ELSEVIER

www.elsevier.nl/locate/carres

Carbohydrate Research 329 (2000) 495–505

CARBOHYDRATE RESEARCH

Synthesis of glycosides bearing the disaccharide of OSW-1 or its 1→4-linked analogue and their antitumor activities

Xingquan Ma [a], Biao Yu [a,*1], Yongzheng Hui [a,*2], Dong Xiao [b], Jian Ding [b]

[a] *State Key Laboratory of Bio-organic and Natural Products Chemistry, Shanghai Institute of Organic Chemistry, Chinese Academy of Sciences, Shanghai 200032, PR China*

[b] *Shanghai Institute of Materia Medica, Chinese Academy of Sciences, Shanghai 200031, PR China*

Received 30 May 2000; accepted 17 July 2000

Abstract

Twelve glycosides bearing the disaccharide of OSW-1, namely 2-*O*-(4-methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-*O*-acetyl-α-L-arabinopyranosides, or its 1→4-linked analogue, were synthesized, and their antitumor activities were determined. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: 2-*O*-(4-Methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-*O*-acetyl-α-L-arabinopyranosides; Synthesis; Antitumor activity

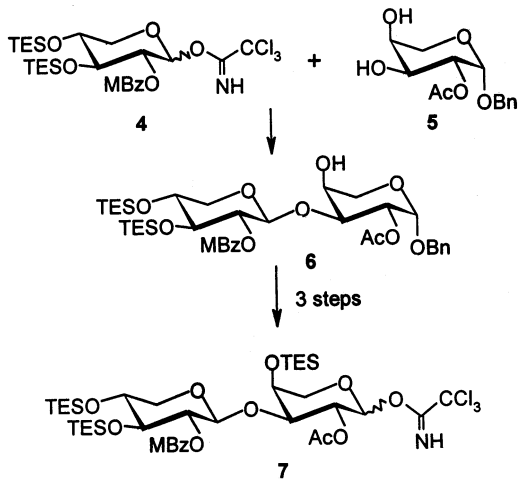
1. Introduction

OSW-1 is the major component of a group of cholestane saponins isolated by Sashida et al. from the bulbs of *Ornithogalum saudersiae*, a species of the lily family, which has no known medicinal use from medicinal folklore [1]. In vitro assays showed that OSW-1 was extremely toxic to a broad spectrum of malignant tumor cells such as leukemia HL-60, mouse mastrocarcinoma, human pulmonary adenocarcinoma, human pulmonary large cell carcinoma and human pulmonary squamous cell carcinoma, including adriamycin-resistant P388 leukemia and camptothecin-resistant P388. Its IC_{50} was between 0.1 and 0.7 nM, which is about 10–100 times more potent than those of the traditional, clinically applied anticancer agents, such as mitomycin C, adriamycin, cisplatin, camptothecin, and taxol. Moreover, OSW-1 exhibited little toxicity to normal cells in vitro and prolonged the life span of P388 leukemia infected mice by 59% via a single administration at 10 μg/kg [1b]. Interestingly, removal of the acetyl (Ac) and the 4-methoxybenzoyl (MBz) groups on the disaccharide moiety (compound **1**) diminished the cytotoxicity significantly (about 1000 times less potent) [1b]. Saponins **2** and **3**, isolated from the same plant as OSW-1, bearing the same aglycone also exhibited significantly different antitumor activities, i.e., saponin **2** showed strong antitumor activity against tumor cells (e.g., $IC_{50} = 3.2$ nM against human T-lymphocytic leukemia MOLT-4 cells), while saponin **3** showed little activity [2,3]. These results imply that the disaccharide moiety is essential to the antitumor activity of these compounds. Herein we have chemically attached the disaccharide moiety of OSW-1 or

[1] *Corresponding author. Tel.: +86-21-64163300; fax: +86-21-64166128; e-mail: byu@pub.sioc.ac.cn

[2] *Corresponding author.

PII: S0008-6215(00)00225-1

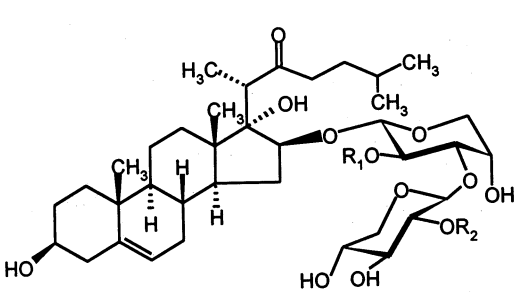


Scheme 1.

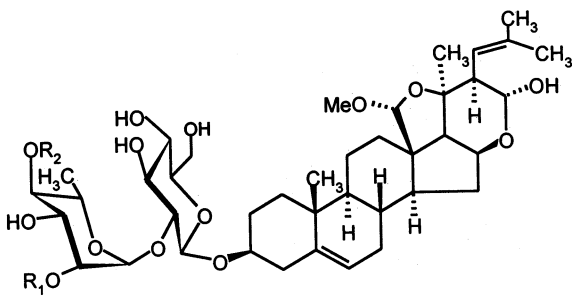
its 1→4-linked analogue to several readily accessible steroid aglycones or simple alcohols and have tested the antitumor activity of these glycosides.

preparation of trichloroacetimidate **7** was employed (Scheme 2). Surprisingly, glycosylation of diol **10**, which is readily prepared from L-arabinose, with trichloroacetimidate **4** gave a reversed regioselectivity: the 1→3 coupling product **12** was obtained in 20% yield and the 1→4 coupling product **11** in 80% yield. The classification of the coupling position was confirmed by comparison of the 'acylation shift' of **11** with its acetylation product **13**, and **12** with its acetylation product **14**, i.e., the chemical shift of ara-H-3 (dd, *J* 5.2, 3.4 Hz) for **13** was found to be downshifted to 5.14 ppm; the chemical shift of ara-H-4 (m) for **14** was downshifted to 5.17 ppm.

Glycosylation of cholesterol (**20**) and diosgenin (**17**) with 1→4-linked thio-disaccharide **15** and the glycosylation of diosgenin with 1→3-linked thio-disaccharide **16** under the promotion of NIS/AgOTf gave the corresponding glycosides (**24**–**26**) in moderate



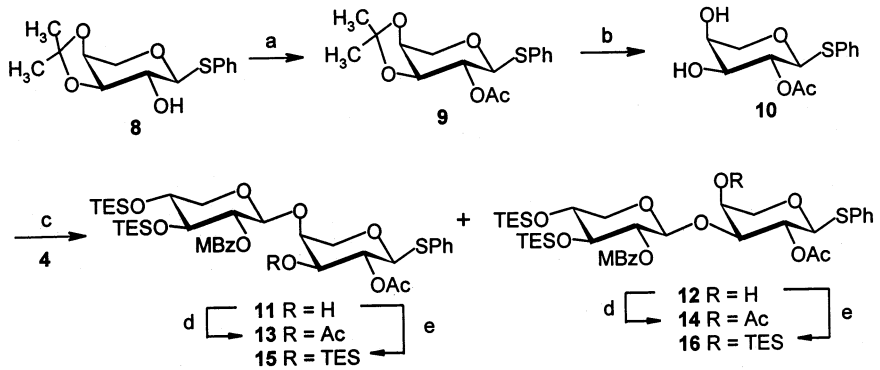
1: $R_1 = R_2 = H$
OSW-1: R_1 = Ac, R_2 = MBz



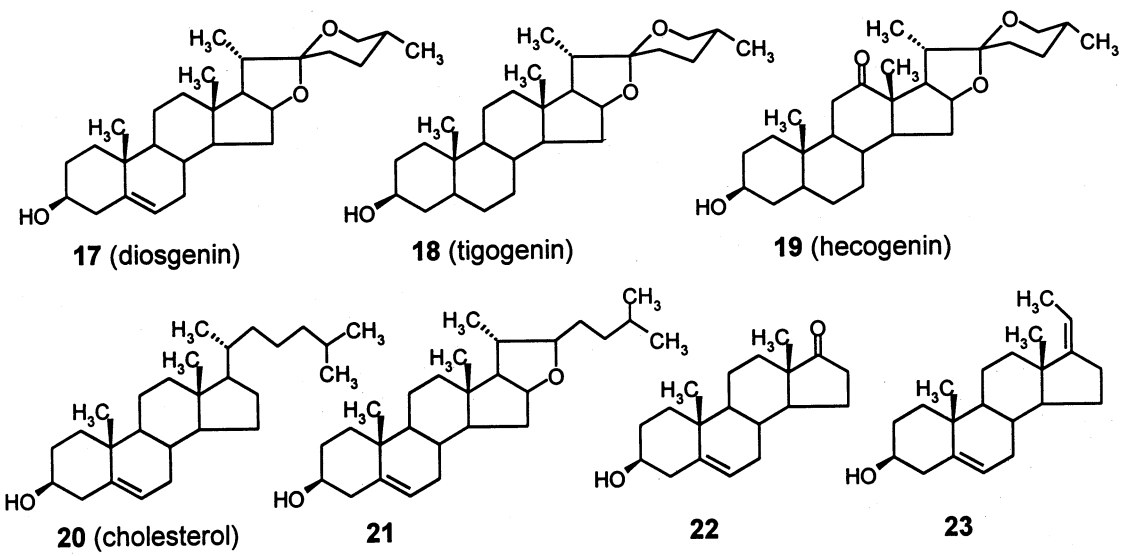
2: $R_1 = H$, R_2 = MBz
3: R_1 = α-L-Rhamnose, $R_2 = H$

