# First Total Synthesis of an Exceptionally Potent Antitumor Saponin, OSW-1

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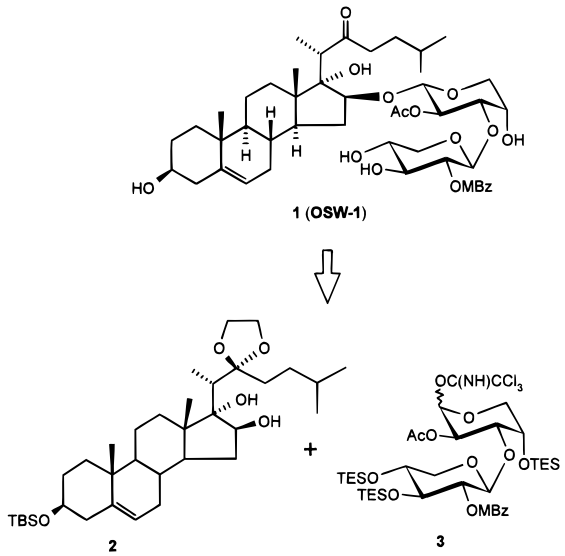
OSW-1 (**1**), an acylated disaccharide cholestane saponin from *Ornithogalum saudersiae* with exceptionally potent antitumor activity, was first synthesized from commercially available dehydroisoandrosterone, L-arabinose, and D-xylose in total 27 steps with the longest linear sequence of 14 steps and in 6% yield.

## Introduction

Saponins, a large family of glycoconjugates with formidably enormous structural diversity, have recently been attracting a surge of interest due to the increased understanding of their wide spectrum of biological and pharmacological activities.[1,2] Saponin OSW-1 (**1**),[3,4] namely 3$\beta$,16$\beta$,17$\alpha$-trihydroxycholest-5-en-22-one 16-*O*-{*O*-(2-*O*-(4-methoxybenzoyl)-$\beta$-D-xylopyranosyl)-(1→3)-2-*O*-acetyl-$\alpha$-arabinopyranoside}, is the major component of a small group of cholestane saponins isolated recently by Sashida et al. from the bulbs of *Ornithogalum saudersiae*,[3−5] a species of the lily family without any medicinal folkloric background. Tremendous attention has been given to this molecule since the report of its extraordinarily potent antitumor activities at the 210th National Meeting of the American Chemical Society (1995, Chicago, IL).[2] In vitro assays showed that OSW-1 was extremely toxic against 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, with $IC_{50}$ between 0.1 and 0.7 nM, which is about 10−100 times more potent than those of the clinically applied anticancer agents, such as mitomycin C, adriamycin, cisplatin, camptothecin, and taxol.[4] The cytotoxicity profile of OSW-1 is strikingly similar to that of cephalostatins, a group of dimeric steroid-pyrazines from marine organisms,[6] with Pearson correlation coefficients between 0.60 and 0.83,[4] while structurally, the aglycon of OSW-1 is reminiscent of half of the cephalostatins. Fuchs therefore hypothesized that they might have the same mechanism of action.[7] 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 $\mu$g/kg.[4] Thus, synthesis of this saponin was an attractive goal, and herein we report the first total synthesis of this molecule. It is worth noting that, very recently, Fuchs et al. have reported the first synthesis of the aglycone part of this molecule;[7] coincidentally, we adopted an essentially similar strategy for this part.

**Scheme 1. Retrosynthesis of OSW-1 (1)**




## Results and Discussion

Saponin OSW-1(**1**) was logically disconnected into two quite distinct parts, i.e., cholestane aglycone **2** and disaccharide moiety **3** (Scheme 1), which could be further envisioned to be derived from dehydroisoandrosterone, L-arabinose, and D-xylose. Judicious choice of protecting groups is of great importance for the syntheses of polyhydroxyl glycoconjugates; therefore, protecting groups (silyl groups for hydroxyls and ethylene glycol ketal for

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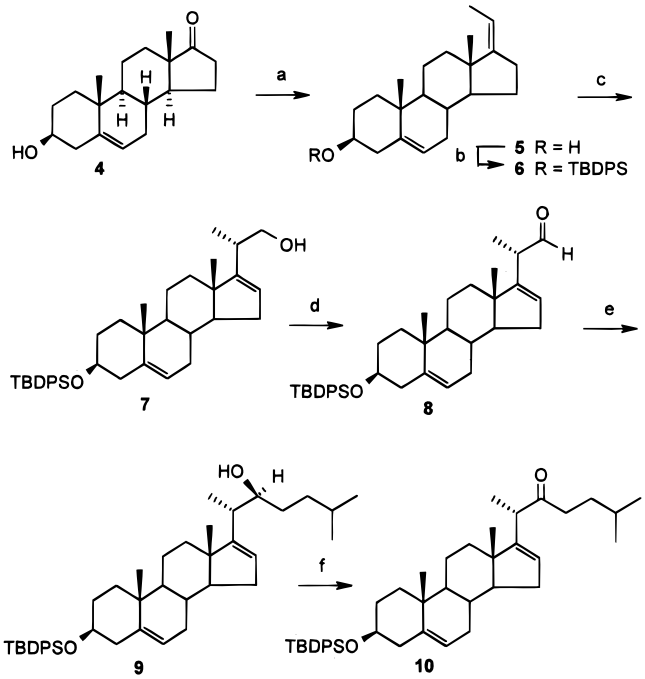
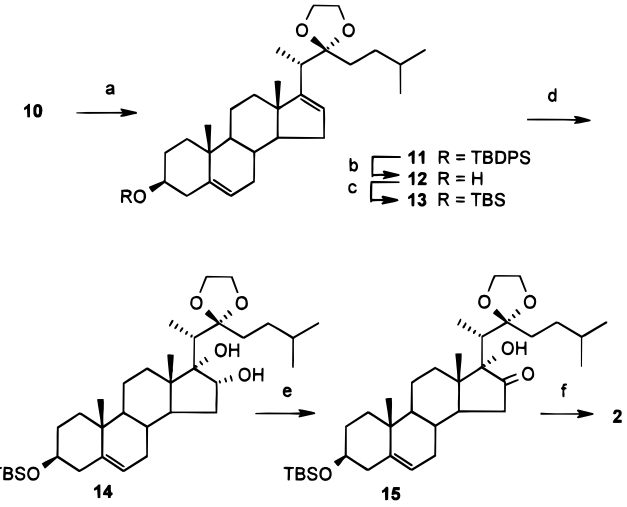
**Scheme 2. Installation of the C17 Side Chain**[a]




[a] Reagents and conditions: (a) $Ph_3PEtBr$, *tert*-BuOK, THF, reflux, 4 h, 78%; (b) TBDPSCl, imidazole, DMF, rt, overnight, 100%; (c) $(CH_2O)_n$, $BF_3{-}OEt_2$ (0.05 equiv), $CH_2Cl_2$, rt, 10 min, 75%; (d) Dess−Martin periodinane, $CH_2Cl_2$, rt, 3 h, 86%; (e) (3-methylbutyl)magnesium bromide, ether, rt, 1 h, 96%; (f) PDC, $CH_2Cl_2$, DMF, rt, overnight, 83%.

