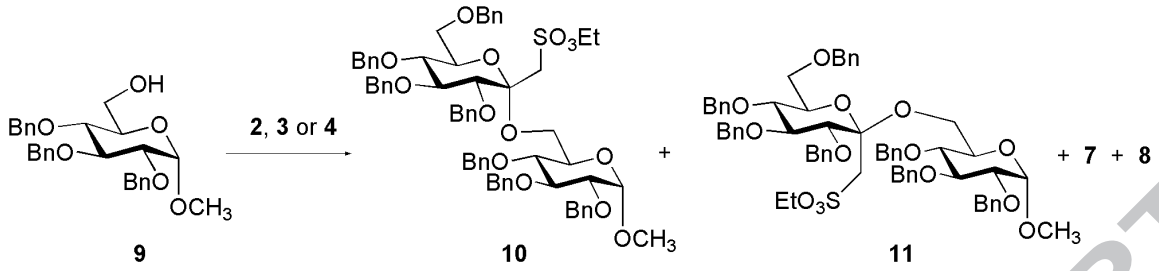


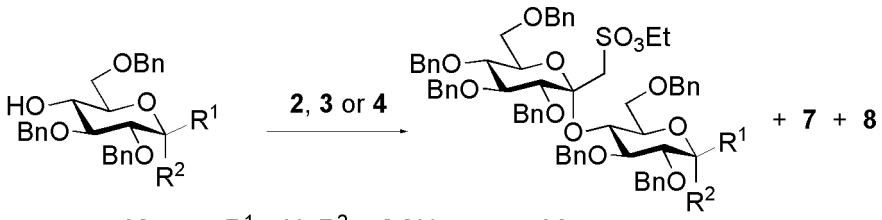








9 **10** **11**



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13 $R^1 = OPMP$, $R^2 = H$ **15**