2. Results and discussion

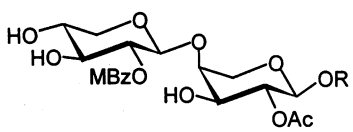
We recently accomplished the first total synthesis of OSW-1 [4]. In the synthetic route to OSW-1, the disaccharide moiety was attached to the aglycone by a glycosylation reaction using disaccharide trichloroacetimidate **7** as a donor. Trichloroacetimidate **7** was prepared by a regioselective glycosylation of diol **5** with imidate donor **4** (1→3 coupling product (**6**):1→4 coupling product = 7:2), followed by protecting group transformations (Scheme 1). Because trichloroacetimidate **7** was moderately stable, herein we attempted to prepare the corresponding thiodisaccharide **16** as a glycosyl donor. A similar approach to the yields (40–50%) (Table 1, entries 1–3). Therefore, we again used disaccharide trichloroacetimidate **7** in the glycosylation reaction of readily accessible steroids and simple alcohol (nonaol), giving the corresponding glycosides in good to high yields (54–86%) (Table 1, entries 4–11). Removal of the TES protecting groups on the disaccharide moieties was carried out using either a catalytic amount of $Pd(MeCN)Cl_2$ (in good yields, entries 1 and 2) or 70% AcOH (in excellent yields, entries 3–13), giving the target glycosides **34**–**45**. The acetyl (Ac) and the 4-methoxybenzoyl (MBz) groups on the disaccharide moiety were found to be intact by ^1H and ^{13}C NMR spectroscopy.



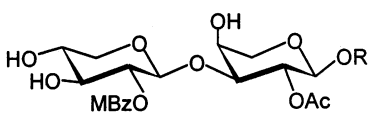
Scheme 2. Reagents and conditions: (a) Ac_2O, pyridine, rt, 74%; (b) 70% AcOH, 70 °C, 98%; (c) Me_3SiOTf, 4 Å MS, CH_2Cl_2, −20 °C, 80% (for **11**), 20% (for **12**); (d) Ac_2O, pyridine, rt, 100%; (e) TESCl, imidazole, DMAP, DMF, rt, 100%.



The in vitro antitumor activities of the resulting glycosides **34**–**45** against P388 (mouse leukemia) and A-549 (human pulmonary adenocarcinoma) were evaluated. The results are listed in Table 2. The diosgenyl glycoside **36** showed the strongest activities, with 51.9% inhibition against P388 and 61.3% inhibition against A-549 at 10^{-5} M. However, it lost its activity at 10^{-6} M. This activity is much less potent than that of OSW-1, which has been reported to have an IC_{50} around 10^{-4} μM [2b]. This result demonstrates that the aglycone is also essential to the antitumor activities of glycosides. Herein, the glycosides of cholesterol (**34** and **39**) and simple alcohols (nonaol, benzyl, and phenylthiol) (**43**, **44**, and **45**, respectively) were just inactive at 10^{-5} M.



34 R = (**20**)-3-yl; **35** R = (**17**)-3-yl



36 R = (**17**)-3-yl; **37** R = (**18**)-3-yl
38 R = (**19**)-3-yl; **39** R = (**20**)-3-yl
40 R = (**21**)-3-yl; **41** R = (**22**)-3-yl
42 R = (**23**)-3-yl; **43** R = nonayl
44 R = benzyl; **45** phenyl 1-thio-

Table 1
Synthesis of the final glycosides

$$\text{Donor} + \text{acceptor} \xrightarrow[\text{A or B}]{\text{conditions}} \text{protected glycosides} \xrightarrow[\text{C or D}]{\text{conditions}} \text{glycosides}$$

Entry	Donor	Acceptor	Coupling conditions [a]	Protected glycoside (Yield %) [c]	Deprotection conditions [b]	Deprotected product (Yield %) [c]
1	**15**	**20**	A	**24** (40)	C	**34** (80)
2		**17**		**25** (50)		**35** (79)
3	**16**			**26** (50)	D	**36** (97)
4	**7**		B	**26** (80)		
5		**18**		**27** (71)		**37** (88)
6		**19**		**28** (86)		**38** (98)
7		**20**		**29** (85)		**39** (92)
8		**21**		**30** (64)		**40** (91)
9		**22**		**31** (54)		**41** (89)
10		**23**		**32** (69)		**42** (89)
11		nonaol		**33** (71)		**43** (97)
12				**6**		**44** (93)
13				**16**		**45** (94)

[a] Conditions A: donor (1.0 equiv), acceptor (1.0 equiv), NIS (1.2 equiv)/AgOTf (0.4 equiv), CH_2Cl_2, −20 °C. Conditions B: donor (1.2 equiv), acceptor (1.0 equiv), Me_3SiOTf (0.02 equiv), CH_2Cl_2, −20 °C.
[b] Conditions C: $Pd(MeCN)Cl_2$ (cat.), 20:1 acetone–water, rt. Conditions D: 70% AcOH, 65 °C.
[c] Isolated yields.

Table 2
Inhibition ratio (%) of glycosides **34**–**45** on tumor cells (P388 and A-549) [a]

Compound	P388			A-549		
	10^{-4} M	10^{-5} M	10^{-6} M	10^{-4} M	10^{-5} M	10^{-6} M
34	39.4	1.8	1.9	43.6	0.0	0.0
35	100.0	20.9	11.9	98.6	8.6	0.0
36	100.0	51.9	16.6	98.6	61.3	1.6
37	68.7	13.9	9.7	97.9	0.0	0.0
38	51.0	10.9	4.7	98.7	0.0	9.9
39	38.9	6.2	4.8	15.1	17.2	0.0
40	80.4	6.8	7.7	98.7	0.0	0.0
41	60.5	16.3	11.6	96.2	2.4	10.9
42	85.4	36.1	6.5	98.2	20.7	0.0
43	85.6	6.2	4.3	97.9	0.2	0.0
44	44.9	6.5	5.4	8.2	0.0	0.0
45	54.1	6.2	2.4	25.5	2.7	7.3

[a] Detected by the standard MTT method (Ref. [5]).

3. Experimental

General methods — see Ref. [6].

*Phenyl 2-*O*-acetyl-3,4-*O*-isopylidene-1-thio-α-*L*-arabinopyranoside* (**9**). A solution of phenyl 3,4-*O*-isopylidene-1-thio-α-L-arabinopyranoside (**8**) [7] (500 mg, 1.8 mmol) in pyridine (6 mL) and Ac_2O (4 mL) was stirred at rt overnight. The solvent was removed in vacuo. The residue was purified by silica gel column chromatography (4:1 petroleum ether–EtOAc) to give **9** (425 mg, 74%) as a colorless syrup: R_f 0.60 (9:2 petroleum ether–EtOAc); $[\alpha]_D^{21}$ −17.7° (*c* 0.65, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.50–7.25 (m, 5 H), 5.15 (dd, 1 H, *J* 7.4, 6.0 Hz), 4.89 (d, 1 H, *J* 7.1 Hz),

4.23–4.34 (m, 2 H), 4.18 (d, 1 H, *J* 5.5 Hz), 3.80 (dd, 1 H, *J* 12.6, 4.0 Hz), 2.12 (s, 3 H), 1.57 (s, 3 H), 1.36 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 169.5, 134.1, 131.8, 128.9, 127.6, 110.6, 110.5, 85.8, 75.5, 72.0, 71.2, 64.0, 27.7, 26.3, 21.0. EIMS (*m*/*z*): 325 [M + 1], 181, 109, 91 (base), 77. Anal. Calcd for $C_{16}H_{20}O_5S$: C, 29.27; H, 6.17. Found: C, 29.76; H, 6.50.