**Scheme 3. Synthesis of the Aglycone 2**[a]




[a] Reagents and conditions: (a) $HOCH_2CH_2OH$, $CH(OEt)_3$, $TsOH{\cdot}H_2O$ (cat.), $CH_2Cl_2$, rt, 4 days, 96%; (b) TBAF, THF, rt, 10 h, 95%; (c) TBSCl, imidazole, DMF, rt, overnight, 96%; (d) $OsO_4$ (1.2 equiv), Py, ether, −20 °C, 3 h, 41%; (e) ClCOCOCl, DMSO, $Et_3N$, $CH_2Cl_2$, −78 °C, 1 h, 78%; (f) $NaBH_4$, $CeCl_3{\cdot}7H_2O$, THF, 0 °C, 3 h, 93%.

keto) were selected to allow complete removal under neutral or near neutral conditions.

Cholestane aglycone **2** was synthesized starting from the industrial material dehydroisoandrosterone (**4**). On the basis of well-established vitamin D chemistry,[8] the installation of the C17 side chain was proven to be of little problem (Scheme 2). Wittig olefination of ketone **4** gave diene **5** stereoselectively,[9] and then the 3-OH of **5** was masked as its TBDPS (*tert*-butyldiphenylsilyl) ether to provide **6**, which underwent an ene reaction with paraformaldehyde in the presence of catalytic $BF_3{\cdot}OEt_2$ to generate the desired homoallylic alcohol **7** stereoselectively and in satisfactory yield (75%).[10] With the use of $BF_3{-}OEt_2$, the corresponding ene reaction did not happen between isoamyl-CHO and **6**, and a 3-OTBS (*tert*-butyldimethylsilyl) ether could not survive. Oxidation of alcohol **7** with Dess−Martin periodinane[11] provided aldehyde **8** smoothly and in good yield (86%), while under Swern conditions,[12] **8** was obtained in a mixture with another inseparable product, conceivably its C20 epimer. Grignard addition of aldehyde **8** with (3-methylbutyl)-magnesium bromide afforded the expected adduct in high yield (96%), based on its $^1H$ NMR spectrum, containing only one isomer (**9**). Grignard additions to the cholestane C22 aldehyde, where the formation of the Cram product, i.e., the 22α-epimer, predominates, have been well-precedented.[10b,13] Finally, the installation of the C17 side chain was completed by oxidation of alcohol **9** with PDC, providing C22-keto **10** in 83% yield.

With cholestane **10** at hand, the elaboration of the 16*β*,17α-diol proceeded successfully (Scheme 3). First, the C22 carbonyl of **10** was masked as an ethylene glycol ketal under very mild conditions (catalytic TsOH, $HC(OEt)_3$, and room temperature),[14] giving **11** slowly (4 days) and in high yield (96%). Then the 3-TBDPS ether of **11** was converted to the 3-TBS ether in two steps giving **13**, to avoid the possible problems associated with acyl group migration and cleavage in the final removal of the robust TBDPS ether under TBAF or HF/Py. At this stage, a model reaction was carried out by treatment of disaccharide moiety **29** with TBAF, which led to very complex mixtures of products. Finally, diene **13** was subjected to $OsO_4$ (1.2 equiv),[15] affording the corresponding 16α,17α-diol **14** in moderate yield (41%), accompanied by some more polar byproducts and starting material. In this step, the resulting osmates were highly inert to sodium bisulfite, a common agent used for cleavage of the osmates; therefore, hydrogen sulfide was used instead to quench the reaction.[15b] Treatment of **14** with DMSO/ClCOCOCl[12] conveniently afforded the desired C16 keto **15** in 78% yield, which was then reduced under $NaBH_4$/$CeCl_3$ to provide the required 16*β*-OH aglycone **2** exclusively.[7] Thus, we achieved the preparation of **2** in overall 12 steps and 10% yield from dehydroisoandrosterone (**4**).

The construction of the other part of the target, disaccharide moiety **3**, was carried out in a very concise and straightforward manner (Scheme 4, 5). The xylosyl

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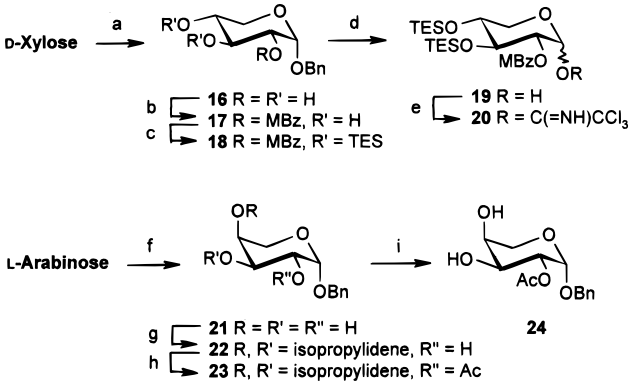
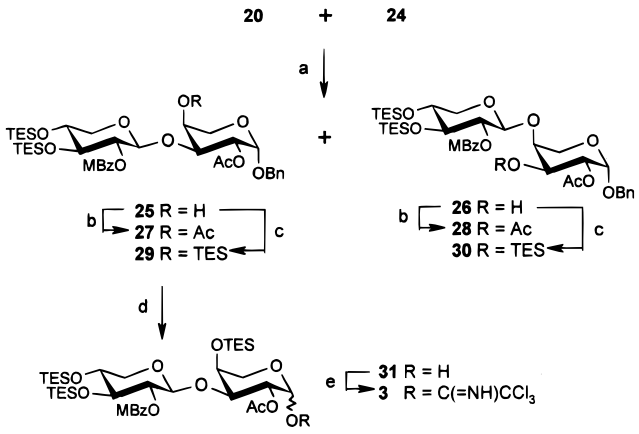
**Scheme 4. Synthesis of Two Monosaccharide Building Blocks**[a]




[a] Reagents and conditions: (a) BnOH, HCl (gas), rt, overnight; (b) MBzCl, Py, −35 °C to room temperature, overnight, 65%; (c) TESCl, imidazole, DMF, rt, 93%; (d) 10% Pd−C, $H_2$ (40 atm), EtOAc, 40 °C, 24 h, 76%; (e) $CCl_3CN$, DBU, $CH_2Cl_2$, rt, 3 h, 79%; (f) BnOH, HCl (gas), rt, overnight; (g) $Me_2C(OMe)_2$, TsOH·$H_2O$ (cat.), DMF, rt, 5 h; (h) $Ac_2O$, Py, rt, overnight, 72% (three steps); (i) 70% HOAc in $H_2O$, 70 °C, 1 h, 94%.