*Phenyl 2-*O*-acetyl-1-thio-α-*L*-arabinopyranoside* (**10**). A solution of **9** (346 mg, 1.1 mmol) in AcOH (1.4 mL) and water (0.6 mL) was stirred at 70 °C for 1 h. The solvent was then removed in vacuo. The residue was purified by silica gel column chromatography (1:1 petroleum ether–EtOAc) to give **10** (297 mg, 98%) as a white solid: R_f 0.28 (1:1 petroleum ether–EtOAc); mp 124 °C; $[\alpha]_D^{21}$ +2.4° (*c* 2.01, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.57–7.25 (m, 5 H), 5.03 (t, 1 H, *J* 7.7 Hz), 4.75 (d, 1 H, *J* 8.0 Hz), 4.16 (dd, 1 H, *J* 12.1, 3.8 Hz), 3.99 (m, 1 H), 3.77 (m, 1 H), 3.61 (dd, 1 H, *J* 12.4, 1.7 Hz), 2.15 (s, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$): 170.8, 134.1, 132.3, 129.0, 127.9, 86.1, 72.1, 67.9, 67.4, 21.0. EIMS (*m*/*z*): 285 [M + 1], 175, 157, 109, 97. Anal. Calcd for $C_{13}H_{16}O_5S$: C, 54.92; H, 5.63. Found: C, 54.80; H, 5.63.

*Phenyl 2-*O*-(4-methoxybenzoyl)-3,4-di-*O*-triethylsilyl-β-*D*-xylopyranosyl-(1→4)-2-*O*-acetyl-1-thio-α-*L*-arabinopyranoside* (**11**) *and phenyl 2-*O*-(4-methoxybenzoyl)-3,4-di-*O*-triethylsilyl-β-*D*-xylopyranosyl-(1→3)-2-*O*-acetyl-1-thio-α-*L*-arabinopyranoside* (**12**). A suspension of imidate **4** (73 mg, 0.11 mmol), diol **10** (29 mg, 0.10 mmol), and 4 Å MS (50 mg) in dry CH_2Cl_2 (6 mL) was stirred at rt for 20 min and then cooled to −78 °C. To the above mixture, a solution of $BF_3{\cdot}OEt_2$ in dry CH_2Cl_2 (0.03 M, 0.02 mL) was added. After stirring for 40 min, the reaction was quenched with Et_3N (two drops) and filtered. The filtrates were concd in vacuo. The residue was purified by silica gel column chromatography (10:1–6:1 petroleum ether–EtOAc) to give **11** (63 mg, 80%) as a pale-yellow amorphous solid and **12** (16 mg, 20%) as a colorless syrup. **11**: R_f 0.32 (4:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ −31.4° (*c* 1.93, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.06 (d, 2 H, *J* 9.2 Hz), 6.94 (d, 2 H, *J* 9.2 Hz), 7.50–7.20 (m, 5 H), 5.09 (t, 1 H, *J* 5.5 Hz), 5.00 (t, 1 H, *J* 7.4 Hz), 4.90 (d, 1 H, *J* 5.2 Hz), 4.65 (d, 1 H, *J* 6.1 Hz), 4.30 (dd, 1 H, *J* 12.0, 6.7 Hz), 4.03 (dd, 1 H, *J* 11.8, 4.3 Hz), 3.93 (m, 1 H), 3.88 (s, 3 H), 3.83–3.65 (m, 3 H), 3.60 (dd, 1 H, *J* 12.0, 3.3 Hz), 3.29 (dd, 1 H, *J* 11.8, 7.9 Hz), 2.07 (s, 3 H), 0.92 (m, 18 H), 0.58 (m, 12 H). EIMS (*m*/*z*): 719, 757, 362, 237, 135 (base). Anal. Calcd for $C_{38}H_{58}O_{11}SSi_2$: C, 58.58; H, 7.50. Found: C, 58.84; H, 7.60. **12**: R_f 0.26 (4:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ −37.1° (*c* 0.39, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.08 (d, 2 H, *J* 8.8 Hz), 6.93 (d, 2 H, *J* 8.8 Hz), 7.50–7.20 (m, 5 H), 5.80 (t, 1 H, *J* 5.6 Hz), 5.09 (t, 1 H, *J* 5.3 Hz), 5.00 (d, 1 H, *J* 6.4 Hz), 4.84 (d, 1 H, *J* 5.5 Hz), 4.30 (dd, 1 H, *J* 12.0, 6.7 Hz), 4.15–4.00 (m, 2 H), 3.85 (s, 3 H), 3.80–3.65 (m, 3 H), 3.62 (dd, 1 H, *J* 12.0, 3.3 Hz), 3.35 (dd, 1 H, *J* 11.8, 7.3 Hz), 2.06 (s, 3 H), 0.94 (dt, 18 H, *J* 7.6 Hz), 0.58 (dq, 12 H, *J* 7.6 Hz). EIMS (*m*/*z*): 750, 719, 670, 597, 495, 362. Anal. Calcd for $C_{38}H_{58}O_{11}SSi_2{\cdot}0.8\ H_2O$: C, 57.52; H, 7.57. Found: C, 57.48; H, 7.41.

*Phenyl 2-*O*-(4-methoxybenzoyl)-3,4-di-*O*-triethylsilyl-β-*D*-xylopyranosyl-(1→4)-2-*O*-acetyl-1-thio-3-*O*-triethylsilyl-α-*L*-arabinopyranoside* (**15**) *and phenyl 2-*O*-(4-methoxybenzoyl)-3,4-di-*O*-triethylsilyl-β-*D*-xylopyranosyl-(1→3)-2-*O*-acetyl-1-thio-4-*O*-triethylsilyl-α-*L*-arabinopyranoside* (**16**). A mixture of **11** and **12** (770 mg, 1.0 mmol), chlorotriethylsilane (0.25 mL, 1.5 mmol), imidazole (600 mg) and DMAP (26 mg) in DMF (10 mL) was stirred at rt for 1 h. The solution was then diluted with EtOAc (50 mL) and washed with satd $NaHCO_3$ and brine. The organic layer was dried over $MgSO_4$ and then concd in vacuo. The residue was purified by silica gel column chromatography (14:1–10:1 petroleum ether–EtOAc) to give **15** (710 mg, 80%) as a pale-yellow amorphous solid and **16** (180 mg, 20%) as a colorless syrup. Data for **15**: R_f 0.60 (10:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ −62.1° (*c* 0.43, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.04 (d, 2 H, *J* 7.1 Hz), 6.93 (d, 2 H, *J* 7.1 Hz), 7.47–7.17 (m, 5 H), 5.12–4.95 (m, 3 H), 4.73 (d, 1 H, *J* 5.8 Hz), 4.39 (t, 1 H, *J* 10.0 Hz), 4.02 (dd, 1 H, *J* 11.7, 4.0 Hz), 3.88 (s, 3 H), 3.75 (dd, 1 H, *J* 12.4, 6.8 Hz), 3.70–3.62 (m, 2 H), 3.30 (dd, 1 H, *J* 11.7, 7.6 Hz), 2.03 (s, 3 H), 0.92 (m, 27 H), 0.63 (m, 18 H). EIMS

(m/z): 875, 717, 652, 571, 495, 362, 135 (base). Anal. Calcd for $C_{44}H_{72}O_{11}SSi_3$: C, 59.16; H, 8.12. Found: C, 59.00; H, 8.40. Data for **16**: R_f 0.51 (10:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ −56.6° (c 0.53, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.03 (d, 2 H, J 7.1 Hz), 6.90 (d, 2 H, J 7.1 Hz), 7.60–7.10 (m, 5 H), 5.20 (dd, 1 H, J 5.6, 4.1 Hz), 5.08 (t, 1 H, J 5.8 Hz), 4.96 (brs, 1 H), 4.81 (d, 1 H, J 5.0 Hz), 4.22 (dd, 1 H, J 5.7, 3.6 Hz), 4.25–4.10 (m, 1 H), 4.06 (m, 1 H), 3.88 (m, 1 H), 3.85 (s, 3 H), 3.81 (t, 1 H, J 6.3 Hz), 3.66 (dt, 1 H, J 10.0, 6.4, 3.6 Hz), 3.47 (dd, 1 H, J 11.0, 3.1 Hz), 3.26 (dd, 1 H, J 11.5, 6.5 Hz), 1.97 (s, 3 H), 0.96 (m, 27 H), 0.61 (m, 18 H). EIMS (m/z): 579, 495, 362, 237, 135 (base). Anal. Calcd for $C_{44}H_{72}O_{11}SSi_3$: C, 59.16; H, 8.12. Found: C, 59.38; H, 8.50.