**Scheme 5. Synthesis of the Disaccharide Moiety 3**[a]




[a] Reagents and conditions: (a) $BF_3$−$OEt_2$ (0.05 equiv), 4 Å MS, $CH_2Cl_2$, −60 °C to −40 °C, 30 min, 100% (two isomers); (b) $Ac_2O$, Py, overnight; (c) TESOTf, lutidine, $CH_2Cl_2$, −20 °C, 1 h, 70% (for **29**), 21% (for **30**); (d) 10% Pd−C, $H_2$ (50 atm), EtOAc, 50 °C, 3 days, 50%; (e) $CCl_3CN$, DBU, $CH_2Cl_2$, rt, 6 h, 65%.

donor **20** was readily prepared from D-xylose in five steps as shown in Scheme 4. Therein, the 2-O-MBz (4-methoxybenzoyl) group was regioselectively introduced by treatment of triol **16** under MBzCl/Py, affording **17** in 65% yield.[16] The chemical shift for H-2 of **16** was 3.23 ppm, which was downshifted to 5.11 ppm for **17**.[17] Then, the diol of **17** was masked as the bis-TES ether to afford **18** in excellent yield (93%). The anomeric benzyl group of **18** was found to be rather resistant to hydrogenolysis; therefore, stronger conditions (10% Pd−C, 40 atm $H_2$, 40 °C, 24 h) were employed to generate the hemiacetal **19** (76% yield, 20% of **18** recovered), which was then converted[18] to the corresponding trichloroacetimidate **20**. Meanwhile, the arabinosyl acceptor **24** was readily prepared from L-arabinose in four steps and in 67% yield, i.e., benzylation of 1-OH, isopropylidenation of 3,4-OH, acetylation of 2-OH, and final removal of isopropylidene.

Although the arabinosyl acceptor **24** has two hydroxyl groups, a regioselective glycosylation with the xylosyl donor **20** was expected because it is well-known that the equatorial 3-OH is much more active than the axial 4-OH for a pyranoside.[19] Consequently, glycosylation of diol **24** with **20** under $BF_3$·$Et_2O$[20] catalysis gave the desired 1→3 linked disaccharide **25** as the major product, which could not be separated from its 1→4 linked isomer **26** through silica gel column chromatography on a large scale. The classification of the glycosylation position was readily confirmed by comparison of the "acylation shift"[17] of **25** with its acetylation product **27**, or **26** with its acetylation product **28**, i.e., the chemical shift of ara-H-4 for **25** was 4.02−4.06 ppm, which was found to be downshifted to 5.25 ppm after acetylation; the chemical shift of ara-3-H for **26** was 3.92 ppm, while that of **28** was 5.05−4.98 ppm. The mixture of **25** and **26**, without separation, was further subjected to TESOTf,[21] affording disaccharides **29** (70%) and **30** (21%), which were readily separable on a silica gel column (Scheme 5). In this step of transformation, the conditions previously used for converting diol **17** to its corresponding TES ether **18**; (TESCl, imidazole, DMF) led to no reaction. The following removal of the anomeric benzyl group of **29** was found to be even more difficult than in the case of **18**, under forcing conditions (10% Pd−C, 50 atm $H_2$, 50 °C, 3 days), the corresponding hemiacetal **31** was generated in 50% yield and 36% of **29** was recovered. Finally, treatment of **31** with $CCl_3CN$/DBU[18] provided the expected disaccharide donor **3** (65%), which was found to be very unstable and should be directly used in the next step.

Although the research in our group and others have shown that the glycosylation of a steroid acceptor, especially those with a stereo-hindered hydroxyl group, with a sugar donor which has a neighboring acetyl group was rather difficult,[22] glycosylation of the 16$\beta$,17$\alpha$-diol **2** with disaccharide imidate **3** proceeded smoothly under the promotion of TMSOTf[23] to provide the fully protected OSW-1 (**32**) in satisfactory yield (69%). Whereas this reaction has not happened under the promotion of $BF_3$·$Et_2O$. It was interestingly noted that both the xylosyl and arabinosyl moiety comformationally preferred the $^1C_4$ form, which was deduced from the small coupling constants between trans H-1 and H-2 of both sugars, i.e., $J_{1,2}$ (ara) < 1 Hz, and $J_{1,2}$ (xyl) ≈ 0.9 Hz.[24] The C22 ethylene glycol ketal of **32** was found to be easily cleaved during the course of NMR analysis under the action of the trace acid containing in $CDCl_3$. Finally, all of the

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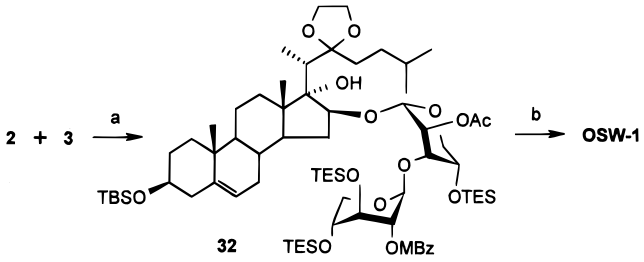
**Scheme 6. Assembly of the Target OSW-1 (1)**[a]




[a] Reagents and conditions: (a) TMSOTf (0.05 equiv), 4 Å MS, $CH_2Cl_2$, −20 °C, 45 min, 69%; (b) $Pd(MeCN)_2Cl_2$, acetone−water (v:v, 20:1), rt, overnight, 79%.

protecting groups (one TBS, three TES, and one ethylene glycol ketal) were removed smoothly and cleanly in a single step by employing $Pd(MeCN)_2Cl_2$ as a catalyst[25] to furnish the final target OSW-1 (**1**) in satisfactory yield (79%) (Scheme 6). The physical data obtained were absolutely identical to those reported by Sashida.[3]

In summary, the extraordinarily potent antitumor saponin OSW-1 (**1**) was constructed from commercially available dehydroisoandrosterone, L-arabinose, and D-xylose in total 27 steps, with the longest linear sequence being 14 steps, and in 6% yield.