*Typical procedure for glycosylation with thio-disaccharide donors **15** and **16** (conditions A).* A suspension of **16** (48 mg, 0.053 mmol), diosgenin **17** (22 mg, 0.053 mmol), and 4 Å MS (200 mg) in dry CH_2Cl_2 (4 mL) was stirred at rt for 20 min and then cooled to −20 °C. NIS (14 mg, 0.062 mmol) was added to the above mixture, followed by a solution of AgOTf (6 mg, 0.023 mmol) in dry toluene (0.7 mL). After stirring for a further 30 min, the reaction was quenched with Et_3N (two drops) and filtered. The filtrates were concd in vacuo. The residue was purified by silica gel column chromatography (10:1–6:1 petroleum ether–EtOAc) to give **26** (31 mg, 50%) as a white foam.

Cholesterol-3-yl 2-O-(4-methoxybenzoyl)-3,4-di-O-triethylsilyl-β-D-xylopyranosyl-(1→4)-2-O-acetyl-3-O-triethylsilyl-α-L-arabinopyranoside (**24**): A white foam (25 mg, 40%); R_f 0.80 (10:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ −8.9° (c 0.41, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.03 (d, 2 H, J 8.8 Hz), 6.91 (d, 2 H, J 8.8 Hz), 5.30 (m, 1 H), 4.97 (dd, 1 H, J 12.2, 6.6 Hz), 4.79 (m, 1 H), 4.42 (m, 1 H), 4.33 (d, 1 H, J 5.5 Hz), 4.10–4.00 (m, 2 H), 4.00–3.92 (m, 1 H), 3.90 (m, 1 H), 3.87 (s, 3 H), 3.80–3.63 (m, 3 H), 3.45 (m, 1 H), 3.25 (m, 1 H), 2.00 (s, 3 H). ESIMS (m/z): 1193 [M + Na$^+$].

Diosgenin-3-yl 2-O-(4-methoxybenzoyl)-3,4-di-O-triethylsilyl-β-D-xylopyranosyl-(1→4)-2-O-acetyl-3-O-triethylsilyl-α-L-arabinopyranoside (**25**): A white foam (32 mg, 50%); R_f 0.48 (10:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ −52.4° (c 0.66, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.03 (d, 2 H, J 8.8 Hz), 6.92 (d, 2 H, J 8.8 Hz), 5.32 (d, 1 H), 5.03 (t, 1 H, J 7.3 Hz), 4.61 (dd, 1 H, J 8.4, 3.3 Hz), 4.45 (d, 1 H, J 6.9 Hz), 4.40 (q, 1 H, J 7.3 Hz), 4.34 (d, 1 H, J 6.6 Hz), 4.05 (dd, 1 H, J 11.8, 4.9 Hz), 4.00–3.90 (m, 2 H), 3.88 (s, 3 H), 3.85–3.75 (m, 3 H), 3.55–3.33 (m, 4 H), 3.20 (m, 1 H), 1.62 (s, 3 H), 1.02–0.70 (m, 39 H), 0.70–0.40 (m, 18 H). ESIMS (m/z): 1220 [M + Na$^+$].

Diosgenin-3-yl 2-O-(4-methoxybenzoyl)-3,4-di-O-triethylsilyl-β-D-xylopyranosyl-(1→3)-2-O-acetyl-3-O-triethylsilyl-α-L-arabinopyranoside (**26**): R_f 0.64 (10:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ −38.7° (c 3.88, $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.97 (d, 2 H, J 8.8 Hz), 6.89 (d, 2 H, J 8.8 Hz), 5.25 (m, 1 H), 4.96 (dd, 2 H, J 7.4, 6.6 Hz), 4.67 (d, 1 H, J 6.6 Hz), 4.38 (t, 1 H, J 7.2 Hz), 4.34 (d, 1 H, J 5.8 Hz), 3.99 (m, 2 H), 3.84 (s, 3 H), 3.80–3.62 (m, 3 H), 3.50–3.28 (m, 5 H), 3.20 (dd, 1 H, J 11.5, 8.5 Hz), 1.86 (s, 3 H). ^{13}C NMR (300 MHz, $CDCl_3$): 168.9, 164.5, 163.2, 140.9, 131.9, 123.0, 121.3, 113.3, 109.3, 101.5, 99.1, 80.8, 78.2, 76.6, 75.2, 73.6, 71.6, 68.8, 66.8, 65.3, 62.1, 56.5, 55.3, 50.1, 41.6, 40.2, 39.8, 38.6, 37.3, 36.9, 32.1, 31.8, 31.4, 30.3, 29.3, 28.8, 20.8, 19.4, 17.1, 16.2, 14.5, 6.8, 5.1, 5.0, 4.8. ESIMS (m/z): 1220 [M + Na$^+$]. Anal. Calcd for $C_{65}H_{108}O_{14}Si_3$: C, 65.18; H, 9.09. Found: C, 65.18; H, 8.92.

*Typical procedure for glycosylation with trichloroacetimidate donor **7** (conditions B).* A solution of **7** (87 mg, 0.09 mmol), hecogenin **19** (32 mg, 0.074 mmol), and 4 Å MS (200 mg) in dry CH_2Cl_2 (3 mL) was stirred at rt for 20 min, and then cooled to −20 °C. To the above mixture, a solution of Me_3SiOTf (0.015 M, 0.2 mL) in CH_2Cl_2 was added. After stirring for another 30 min, the reaction was quenched with Et_3N and filtered. The filtrates were concd in vacuo to give a residue, which was purified by silica gel column chromatography (10:1–6:1 petroleum ether–EtOAc) to give **28** (78 mg, 86%) as a white foam.

Tigogenin-3-yl 2-O-(4-methoxybenzoyl)-3,4-di-O-triethylsilyl-β-D-xylopyranosyl-(1→3)-2-O-acetyl-3-O-triethylsilyl-α-L-arabinopyranoside (**27**): A white foam (62 mg, 71%); R_f 0.80 (8:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$

−5.2° (*c* 0.82, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.94 (d, 2 H, *J* 8.8 Hz), 6.92 (d, 2 H, *J* 8.8 Hz), 4.95 (dd, 2 H, *J* 12.1, 6.6 Hz), 4.66 (d, 1 H, *J* 6.4 Hz), 4.35 (d, 1 H, *J* 5.5 Hz), 4.42–4.18 (m, 1 H), 4.06 (t, 1 H, *J* 5.7 Hz), 3.97 (m, 2 H), 3.84 (s, 3 H), 3.66 (m, 3 H), 3.48–3.28 (m, 4 H), 3.18 (dd, 1 H, *J* 10.7, 8.0 Hz), 1.89 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 169.0, 164.5, 163.2, 131.9, 123.0, 113.3, 109.2, 101.5, 98.8, 80.8, 75.1, 73.5, 71.5, 68.8, 66.8, 65.2, 62.2, 56.3, 55.4, 54.4, 44.7, 41.6, 40.6, 40.0, 37.0, 35.7, 35.1, 34.3, 23.3, 31.8, 31.4, 30.3, 29.1, 28.8, 21.0, 20.9, 17.1, 16.5, 14.5, 12.3, 6.8, 5.0, 4.8. ESIMS (*m*/*z*): 1222 [M + Na^+].

*Hecogenin-3-yl 2-*O*-(4-methoxybenzoyl)-3,4-di-*O*-triethylsilyl-β-*D*-xylopyranosyl-(1→3)-2-*O*-acetyl-3-*O*-triethylsilyl-α-*L*-arabinopyranoside* (**28**): R_f 0.33 (10:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ +8.5° (*c* 0.56, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.95 (d, 2 H, *J* 8.8 Hz), 6.88 (d, 2 H, *J* 8.8 Hz), 4.93 (dd, 2 H, *J* 13.7, 6.6 Hz), 4.66 (d, 1 H, *J* 6.3 Hz), 4.34 (d, 1 H, *J* 5.5 Hz), 4.39–4.24 (m, 1 H), 4.19 (t, 1 H, *J* 5.0 Hz), 4.14–3.94 (m, 2 H), 3.84 (s, 3 H), 3.76–3.60 (m, 3 H), 3.50–3.26 (m, 4 H), 3.19 (dd, 1 H, *J* 10.4, 8.0 Hz), 1.86 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 213.5, 169.0, 164.5, 163.2, 131.9, 130.8, 128.8, 123.0, 113.3, 109.2, 101.3, 79.2, 74.9, 73.4, 71.4, 71.3, 68.5, 68.1, 66.9, 65.1, 55.8, 55.6, 55.3, 55.0, 53.5, 44.6, 42.2, 37.8, 36.5, 36.2, 34.3, 34.1, 31.6, 31.4, 31.1, 30.4, 30.2, 28.9, 28.8, 28.4, 23.8, 20.8, 17.1, 16.0, 14.0, 13.2, 11.8, 10.9, 6.8, 5.0, 4.8. ESIMS (*m*/*z*): 1214 [M + Na^+]. Anal. Calcd for $C_{65}H_{108}O_{15}Si_3$: C, 64.32; H, 8.97. Found: C, 64.74; H, 9.04.