## Experimental Section[26]

**(*Z*)-3$\beta$-(*tert*-Butyldiphenylsiloxy)-5,17(20)-pregnadiene (6).** To a suspension of $Ph_3PEtBr$ (35.65 g, 96.0 mmol) in THF (150 mL) was added a solution of *t*-BuOK (10.77 g, 96.0 mmol) in THF (80 mL) at room temperature. After the resulting orange suspension was stirred for 1 h, a solution of dehydroisoandrosterone (7.0 g, 24.3 mmol) was added, and the mixture was then refluxed for another 4 h. After being cooled to room temperature, the reaction was quenched with saturated $NH_4Cl$ solution and then extracted with EtOAc. The combined organic layer was washed with brine, dried over anhydrous $MgSO_4$, and concentrated in vacuo. The residue was purified by flash column chromatography (petroleum ether−EtOAc, 6:1 to 4:1) to afford **5** (5.62 g, 78%) as a white solid: $[\alpha]^{29}_D$ −68.83 (*c* 2.19 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 5.34 (1H, brd, *J* = 5.2), 5.12 (1H, tq, *J* = 2.1, 7.2), 3.51 (1H, m), 1.65 (3H, dt), 1.01 (3H, s), 0.88 (3H, s); EIMS *m*/*z* 301, 300.

A mixture of **5** (2.26 g, 7.51 mmol), TBDPSCl (2.5 mL, 9.77 mmol), and imidazole (1.28 g, 18.8 mmol) in dry DMF (20 mL) was stirred overnight at room temperature. The suspension was then diluted with petroleum ether, the organic layer was washed with saturated $NaHCO_3$ and brine, respectively, dried over $MgSO_4$, and filtered. The filtrate was concentrated in vacuo to give a residue, which was purified by a flash column chromatography (petroleum ether) to afford **6** (4.08 g, 100%) as a white solid: $[\alpha]^{18}_D$ −56.26 (*c* 1.85 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 7.70−7.30 (10H, m), 5.18−5.08 (2H, m), 3.60−3.48 (1H, m), 1.64 (3H, dt, *J* = 2.0, 7.1), 1.06 (9H, s), 1.00 (3H, s), 0.87 (3H, s); $^{13}$C NMR (75 MHz, $CDCl_3$) 150.29, 141.32, 135.77, 134.84, 129.42, 127.45, 121.00, 113.43, 73.23, 56.53, 50.08, 44.04, 42.49, 37.17, 36.98, 36.56, 31.89, 31.70, 31.44, 31.39, 27.02, 24.46, 21.18, 19.39, 19.15, 16.60, 13.12; EIMS *m*/*z* 537, 481. Anal. Calcd for $C_{37}H_{50}OSi$: C, 82.47; H, 9.35. Found: C, 82.46; H, 9.20.

**22-Homoallylic Alcohol (7).** To a suspension of **6** (8.20 g, 15.2 mmol) and paraformaldehyde (2.28 g, 75.9 mmol) in dry $CH_2Cl_2$ (80 mL) was added a solution of $BF_3$−$OEt_2$ in $CH_2Cl_2$ (10 mL, 0.07 M). After being stirred at room temperature for 10 min, the mixture was quenched with $Et_3N$ (1 mL) and filtered. The filtrates were concentrated in vacuo to give a residue, which was purified by flash column chromatography (petroleum ether−EtOAc, 50:1 to 20:1 and then 10:1) to afford **7** (6.51 g, 75%) as a white foam, and recovered starting material **6** (1.61 g, 20%). **7**: $[\alpha]^{20}_D$ −55.99 (*c* 1.15 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 7.70−7.30 (10H, m), 5.41 (1H, brs), 5.13 (1H, brd, *J* = 5.0), 3.60−3.45 (3H, m), 1.05 (9H, s), 1.01 (3H, s), 1.00 (3H, d), 0.78 (3H, s); $^{13}$C NMR (75 MHz, $CDCl_3$) 157.56, 141.57, 135.77, 134.82, 129.44, 127.45, 122.96, 120.91, 73.19, 66.53, 57.34, 50.65, 46.98, 42.52, 37.15, 36.73, 35.35, 34.85, 31.87, 31.56, 31.21, 30.53, 27.01, 20.74, 19.35, 19.15, 18.07, 16.21; EIMS *m*/*z* 567, 511. Anal. Calcd for $C_{38}H_{52}O_2Si\cdot 0.5H_2O$: C, 78.98; H, 9.24. Found: C, 78.93; H, 9.38.

**C22 Aldehyde (8).** A suspension of **7** (6.51 g, 11.44 mmol) and Dess−Martin periodinane (6.32 g, 14.9 mmol) in $CH_2Cl_2$ (70 mL) was stirred at room temperature for 3 h and then quenched by addition of $Na_2S_2O_3$ and $NaHCO_3$ solution and extracted with $CH_2Cl_2$. The organic layer was washed with brine, dried over $MgSO_4$, and concentrated in vacuo. The residue was purified by flash column chromatography (petroleum ether−EtOAc, 50:1) to afford **8** (5.57 g, 86%) as a white solid, and recovered the starting material **7** (411 mg, 6%). **8**: $[\alpha]^{29}_D$ −32.30 (*c* 1.35 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 9.44 (1H, d, *J* = 2.2), 7.70−7.30 (10H, m), 5.46 (1H, br), 5.13 (1H, d, *J* = 5.2 Hz), 3.53 (1H, m), 3.01 (1H, dq, *J* = 6.9), 1.17 (3H, d, *J* = 6.9), 1.05 (9H, s), 1.01 (3H, s), 0.78 (3H, s); $^{13}$C NMR (75 MHz, $CDCl_3$) 201.07, 152.00, 141.63, 135.78, 134.83, 129.44, 127.46, 127.01, 120.80, 73.19, 57.04, 50.60, 47.07, 46.07, 42.52, 37.16, 36.75, 34.58, 31.87, 31.50, 30.54, 27.02, 20.65, 19.34, 19.15, 15.98, 14.31; EIMS *m*/*z* 509, 199. Anal. Calcd for $C_{38}H_{50}O_2Si$: C, 80.51; H, 8.89. Found: C, 80.31; H, 8.48.

**22-Alcohol (9).** To a solution of **8** (5.57 g, 9.83 mmol) in dry ether (100 mL) was slowly added a solution of (3-methylbutyl)magnesium bromide (14.7 mmol, 1 M) in ether, which was prepared from 3-methylbutyl bromide and magnesium. After being stirred at room temperature for 1 h, the mixture was quenched with saturated $NH_4Cl$ solution and extracted with ether. The ether layer was then washed with brine, dried over $MgSO_4$, and concentrated in vacuo. The residue was purified by flash column chromatography (petroleum ether−EtOAc, 20:1 to 10:1) to provide **9** (6.04 g, 96%) as a pale yellow foam: $[\alpha]^{18}_D$ −46.84 (*c* 2.36 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 7.70−7.30 (10H, m), 5.47 (1H, brd, *J* = 3.0), 5.13 (1H, brd, *J* = 5.0), 3.64−3.48 (2H, m), 1.05 (9H, s), 1.01 (3H, s), 0.99 (3H, d, *J* = 6.9), 0.88 (3H, d, *J* = 6.6), 0.87 (3H, d, *J* = 6.6), 0.84 (3H, s); EIMS *m*/*z* 581, 199. Anal. Calcd for $C_{43}H_{62}O_2Si$: C, 80.82; H, 9.78. Found: C, 81.07; H, 9.82.

**22-Ketone (10).** A suspension of **9** (6.0 g, 9.39 mmol), pyridinium dichromate (5.3 g, 14.1 mmol), and crushed 4 Å MS (5 g) in dry $CH_2Cl_2$ (50 mL) and DMF (10 mL) was stirred at room temperature for 2 h and then filtered through a short silica gel column. The filtrates were washed with brine, dried over $MgSO_4$, and concentrated in vacuo. The residue was purified by flash column chromatography (petroleum ether−EtOAc, 100:1 to 50:1) to afford **10** (4.97 g, 83%) as a pale yellow syrup: $[\alpha]^{18}_D$ +3.60 (*c* 1.1 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 7.70−7.30 (10H, m), 5.34 (1H, br), 5.12 (1H, d), 3.52 (1H, m), 3.16 (1H, q, *J* = 6.9), 1.13 (3H, d), 1.05 (9H, s), 1.01 (3H, s), 0.85 (3H, d, *J* = 6.0), 0.84 (3H, d, *J* = 6.0), 0.81 (3H, s); $^{13}$C NMR (75 MHz, $CDCl_3$) 211.54, 154.36, 141.59, 135.79, 134.85, 129.46, 127.47, 125.19, 120.89, 73.22, 57.18, 50.60, 47.36, 45.74, 42.54, 38.30, 37.18, 36.76, 34.70, 33.10, 31.90, 31.53, 31.25, 30.62, 27.65, 27.05, 22.50, 22.27, 20.73, 19.36, 19.17, 16.86, 16.29; EIMS *m*/*z*: 636, 579, 199. Anal. Calcd for $C_{43}H_{60}O_2Si$: C, 81.06; H, 9.51. Found: C, 81.41; H, 9.88.

**Ethylene Glycol Ketal (11).** A solution of ketone **10** (4.79 g, 7.80 mmol), ethylene glycol (4.5 mL, 82 mmol), triethylorthoformate (6.5 mL, 39 mmol) and $TsOH\cdot H_2O$ (80 mg) in $CH_2Cl_2$ (50 mL) was stirred at room temperature for 4 d and then quenched with $Et_3N$ (0.5 mL). The mixture was extracted with $CH_2Cl_2$, and the organic layer was washed with brine, dried over $MgSO_4$, and concentrated in vacuo. The residue was purified by flash column chromatography to afford ketal **11** (5.12 g, 96%) as a pale yellow foam: $[\alpha]^{22}_D$ −40.56 (*c* 1.92

(25) Lipshutz, B. H.; Pollart, D.; Monforte, J.; Kotsuki, H. *Tetrahedron Lett.* **1985**, *26*, 705.

(26) For "General Methods", see: Lu, S.-F.; O'yang, Q.-Q.; Guo, Z.-W.; Yu, B.; Hui, Y.-Z. *J. Org. Chem.* **1997**, *62*, 8400.

$CHCl_3$); $^1H$ NMR (300 MHz, $CDCl_3$) 7.90−7.30 (10 H, m), 5.65 (1H, br), 5.14 (1H, br), 3.95 (4H, s), 3.54 (1H, m), 1.06 (9H, s), 1.02 (3H, s), 1.01 (3H, d, $J$ = 6.1), 0.86 (3H, d, $J$ = 6.6), 0.84 (3H, d, $J$ = 6.6), 0.79 (3H, s); $^{13}C$ NMR (75 MHz, $CDCl_3$) 156.59, 141.56, 135.79, 134.88, 129.45, 127.48, 124.05, 121.10, 113.86, 73.28, 65.86, 65.27, 57.36, 50.73, 47.53, 42.58, 39.21, 37.21, 36.78, 34.94, 33.99, 32.47, 31.94, 31.67, 31.43, 30.60, 28.41, 27.06, 22.68, 20.81, 19.26, 19.17, 17.38, 15.69; EIMS *m*/*z*: 680, 199, 143. Anal. Calcd for $C_{45}H_{64}O_3Si$: C, 79.36; H, 9.47. Found: C, 79.42; H, 9.82.

**3-Alcohol (12).** A solution of the TBDPS ether **11** (290 mg, 0.426 mmol) and tetrabutylammonium fluoride (0.85 mL, 1 M solution in THF) in dry THF (1 mL) was stirred at room temperature for 10 h and then diluted with ether. The organic layer was washed with brine, dried over $MgSO_4$, and concentrated in vacuo. The residue was purified by flash column chromatography (petroleum ether−EtOAc, 4:1) to afford **12** (179 mg, 95%) as a white solid: $[\alpha]^{25}_D$ −46.01 (*c* 2.08 $CHCl_3$); $^1H$ NMR (300 MHz, $CDCl_3$) 5.65 (1H, brs), 5.34 (1H, d, $J$ = 4.9), 3.94 (4H, brs), 3.50 (1H, m); $^{13}C$ NMR (75 MHz, $CDCl_3$) 156.53, 141.04, 124.01, 121.57, 113.84, 71.72, 65.83, 65.23, 57.31, 50.76, 47.50, 42.32, 39.17, 37.21, 36.74, 34.90, 33.95, 32.42, 31.63, 31.38, 30.68, 28.36, 22.77, 22.62, 20.82, 19.30, 17.34, 15.67; EIMS *m*/*z* 441, 143. Anal. Calcd for $C_{29}H_{46}O_3 \cdot 0.25H_2O$: C, 77.89; H, 10.48. Found: C, 77.99; H, 10.78.