*Cholesterol-3-yl 2-*O*-(4-methoxybenzoyl)-3,4-di-*O*-triethylsilyl-β-*D*-xylopyranosyl-(1→3)-2-*O*-acetyl-3-*O*-triethylsilyl-α-*L*-arabinopyranoside* (**29**): A white foam (58 mg, 67%); R_f 0.85 (10:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ −7.0° (*c* 3.43, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.97 (d, 2 H, *J* 8.8 Hz), 6.90 (d, 2 H, *J* 8.8 Hz), 5.26 (m, 1 H), 5.00 (m, 2 H), 4.69 (d, 1 H, *J* 6.4 Hz), 4.36 (d, 1 H, *J* 5.8 Hz), 4.10–3.55 (m, 5 H), 3.86 (s, 3 H), 3.48–3.25 (m, 2 H), 3.21 (dd, 1 H, *J* 11.3, 7.8 Hz), 1.88 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 69.0, 164.5, 163.2, 140.9, 131.9, 123.0, 121.5, 113.3, 101.5, 99.1, 78.3, 75.2, 73.6, 71.6, 71.4, 68.9, 65.3, 56.8, 56.2, 55.3, 50.2, 43.2, 39.8, 39.5, 38.7, 37.3, 36.7, 36.2, 35.8, 31.9, 29.7, 29.3, 28.2, 28.0, 24.3, 23.8, 22.8, 22.5, 21.0, 20.8, 19.3, 18.7, 11.8, 6.8, 5.0, 4.8. ESIMS (*m*/*z*): 1193 [M + Na^+]. Anal. Calcd for $C_{65}H_{112}O_{12}Si_3$: C, 66.73; H, 9.65. Found: C, 66.85; H, 9.88.

*26-Deoxydihydrodiosgenin-3-yl 2-*O*-(4-methoxybenzoyl)-3,4-di-*O*-triethylsilyl-β-*D*-xylopyranosyl-(1→3)-2-*O*-acetyl-3-*O*-triethylsilyl-α-*L*-arabinopyranoside* (**30**): A white foam (56 mg, 64%); R_f 0.75 (8:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ −19.7° (*c* 1.75, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.99 (d, 2 H, *J* 8.8 Hz), 6.90 (d, 2 H, *J* 8.8 Hz), 5.26 (m, 1 H), 4.98 (t, 2 H, *J* 7.4 Hz), 4.69 (d, 1 H, *J* 6.7 Hz), 4.52 (d, 1 H, *J* 6.8 Hz), 4.27 (m, 2 H), 3.91 (m, 2 H), 3.86 (s, 3 H), 3.81 (m, 1 H), 3.70 (m, 3 H), 3.38–3.23 (m, 3 H), 3.21 (dd, 1 H, *J* 11.4, 8.0 Hz), 1.88 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 169.0, 164.5, 163.2, 140.9, 131.9, 123.0, 121.3, 113.3, 101.5, 99.2, 90.5, 83.1, 78.1, 75.2, 73.6, 71.6, 71.3, 65.3, 57.0, 55.3, 50.2, 40.7, 39.5, 38.6, 37.9, 37.3, 36.9, 35.9, 32.3, 32.0, 31.6, 31.4, 29.7, 29.3, 28.3, 22.5, 22.4, 20.8, 20.6, 19.4, 19.0, 16.4, 6.8, 5.1, 5.0, 4.8.

*Dehydroisoandrosterone-3-yl 2-*O*-(4-methoxybenzoyl)-3,4-di-*O*-triethylsilyl-β-*D*-xylopyranosyl-(1→3)-2-*O*-acetyl-3-*O*-triethylsilyl-α-*L*-arabinopyranoside* (**31**): A white foam (43 mg, 54%); R_f 0.71 (10:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ +3.9° (*c* 1.82, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.98 (d, 2 H, *J* 8.5 Hz), 6.90 (d, 2 H, *J* 8.5 Hz), 5.26 (m, 1 H), 4.97 (t, 2 H, *J* 7.6 Hz), 4.72 (d, 1 H, *J* 5.1 Hz), 4.38 (d, 1 H, *J* 5.8 Hz), 4.00 (m, 2 H), 3.93–3.63 (m, 5 H), 3.83 (s, 3 H), 3.40–3.25 (m, 2 H), 3.22 (dd, 1 H, *J* 11.3, 7.9 Hz), 1.88 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 221.0, 169.0, 164.5, 163.2, 141.0, 131.8, 122.9, 120.8, 113.3, 101.4, 99.1, 78.1, 75.1, 73.6, 71.4, 71.2, 68.1, 65.2, 55.3, 51.8, 50.3, 47.5, 38.7, 37.2, 36.8, 35.8, 31.4, 30.8, 30.3, 29.3, 28.9, 23.7, 22.9, 21.8, 20.8, 20.3, 19.3, 14.0, 13.5, 10.9, 6.8, 5.0, 4.8. ESIMS (*m*/*z*): 1095 [M + Na^+]. Anal. Calcd for $C_{57}H_{94}O_{13}Si_3 \cdot 3.5\ H_2O$: C, 60.33; H, 8.97. Found: C, 60.27; H, 8.88.

*(Z)-5,17(20)-Pregnadiene-3-yl 2-*O*-(4-methoxybenzoyl)-3,4-di-*O*-triethylsilyl-β-*D*-xylopyranosyl-(1→3)-2-*O*-acetyl-3-*O*-triethylsilyl-*

α-L-*arabinopyranoside* (**32**): A white foam (55 mg, 69%); R_f 0.83 (9:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ −3.3° (*c* 0.85, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.96 (d, 2 H, *J* 8.8 Hz), 6.88 (d, 2 H, *J* 8.8 Hz), 5.27 (m, 1 H), 5.12 (q, 1 H, *J* 7.1 Hz), 4.96 (dd, 2 H, *J* 8.0, 6.4 Hz), 4.67 (d, 1 H, *J* 6.5 Hz), 4.34 (d, 1 H, *J* 5.8 Hz), 4.20 (dd, 2 H, *J* 5.8, 3.6 Hz), 3.97 (m, 2 H), 3.84 (s, 3 H), 3.67 (m, 2 H), 3.35 (m, 2 H), 3.20 (dd, 1 H, *J* 11.5, 8.2 Hz), 1.86 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 168.9, 164.5, 163.2, 150.2, 140.9, 131.9, 130.8, 128.8, 123.0, 121.4, 113.4, 101.5, 99.1, 78.3, 76.6, 75.1, 71.3, 68.8, 68.1, 65.3, 56.5, 55.3, 50.2, 40.0, 38.7, 37.2, 37.0, 36.8, 31.7, 31.4, 30.4, 29.3, 28.9, 24.4, 23.8, 23.0, 21.2, 20.8, 19.3, 16.6, 14.0, 13.1, 10.9, 6.8, 5.1, 4.8. ESIMS (*m*/*z*): 1106 $[M + Na^+]$. Anal. Calcd for $C_{59}H_{98}O_{12}Si_3$: C, 65.43; H, 9.11. Found: C, 65.99; H, 9.23.

*Nonayl 2-*O*-(4-methoxybenzoyl)-3,4-di-*O*-triethylsilyl-β-*D*-xylopyranosyl-(1→3)-2-*O*-acetyl-3-*O*-triethylsilyl-α-*L*-arabinopyranoside* (**33**): A white foam (48 mg, 71%); R_f 0.52 (8:1 petroleum ether–EtOAc). $[\alpha]_D^{21}$ −8.3° (*c* 2.85, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.96 (d, 2 H, *J* 9.1 Hz), 6.89 (d, 2 H, *J* 9.1 Hz), 5.01 (dd, 1 H, *J* 8.0, 6.0 Hz), 4.95 (dd, 1 H, *J* 7.1, 5.5 Hz), 4.67 (d, 1 H, *J* 6.6 Hz), 4.24 (d, 1 H, *J* 6.0 Hz), 3.98 (m, 2 H), 3.84 (s, 3 H), 3.80–3.54 (m, 5 H), 3.36 (dd, 1 H, *J* 11.8, 1.4 Hz), 3.32–3.20 (m, 1 H), 3.20 (dd, 1 H, *J* 11.5, 8.2 Hz), 1.83 (s, 3 H), 1.42 (m, 2 H), 1.35–1.10 (m, 12 H). ^{13}C NMR (75 MHz, $CDCl_3$): 168.9, 164.5, 163.2, 131.8, 123.0, 113.4, 101.3, 100.5, 75.0, 73.5, 71.5, 70.8, 68.9, 68.7, 65.2, 55.3, 31.8, 29.5, 29.3, 29.2, 25.8, 22.6, 20.7, 14.0, 6.8, 6.7, 5.1, 5.0, 4.8, 4.6, 4.4. ESIMS (*m*/*z*): 988 $[M + Na^+ + K^+]$, 950 $[M + Na^+]$.

Typical procedure for removal of TES protecting groups (conditions C). A solution of **25** (23 mg, 0.019 mmol) and $Pd(MeCN)_2Cl_2$ (2 mg) in acetone and water (1.5 mL, v/v, 20:1) was stirred at rt for 4 h. The solution was then concd in vacuo to give a residue that was purified by flash column chromatography (20:1 CH_2Cl_2–CH_3OH) to give **35** (13 mg, 79%) as a pale-yellow solid.

*Cholesterol-3-yl 2-*O*-(4-methoxybenzoyl)-β-*D*-xylopyranosyl-(1→4)-2-*O*-acetyl-α-*L*-arabinopyranoside* (**34**): A pale-yellow solid (13 mg, 80%); R_f 0.70 (20:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ −21.7° (*c* 1.54, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 8.01 (d, 2 H, *J* 8.8 Hz), 6.90 (d, 2 H, *J* 8.8 Hz), 5.31 (d, 1 H, *J* 3.7 Hz), 4.98 (dd, 1 H, *J* 7.2, 6.6 Hz), 4.84 (dd, 1 H, *J* 6.9, 4.7 Hz), 4.82 (d, 1 H, *J* 6.6 Hz), 4.46 (d, 1 H, *J* 4.7 Hz), 4.34–3.88 (m, 2 H), 3.92 (m, 1 H), 3.84 (s, 3 H), 3.82–3.70 (m, 3 H), 3.60–3.30 (m, 3 H), 2.05 (s, 3 H), 0.96 (s, 3 H), 0.89 (d, 3 H, *J* 6.6 Hz), 0.85 (d, 6 H, *J* 6.6 Hz), 0.65 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 170.1, 166.4, 163.9, 140.2, 132.0, 122.1, 113.8, 102.0, 101.6, 79.0, 78.5, 75.0, 73.7, 72.1, 69.9, 69.1, 66.7, 65.7, 64.2, 61.4, 56.7, 55.4, 50.1, 42.6, 39.7, 39.5, 38.7, 38.5, 37.2, 36.7, 36.2, 35.7, 31.9, 29.7, 29.4, 28.2, 28.0, 24.2, 23.8, 22.8, 22.5, 21.0, 20.6, 19.3, 18.7. ESIMS (*m*/*z*): 1674 $[2M + Na^+]$, 850 $[M + Na^+]$. Anal. Calcd for $C_{47}H_{70}O_{12}\cdot 0.5\ H_2O$: C, 67.52; H, 8.56. Found: C, 67.30; H, 8.60.

*Diosgenin-3-yl 2-*O*-(4-methoxybenzoyl)-β-*D*-xylopyranosyl-(1→4)-2-*O*-acetyl-α-*L*-arabinopyranoside* (**35**): A pale-yellow solid (13 mg, 79%); R_f 0.68 (20:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ −30.1° (*c* 0.86, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 8.05 (d, 2 H, *J* 8.8 Hz), 6.93 (d, 2 H, *J* 8.8 Hz), 5.34 (m, 1 H), 4.96 (dd, 1 H, *J* 6.1, 7.7 Hz), 4.84 (dd, 1 H, *J* 9.9, 3.0 Hz), 4.65 (d, 1 H, *J* 6.3 Hz), 4.40 (q, 1 H, *J* 7.1 Hz), 4.37 (d, 1 H, *J* 7.2 Hz), 4.16–4.00 (m, 3 H), 3.88 (s, 3 H), 3.80–3.72 (m, 3 H), 3.60–3.34 (m, 6 H), 1.88 (s, 3 H), 1.01 (s, 3 H), 0.97 (d, 3 H, *J* 6.9 Hz), 0.79 (d, 3 H, *J* 6.0 Hz), 0.78 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 170.9, 166.2, 163.9, 140.3, 132.1, 121.8, 113.8, 109.3, 101.9, 101.6, 80.8, 78.9, 74.8, 73.9, 73.7, 69.9, 69.1, 66.8, 65.7, 64.1, 62.1, 56.5, 55.5, 50.0, 41.6, 40.2, 39.7, 38.7, 36.8, 32.0, 31.8, 31.4, 30.3, 29.7, 29.5, 28.8, 20.9, 20.6, 19.3, 17.1, 16.2, 14.5. ESIMS (*m*/*z*): 1733 $[2M + Na^+]$, 878 $[M + Na^+]$. Anal. Calcd for $C_{47}H_{66}O_{14}\cdot 1.5\ H_2O$: C, 64.00; H, 7.82. Found: C, 63.94; H, 7.82.

Typical procedure for removal of TES protective groups (conditions D). A solution of protected glycosides **26** (47 mg, 0.04 mmol) in AcOH (1.4 mL) and water (0.6 mL) was warmed to 65 °C and stirred for 3 h, and the solvent was then removed in vacuo. The residue was purified by flash column chromatography (15:1 CH_2Cl_2–CH_3OH) to afford **36** (33 mg, 97%) as a white amorphous solid.

Diosgenin-3-yl 2-O-(4-methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-O-acetyl-α-L-arabinopyranoside (**36**): R_f 0.40 (15:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ −40.3° (*c* 2.80, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.95 (d, 2 H, *J* 8.8 Hz), 6.87 (d, 2 H, *J* 8.8 Hz), 5.23 (m, 1 H), 4.98 (m, 2 H), 4.68 (d, 1 H, *J* 6.6 Hz), 4.38 (d, 1 H, *J* 6.1 Hz), 4.10–4.03 (m, 1 H), 4.09 (dd, 1 H, *J* 11.8, 4.7 Hz), 3.99 (m, 1 H), 3.92 (dd, 1 H, *J* 12.3, 4.8 Hz), 3.82 (s, 3 H), 3.74 (dd, 2 H, *J* 8.7, 4.8 Hz), 3.48–3.28 (m, 5 H), 1.72 (s, 3 H), 0.95 (d, 3 H, *J* 6.9 Hz), 0.94 (s, 3 H), 0.77 (d, 3 H, *J* 8.0 Hz), 0.75 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 169.7, 165.9, 163.8, 140.6, 132.1, 121.7, 113.7, 109.3, 101.6, 98.4, 80.8, 79.6, 78.2, 74.3, 73.5, 70.7, 69.7, 66.8, 64.8, 63.5, 62.1, 56.5, 55.4, 50.0, 41.6, 40.2, 39.7, 38.5, 37.2, 36.8, 32.0, 31.8, 31.4, 30.3, 29.3, 28.8, 20.8, 20.5, 19.3, 17.1, 16.2, 14.5. ESIMS (*m*/*z*): 1733 [2M + Na^+], 878 [M + Na^+], 854 [M + 1]. Anal. Calcd for $C_{47}H_{66}O_{14}·H_2O$: C, 64.66; H, 7.85. Found: C, 64.44; H, 7.76.