**3-TBS Ether (13)**. A solution of alcohol **12** (179 mg, 0.404 mmol), TBDMSCl (91 mg, 0.603 mmol), and imidazole (69 mg, 1.01 mmol) in DMF (1.5 mL) was stirred at room temperature overnight and then diluted with ether. The organic layer was washed with brine, dried over $MgSO_4$, and concentrated in vacuo. The residue was purified by flash column chromatography (petroleum ether−EtOAc, 100:1) to afford **13** (216 mg, 96%) as a white solid: $[\alpha]^{25}_D$ −37.96 (*c* 2.24 $CHCl_3$); $^1H$ NMR (300 MHz, $CDCl_3$) 5.66 (1H, brs), 5.32 (1H, d, $J$ = 4.9), 3.96 (4H, brs), 3.47 (1H, m), 0.88 (9H, s), 0.05 (6H, s); $^{13}C$ NMR (75 MHz, $CDCl_3$) 156.59, 141.83, 124.01, 121.06, 113.84, 72.60, 65.83, 65.24, 57.37, 50.86, 47.52, 42.87, 39.19, 37.34, 36.84, 34.95, 33.96, 32.43, 32.10, 31.68, 31.40, 30.71, 28.37, 25.93, 22.62, 20.82, 19.33, 18.23, 17.34, 15.65, −4.58; EIMS *m*/*z*: 556, 485, 143. Anal. Calcd for $C_{35}H_{60}O_3Si$: C, 75.48; H, 10.86. Found: C, 75.68; H, 11.26.

**16α,17α-Cis Diol (14).** To a cooled solution (−20 °C) of **13** (849 mg, 1.52 mmol) in ether (20 mL) and Py (1 mL) was added $OsO_4$ (480 mg, 1.89 mmol), and the resulting black solution was stirred at −20 °C to room temperature for 3 h and then quenched by bubbling $H_2S$ through the solution and filtered. The filtrates were concentrated in vacuo to afford a residue, which was purified by flash column chromatography (petroleum ether−EtOAc, 50:1 to 20:1) to afford **14** (367 mg, 41%) as a white solid, and recovered starting material **13** (169 mg, 20%). **14**: $[\alpha]^{25}_D$ −56.67 (*c* 0.99 $CHCl_3$); $^1H$ NMR (300 MHz, $CDCl_3$) 5.30 (1H, d, $J$ = 4.2), 4.28 (1H, m), 3.97 (4H, m), 3.47 (1H, m), 1.12 (3H, d, $J$ = 7.0), 0.98 (3H, s), 0.88 (9H, s), 0.77 (3H, s), 0.04 (6H, s); $^{13}C$ NMR (75 MHz, $CDCl_3$) 141.55, 120.95, 115.68, 82.42, 75.93, 72.57, 65.79, 64.40, 49.88, 49.56, 48.04, 45.29, 42.80, 37.21, 36.45, 33.26, 32.77, 32.05, 31.84, 31.30, 29.68, 28.12, 25.93, 22.73, 20.41, 19.40, 18.23, 14.30, 13.08, −4.60; EIMS *m*/*z*: 575, 361, 143. Anal. Calcd for $C_{35}H_{62}O_5Si$: C, 71.14; H, 10.57. Found: C, 70.99; H, 10.90.

**α-Hydroxy Ketone (15).** To a cooled solution (−78 °C) of ClCOCOCl (0.11 mL, 1.26 mmol) in $CH_2Cl_2$ (2 mL) was added dropwise a solution of DMSO (0.18 mL, 2.54 mmol) in $CH_2Cl_2$ (0.5 mL), and the mixture was stirred for 15 min, before a solution of **14** (287 mg, 0.486 mmol) in $CH_2Cl_2$ (5 mL) was added. After being stirred for another 15 min, the reaction was quenched with $Et_3N$ (0.68 mL, 4.88 mmol) and warmed to room temperature. The mixture was then extracted with $CH_2Cl_2$. The organic layer was washed with brine, dried over $MgSO_4$, and concentrated in vacuo to give a residue, which was purified by flash column chromatography (petroleum ether−EtOAc, 50:1 to 20:1) to afford **15** (222 mg, 78%) as a white solid and recovered starting material **14** (40 mg, 14%). **15**: $[\alpha]^{25}_D$ −150.33 (*c* 1.13 $CHCl_3$); $^1H$ NMR (300 MHz, $CDCl_3$) 5.30 (1H, d, $J$ = 5.2), 4.05−3.90 (4H, m), 3.47 (1H, m), 2.72 (1H, q, $J$ = 7.4), 1.02 (3H, s), 1.01 (3H, d, $J$ = 7.4), 0.87 (9H, s), 0.05 (6H, s); $^{13}C$ NMR (75 MHz, $CDCl_3$) 215.45, 141.56, 120.66, 115.40, 85.36, 72.45, 63.43, 63.28, 49.48, 46.91, 45.38, 42.74, 41.16, 37.18, 37.08, 36.66, 32.73, 32.20, 32.01, 30.75, 30.20, 28.29, 25.92, 22.69, 22.44, 20.12, 19.42, 18.22, 14.99, 14.25, −4.58; EIMS *m*/*z*: 588, 143. Anal. Calcd for $C_{35}H_{60}O_5Si$: C, 71.38; H, 10.27. Found: C, 71.61; H, 10.61.

**16α,17β-Trans Diol (2).** A suspension of **15** (98 mg, 0.166 mmol), $CeCl_3 \cdot 7H_2O$ (80 mg, 0.22 mmol) and $NaBH_4$ (40 mg, 1.1 mmol) in THF (5 mL) was stirred at 0 °C for 3 h and then quenched with methanol and diluted with ether. The organic layer was washed with brine, dried over $MgSO_4$, and concentrated in vacuo. The residue was purified by flash column chromatography to afford **2** (91 mg, 93%) as a while solid: $[\alpha]^{25}_D$ −35.00 (*c* 1.48 $CHCl_3$); $^1H$ NMR (300 MHz, $CDCl_3$) 5.30 (1H, d, $J$ = 4.8), 4.15−3.85 (5H, m), 3.48 (1H, m), 2.59 (1H, q, $J$ = 7.4), 1.18 (3H, s), 0.99 (3H, s), 0.87 (9H, s), 0.03 (6H, s); $^{13}C$ NMR (75 MHz, $CDCl_3$) 141.42, 121.11, 116.49, 86.81, 81.55, 72.57, 64.09, 62.86, 49.66, 47.89, 47.82, 42.77, 37.29, 36.51, 35.97, 33.91, 33.16, 32.81, 32.75, 32.06, 31.92, 29.67, 28.28, 25.93, 22.70, 22.26, 20.69, 19.41, 18.23, 12.55, 11.95, −4.85; EIMS *m*/*z*: 575, 510, 143. Anal. Calcd for $C_{35}H_{62}O_5Si$: C, 71.13; H, 10.57. Found: C, 71.02; H, 10.93.