Tigogenin-3-yl 2-O-(4-methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-O-acetyl-α-L-arabinopyranoside (**37**): A white amorphous solid (37 mg, 88%); R_f 0.31 (15:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ −50.8° (*c* 0.78, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.96 (d, 2 H, *J* 8.8 Hz), 6.83 (d, 2 H, *J* 8.8 Hz), 4.97 (dd, 2 H, *J* 13.8, 6.6 Hz), 4.70 (d, 1 H, *J* 6.3 Hz), 4.41 (d, 1 H, *J* 5.2 Hz), 4.36 (q, 1 H, *J* 7.5 Hz), 4.11 (dd, 1 H, *J* 11.2, 3.9 Hz), 3.97 (brs, 1 H), 3.91 (dd, 1 H, *J* 12.0, 5.0 Hz), 3.83 (s, 3 H), 3.86–3.67 (m, 3 H), 3.52–3.27 (m, 5 H), 1.75 (s, 3 H), 0.94 (d, 3 H, *J* 6.9 Hz), 0.80 (d, 3 H, *J* 7.0 Hz), 0.73 (s, 3 H), 0.68 (s, 3 H). ESIMS (*m*/*z*): 1734 [2M + Na^+], 880 [M + Na^+]. Anal. Calcd for $C_{47}H_{68}O_{14}·1.5\ H_2O$: C, 63.72; H, 8.03. Found: C, 63.42; H, 7.69.

Hecogenin-3-yl 2-O-(4-methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-O-acetyl-α-L-arabinopyranoside (**38**): A white amorphous solid (34 mg, 98%); R_f 0.44 (15:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ −25.5° (*c* 0.96, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.98 (d, 2 H, *J* 8.5 Hz), 6.88 (d, 2 H, *J* 8.5 Hz), 4.97 (m, 2 H), 4.72 (brs, 1 H), 4.43 (brs, 1 H), 4.30 (m, 1 H), 4.13 (m, 1 H), 3.96 (s, 1 H), 3.93–3.67 (m, 3 H), 3.84 (s, 3 H), 3.55–3.28 (m, 5 H), 2.49 (t, 1 H, *J* 7.1 Hz), 2.34 (t, 1 H), 2.16 (dd, 1 H, *J* 14.5, 4.7 Hz), 2.07 (t, 1 H, *J* 7.4 Hz), 1.77 (s, 3 H), 1.04 (d, 3 H, *J* 6.9 Hz), 1.03 (s, 3 H), 0.77 (d, 3 H, *J* 6.3 Hz), 0.76 (s, 3 H). ^{13}C NMR (300 MHz, $CDCl_3$): 213.5, 169.7, 166.0, 163.9, 132.2, 121.6, 113.8, 109.3, 101.3, 97.5, 79.3, 79.2, 74.2, 73.4, 70.7, 69.8, 66.9, 65.9, 64.5, 62.4, 55.8, 55.5, 55.1, 53.5, 44.5, 42.2, 37.7, 36.5, 36.2, 34.3, 33.9, 31.4, 31.1, 30.0, 28.8, 28.3, 20.6, 17.1, 16.0, 13.2, 11.8. ESIMS (*m*/*z*): 1763 [2M + Na^+], 894 [M + Na^+], 872 [M + 1]. Anal. Calcd for $C_{47}H_{66}O_{15}·1.5\ H_2O$: C, 62.86; H, 7.74. Found: C, 62.70; H, 7.54.

Cholesterol-3-yl 2-O-(4-methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-O-acetyl-α-L-arabinopyranoside (**39**): A white amorphous solid (30 mg, 92%); R_f 0.48 (15:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ −23.9° (*c* 0.66, $CHCl_3$). ^1H NMR (300 MHz, C_5D_5N): δ 8.27 (d, 2 H, *J* 8.8 Hz), 7.01 (d, 2 H, *J* 8.8 Hz), 5.83 (dd, 1 H, *J* 9.0, 7.4 Hz), 5.66 (dd, 1 H, *J* 9.1, 8.0 Hz), 5.36 (brs, 1 H), 5.14 (d, 1 H, *J* 8.0 Hz), 4.74 (d, 1 H, *J* 7.4 Hz), 4.46 (brs, 1 H), 4.20–4.00 (m, 5 H), 3.80–3.60 (m, 2 H), 3.68 (s, 3 H), 1.85 (s, 3 H), 0.94 (d, 3 H, *J* 6.0 Hz), 0.89 (s, 3 H), 0.87 (d, 3 H, *J* 6.6 Hz), 0.63 (s, 3 H). ^{13}C NMR (75 MHz, C_5D_5N): 169.0, 165.1, 163.4, 140.6, 132.0, 121.6, 113.7, 103.3, 100.5, 81.0, 78.5, 76.0, 74.9, 71.0, 70.6, 68.3, 66.8, 66.0, 56.5, 56.0, 55.1, 50.0, 42.1, 39.6, 39.4, 39.1, 37.1, 36.5, 36.1, 35.7, 31.8, 31.7, 29.8, 28.1, 27.9, 24.1, 23.8, 22.6, 22.3, 20.9, 20.3, 19.0, 18.7, 18.6, 11.6. ESIMS (*m*/*z*): 1673 [2M + Na^+], 847 [M + Na^+]. Anal. Calcd for $C_{47}H_{70}O_{12}·0.75\ H_2O$: C, 67.15; H, 8.57. Found: C, 67.15; H, 8.63.

26-Deoxydihydrodiosgenin-3-yl 2-O-(4-methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-O-acetyl-α-L-arabinopyranoside (**40**): A white amorphous solid (31 mg, 91%); R_f 0.28 (15:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ −29.9° (*c* 1.07, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.98 (d, 2 H, *J* 8.8 Hz), 6.86 (d, 2 H, *J* 8.8 Hz), 5.22 (brs, 1 H), 5.03–4.88 (m, 2 H), 4.73 (d, 1 H, *J* 6.6 Hz), 4.42 (d, 1 H, *J* 5.2 Hz), 4.28 (dd, 1 H, *J* 12.6, 7.4 Hz), 4.12 (dd, 1 H, *J* 11.6, 4.1 Hz), 3.97 (m, 1 H), 3.91 (dd, 1 H, *J* 12.1, 5.5 Hz), 3.84 (s, 3 H), 3.80–3.68 (m, 2 H), 3.50–3.20 (m, 5 H), 1.80 (s, 3 H), 0.98 (d, 3 H, *J* 6.6 Hz), 0.89 (s, 3 H), 0.86 (d, 6 H, *J* 6.6 Hz), 0.78 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 169.6, 166.0, 163.9, 140.6, 132.1, 121.4, 113.8, 101.3,

97.8, 90.5, 83.7, 79.3, 77.8, 74.2, 73.4, 70.7, 69.8, 66.2, 65.3, 64.5, 62.7, 56.9, 55.5, 50.1, 40.7, 39.4, 38.3, 37.9, 37.2, 36.8, 35.8, 32.3, 32.0, 31.6, 31.4, 29.7, 29.2, 28.2, 22.5, 22.4, 20.6, 19.3, 19.0, 16.4. ESIMS (*m*/*z*): 1704 [2M + Na^+], 880 [M + K^+], 864 [M + Na^+]. Anal. Calcd for $C_{47}H_{68}O_{13}\cdot 2\ H_2O$: C, 64.36; H, 8.27. Found: C, 64.19; H, 8.32.

Dehydroisoandrosterone-3-yl 2-O-(4-methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-O-acetyl-α-L-arabinopyranoside (**41**): A white amorphous solid (25 mg, 86%); R_f 0.91 (15:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ −11.6° (*c* 1.05, $CHCl_3$). ^1H NMR (300 MHz, C_5D_5N): δ 8.26 (d, 2 H, *J* 8.5 Hz), 7.00 (d, 2 H, *J* 8.5 Hz), 5.72 (dd, 1 H, *J* 8.8, 7.7 Hz), 5.65 (dd, 1 H, *J* 9.0, 8.0 Hz), 5.36 (m, 1 H), 5.13 (d, 1 H, *J* 7.7 Hz), 4.73 (d, 1 H, *J* 7.4 Hz), 4.47 (brs, 1 H), 4.32–4.20 (m, 3 H), 4.20–4.06 (m, 2 H), 3.80–3.56 (m, 3 H), 3.69 (s, 3 H), 1.85 (s, 3 H), 0.85 (s, 3 H), 0.74 (s, 3 H). ^{13}C NMR (75 MHz, C_5D_5N): 219.2, 169.0, 165.1, 163.4, 140.8, 132.0, 121.0, 113.7, 103.3, 100.4, 81.0, 78.3, 76.0, 74.9, 71.0, 70.5, 68.3, 66.8, 65.9, 55.1, 51.4, 50.1, 47.2, 39.1, 37.1, 36.7, 35.5, 31.2, 30.7, 29.7, 21.7, 20.4, 20.2, 19.0, 13.2. ESIMS (*m*/*z*): 1478 [2M + Na^+], 749 [M + Na^+], 728 [M + 1]. Anal. Calcd for $C_{39}H_{52}O_{31}\cdot 2\ H_2O$: C, 61.25; H, 7.37. Found: C, 61.41; H, 7.23.

(Z)-5,17(20)-Pregnadiene-3-yl 2-O-(4-methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-O-acetyl-α-L-arabinopyranoside (**42**): A white foam (26 mg, 89%); R_f 0.51 (20:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ −42.2° (*c* 2.01, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.96 (d, 2 H, *J* 8.8 Hz), 6.84 (d, 2 H, *J* 8.8 Hz), 5.25 (m, 1 H), 5.11 (q, 1 H, *J* 7.1 Hz), 4.99 (m, 2 H), 4.69 (d, 1 H, *J* 6.6 Hz), 4.39 (d, 1 H, *J* 5.8 Hz), 4.10 (dd, 1 H, *J* 11.5, 3.5 Hz), 4.00 (brs, 1 H), 3.92 (m, 1 H), 3.83 (s, 3 H), 3.86–3.66 (m, 3 H), 3.50–3.28 (m, 3 H), 1.70 (s, 3 H), 1.64 (d, 3 H, *J* 7.1 Hz), 0.89 (s, 3 H), 0.86 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 169.7, 165.9, 163.8, 150.2, 140.7, 132.2, 121.7, 121.5, 113.7, 113.3, 101.5, 98.3, 79.6, 78.2, 74.3, 73.5, 70.7, 69.7, 66.6, 64.7, 63.3, 56.5, 55.5, 50.2, 44.0, 38.5, 37.2, 37.0, 36.7, 31.7, 31.4, 29.3, 24.5, 21.2, 20.5, 19.3, 16.6, 13.1. ESIMS (*m*/*z*): 1505 [2M + Na^+], 764 [M + Na^+]. Anal. Calcd for $C_{41}H_{56}O_{12}\cdot 1.5\ H_2O$: C, 64.13; H, 7.74. Found: C, 64.26; H, 7.61.

Nonayl 2-O-(4-methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-O-acetyl-α-L-arabinopyranoside (**43**): A white amorphous solid (23 mg, 97%); R_f 0.27 (15:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ −10.1° (*c* 1.44, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.97 (d, 2 H, *J* 8.8 Hz), 6.86 (d, 2 H, *J* 8.8 Hz), 5.00 (q, 2 H), 4.66 (d, 1 H, *J* 6.6 Hz), 4.25 (d, 1 H, *J* 6.0 Hz), 4.14–3.88 (m, 3 H), 3.82 (s, 3 H), 3.80–3.66 (m, 2 H), 3.66–3.52 (m, 2 H), 3.45 (d, 1 H, *J* 10.7 Hz), 3.40–3.20 (m, 2 H), 1.65 (s, 3 H), 1.42–1.00 (m, 14 H), 0.85 (t, 3 H, *J* 6.9 Hz). ^{13}C NMR (75 MHz, $CDCl_3$): 169.7, 165.8, 163.7, 132.1, 121.7, 113.7, 101.6, 100.0, 79.6, 74.4, 73.5, 70.3, 69.6, 68.9, 66.9, 64.9, 63.8, 55.4, 31.8, 29.5, 29.3, 29.2, 25.8, 22.6, 20.4, 14.0. ESIMS (*m*/*z*): 1192 [2M + Na^+], 608 [M + Na^+]. Anal. Calcd for $C_{27}H_{44}O_{12}$: C, 59.57; H, 7.59. Found: C, 59.03; H, 7.78.

Benzyl 2-O-(4-methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-O-acetyl-α-L-arabinopyranoside (**44**): A white amorphous solid (21 mg, 93%); R_f 0.68 (15:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ +99.5° (*c* 1.70, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.89 (d, 2 H, *J* 8.8 Hz), 7.26 (m, 5 H), 6.82 (d, 2 H, *J* 8.8 Hz), 5.04 (dd, 1 H, *J* 9.9, 3.3 Hz), 4.98 (dd, 1 H, *J* 7.7, 6.3 Hz), 4.93 (d, 1 H, *J* 3.5 Hz), 4.65 (d, 1 H, *J* 7.7 Hz), 4.67 and 4.38 (AB, 2 H, *J* 12.0 Hz), 4.10 (brs, 1 H), 4.06–3.97 (m, 3 H), 3.90–3.64 (m, 4 H), 3.78 (s, 3 H), 3.29 (dd, 1 H, *J* 9.9, 11.3 Hz), 1.50 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 170.2, 165.9, 163.8, 137.3, 132.0, 128.3, 127.8, 127.7, 121.7, 113.7, 102.1, 95.9, 76.4, 74.7, 73.8, 69.7, 69.5, 68.9, 65.0, 61.9, 55.4, 20.1. ESIMS (*m*/*z*): 1668 [3M + Na^+], 1120 [2M + Na^+], 571 [M + Na^+], 560 [M + 1]. Anal. Calcd for $C_{27}H_{32}O_{12}\cdot 0.3\ H_2O$: C, 58.54; H, 5.93. Found: C, 58.49; H, 6.03.

Phenyl 2-O-(4-methoxybenzoyl)-β-D-xylopyranosyl-(1→3)-2-O-acetyl-1-thio-α-L-arabinopyranoside (**45**): A white amorphous solid (21 mg, 94%); R_f 0.54 (15:1 CH_2Cl_2–CH_3OH). $[\alpha]_D^{22}$ −48.8° (*c* 1.08, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.99 (d, 2 H, *J* 8.8 Hz), 7.50–7.20 (m, 5 H), 6.93 (d, 2 H, *J* 8.8 Hz), 5.05 (t, 1 H, *J* 6.8 Hz), 4.96 (dd, 1 H, *J* 7.6, 6.2 Hz), 4.83 (d, 2 H, *J* 6.2 Hz), 4.30 (dd, 1 H, *J* 12.1, 6.6 Hz), 4.14 (dd, 1 H, *J* 11.3, 3.7 Hz),

4.04 (m, 1 H), 3.88 (s, 3 H), 3.85–3.74 (m, 3 H), 3.63 (dd, 1 H, *J* 12.1, 1.8 Hz), 3.42 (dd, 1 H, *J* 11.3, 7.8 Hz), 2.10 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): 170.1, 166.3, 164.0, 134.2, 132.0, 131.8, 128.8, 127.5, 121.3, 113.9, 101.3, 85.9, 75.8, 73.8, 73.7, 72.0, 70.2, 69.6, 64.5, 64.3, 55.4, 20.9. ESIMS (*m*/*z*): 1672 [3M + Na^+], 1123 [2M + Na^+], 573 [M + Na^+]. Anal. Calcd for $C_{26}H_{30}O_{11}S{\cdot}0.8\ H_2O$: C, 5.27; H, 5.64. Found: C, 55.36; H, 5.62.

Acknowledgements

This work was supported by the Ministry of Science and Technology of China (G1998051104) and the National Natural Science Foundation of China (29925203). Steroid **21**, readily prepared from diosgenin, was a gift from Professor Weisheng Tian. See: Xiaowen Peng, Thesis, Shanghai Institute of Organic Chemistry, 1999.

References

[1] (a) S. Kubo, Y. Mimaki, M. Terao, Y. Sashida, T. Nikaido, T. Ohmoto, *Phytochemistry*, 31 (1992) 3969–3973. (b) Y. Mimaki, M. Kuroda, A. Kameyama, Y. Sashida, T. Hirano, K. Oka, R. Maekawa, T. Wada, K. Sugita, J.A. Beutler, *Bioorg. Med. Chem. Lett.*, 7 (1997) 633–636.

[2] Y. Mimaki, M. Kuroda, A. Kameyama, Y. Sashida, T. Hirano, K. Oka, A. Dobashi, K. Koike, T. Nikaido, *Bioorg. Med. Chem. Lett.*, 6 (1996) 2635–2638.

[3] M. Kuroda, Y. Mimaki, Y. Sashida, T. Nikaido, T. Ohmoto, *Tetrahedron Lett.*, 34 (1993) 6073–6076.

[4] S. Deng, B. Yu, Y. Lou, Y. Hui, *J. Org. Chem.*, 64 (1999) 202–208.

[5] T. Nakamura, C. Komori, Y. Lee, F. Hashimoto, S. Yahara, T. Nohara, A. Ejima, *Biol. Pharm. Bull.*, 19 (1996) 564–566.

[6] C. Li, B. Yu, M. Liu, Y. Hui, *Carbohydr. Res.*, 306 (1998) 189–195.

[7] K.C. Nicolaou, J.I. Trujillo, K. Chibale, *Tetrahedron*, 53 (1997) 8751–8778.