**Benzyl 2-*O*-(4-methoxylbenzoyl)-α-D-xylopyranoside (17).** A solution of D-xylose (5.0 g) in HCl-saturated BnOH (25 mL) was stirred at room temperature overnight and then poured into ether (250 mL), and placed overnight. The resulting crystal was filtered to obtain benzyl α-D-xylopyranoside **16**[27] (2.5 g, 31%) as a white solid: $^1H$ NMR (300 MHz, $CD_3SOCD_3$) 7.40−7.20 (5H, m), 4.72 (1H, d, $J$ = 3.6), 4.66 and 4.44 (2H, AB peak, $J$ = 11.2), 3.50−3.30 (4H, m), 3.23 (1H, dd, $J$ = 3.6, 9.3); EIMS *m*/*z*: 241, 223, 91.

To a cooled solution (−35 °C) of **16** (14.68 g, 61.1 mmol) in dry Py (100 mL) was slowly added 4-methoxybenzoyl chloride (12.5 g, 73.3 mmol), and then the reaction temperature was gradually elevated to room temperature. After being stirred overnight, the reaction was quenched with MeOH and concentrated *in vacuo*. The residue was dissolved in EtOAc, which was washed with diluted HCl, saturated $NaHCO_3$ solution and brine, respectively, and then dried over $MgSO_4$ and concentrated in vacuo. The residue was purified by flash column chromatography to afford **17** (14.94 g, 65%) as a white foam: $[\alpha]^{29}_D$ +188.8 (*c* 1.35 $CHCl_3$); $^1H$ NMR (300 MHz, $CDCl_3$) 8.10−6.80 (9H, m), 5.11 (1H, d, $J$ = 3.3), 4.89 (1H, dd, $J$ = 3.3, 9.6), 4.76 and 4.50 (2H, AB, $J$ = 12.1), 4.13 (1H, m), 3.88 (3H, s), 3.95−3.70 (3H, m); EIMS *m*/*z*: 375, 357, 135. Anal. Calcd for $C_{20}H_{22}O_7$: C, 64.16; H, 5.92. Found: C, 64.43; H, 5.94.

**Benzyl 3,4-Bis-*O*-(triethylsilyl)-2-*O*-(4-methoxylbenzoyl)-α-D-xylopyranoside (18).** To a solution of **17** (11.45 g, 30.58 mmol), imidazole (10.41 g, 152.9 mmol), and DMAP (500 mg) in dry DMF (100 mL) was added TESCl (12.3 mL, 73.3 mmol). After being stirred for 1 h, the solution was concentrated in vacuo. The residue was dissolved in EtOAc, which was washed with saturated $NaHCO_3$ solution and brine and then dried over $MgSO_4$ and concentrated in vacuo. The residue was purified by flash column chromatography (petroleum ether−EtOAc, 30:1 to 20:1) to afford **18** (17.09 g, 93%) as a pale yellow syrup: $[\alpha]^{20}_D$ −220.38 (*c* 1.01 $CHCl_3$); $^1H$ NMR (300 MHz, $CDCl_3$) 8.10−6.90 (9H, m), 4.99 (1H, d, $J$ = 3.7), 4.90 (1H, dd, $J$ = 3.7, 9.4), 4.72 and 4.45 (2H, AB, $J$ = 12.6), 4.10 (1H, dd, $J$ = 7.9), 3.89 (3H, s), 3.80−3.50 (3H, m), 0.97 and 0.85 (each 9H, each t, $J$ = 7.9), 0.65 and 0.55 (each 6H, each q); EIMS *m*/*z*: 573, 495, 135. Anal. Calcd for $C_{32}H_{50}O_7Si_2$: C, 63.75; H, 8.36. Found: C, 63.51; H, 8.25.

**3,4-Di-*O*-triethylsilyl-2-*O*-(4-methoxylbenzoyl)-α/β-D-xylopyranose (19).** A suspension of **18** (12.84 g, 21.30 mmol), triethylamine (1 mL) and 10% Pd/C (2.5 g) in EtOAc (200 mL) was stirred at 50 °C under $H_2$ atmosphere (40 atm) for 1 d and then filtered. The filtrates were concentrated in vacuo. The residue was purified by flash column chromatography (petroleum ether−EtOAc, 20:1 to 5:1 and then 3:1) to afford **19** (8.34 g, 76%) as a syrup, which could slowly become a solid, and recovered starting material **18** (2.63 g, 20%). **19**: $[\alpha]^{29}_D$

(27) Sivakumaran, T.; Jones,J. K. N. *Can. J. Chem*. **1967**, *45*, 2493.

+54.81 (*c* 1.28 $CHCl_3$). Anal. Calcd for $C_{25}H_{44}O_7Si_2$: C, 58.56; H, 8.65. Found: C, 58.70; H, 8.76.

**3,4-Di-*O*-triethylsilyl-2-*O*-(4-methoxylbenzoyl)-α/*β*-D-xylopyranosyl trichloroacetimidate (20).** To a solution of **19** (7.17 g, 13.98 mmol) and $CCl_3CN$ (7 mL, 70 mmol) in $CH_2Cl_2$ (60 mL) was added DBU (three drops), and the resulting solution was stirred at room temperature for 3 h, and concentrated in vacuo. The residue was purified by flash column chromatography (petroleum ether−EtOAc with 1% of triethylamine: 20:1 to 15:1) to afford a colorless syrup **20** (7.27 g, 79%) as a mixture of α and *β* anomer (2:3, from $^1$H NMR): $[\alpha]^{13}_D$ +14.88 (*c* 0.87 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 8.58 (0.6H, s), 8.45 (0.4H, s), 8.05−7.95 (2H, m), 6.92−6.85 (2H, m), 6.41 (0.4H, d, *J* = 3.4), 6.03 (0.6H, d, *J* = 4.2), 5.17−5.10 (1H, m), 4.23 (0.6H, dd, *J* = 3.3, 11.8), 4.16 (0.4H, m), 3.90−3.70 (5H, m), 3.55 (0.4H, m), 1.00−0.50 (30H, m); EIMS *m*/*z*: 627, 495, 135.

**Benzyl 2-*O*-Acetyl-3,4-*O*-isopropylidene-*β*-L-arabinopyranoside (23).** A solution of L-arabinose (12.0 g, 80 mmol) in HCl saturated BnOH (60 mL) was stirred overnight at room temperature and then diluted with ether (180 mL) and placed in a refrigerator for 4 h. The resulting solid was filtered to afford a crude product (15.44 g, 80%), which was recrystalized from ethanol to give pure benzyl *β*-L-arabinopyranoside (**21**)[28] (12.97 g): $^1$H NMR (300 MHz, $CD_3SOCD_3$) 7.40−7.20 (5H, m), 4.75 (1H, brs), 4.66 and 4.45 (2H, AB, *J* = 12.4), 3.72−3.6 (4H, m), 3.46 (1H, dd, *J* = 2.7); EIMS *m*/*z*: 241, 223, 91.

A mixture of **21** (5.65 g, 23.53 mmol), 2,2-dimethoxylpropane (5.8 mL, 47.2 mmol), and $TsOH\cdot H_2O$ (280 mg) in DMF (50 mL) was stirred at room temperature for 5 h, and triethylamine (1 mL) was added, diluted with EtOAc. The organic layer was washed with saturated $NaHCO_3$ solution and brine, dried over $MgSO_4$, and concentrated in vacuo to afford a colorless syrup, which was dissolved in $Ac_2O$ (10 mL) and Py (10 mL), and stirred overnight at room temperature. After being quenched with MeOH, the mixture was diluted with EtOAc. The organic layer was washed with diluted HCl, saturated $NaHCO_3$, and brine, respectively, dried over $MgSO_4$, and concentrated in vacuo. The residue was purified by flash column chromatography (petroleum ether−EtOAc, 10:1 to 8:1) to afford **23**[28] (6.77 g, 89%) as a syrup: $^1$H NMR (300 MHz, $CDCl_3$) 7.40−7.25 (5H, m), 4.98 (1H, d, *J* = 3.4), 4.90 (1H, dd, *J* = 8.1), 4.71 and 4.48 (2H, AB, *J* = 12.3), 4.36 (1H, dd, *J* = 5.5), 4.24 (1H, brd), 4.00 (1H, brs), 2.06 (3H, s), 1.52 and 1.34 (each 3H, each s); EIMS *m*/*z*: 321, 263, 91.

**Benzyl 2-*O*-Acetyl-*β*-L-arabinopyranoside (24).** A solution of **23** (6.52 g, 20.22 mmol) in 70% HOAc (100 mL) was stirred at 70 °C for 1 h and then concentrated in vacuo, and the traces of HOAc and water were removed by coevaporation with toluene several times. The residue was purified by flash column chromatography (petroleum ether−EtOAc, 1.2:1 to 1:1 and then 1:2) to afford **24** (5.35 g, 94%) as a colorless syrup, which slowly became a solid: $[\alpha]^{20}_D$ +229.58 (*c* 1.35 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 7.40−7.20 (5H, m), 5.06 (1H, d, *J* = 3.6), 4.99 (1H, dd, *J* = 9.9), 4.74 and 4.51 (2H, AB, *J* = 12.4), 4.10 (1H, dd, *J* = 3.4), 4.02 (1H, brs), 3.93 and 3.76 (2H, AB, *J* = 12.6), 2.11 (3H, s); EIMS *m*/*z* 283, 265, 205, 91. Anal. Calcd for $C_{14}H_{18}O_6$: C, 59.57; H, 6.43. Found: C, 60.06; H, 6.46.

**Benzyl 2-*O*-Acetyl-3-*O*-(3,4-di-*O*-triethylsilyl-2-*O*-(4-methoxybenzoyl)-*β*-D-xylopyranosyl)-*β*-L-arabinopyranoside (25) and Benzyl 2-*O*-Acetyl-4-*O*-(3,4-di-*O*-triethylsilyl-2-*O*-(4-methoxybenzoyl)-*β*-D-xylopyranosyl)-*β*-L-arabinopyranoside (26).** A suspension of imidate donor **20** (7.18 g, 10.92 mmol), acceptor **24** (2.28 g, 8.09 mmol) and 4 Å MS (10 g) in dry $CH_2Cl_2$ (60 mL) was stirred at room temperature for 15 min and then cooled to −60 °C, and a solution of $BF_3-OEt_2$ (5.7 mL, 0.07 M) in $CH_2Cl_2$ was slowly added to the reaction. After 30 min, the reaction was quenched with triethylamine (0.5 mL) and filtered. The filtrate was concentrated in vacuo to give a residue, which was purified by flash column chromatography (petroleum ether−EtOAc, 10:1, 5:1, 4:1, and then 2:1) to give **25** (0.50 g), a mixture of **25** and **26** (5.83 g), and a small amount of **26** (overall 100% yield). **25**: $[\alpha]^{16}_D$ +78.35 (*c* 2.16 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 7.99 and 6.89 (4H, AB), 7.30−7.20 (5H, m), 5.05−4.94 (3H, m), 4.69 (1H, d, *J* = 6.6), 4.65 and 4.34 (2H, AB, *J* = 12.1), 4.06−4.02 (2H, m), 3.96 (1H, dd, *J* = 4.3, 11.7), 3.85 (1H, m), 3.84 (3H, s), 3.75 (1H, t, *J* = 7.1), 3.75−3.64 (2H, m), 3.27 (1H, dd, *J* = 8.2), 1.65 (3H, s), 0.95 (9H, t, *J* = 8.2), 0.85 (9H, t, *J* = 8.0), 0.62 (6H, q, *J* = 8.2), 0.51 (6H, q, *J* = 8.0); $^{13}$C NMR (75 MHz, $CDCl_3$) 170.04, 164.78, 163.47, 137.32, 131.82, 128.32, 127.76, 127.61, 122.43, 113.55, 101.68, 95.87, 75.61, 74.39, 73.04, 71.03, 69.82, 69.61, 68.38, 65.08, 61.74, 55.40, 20.24, 6.80, 5.00; EIMS *m*/*z*: 748, 640, 135. Anal. Calcd for $C_{39}H_{60}O_{12}Si_2$: C, 60.28; H, 7.78. Found: C, 60.61; H, 7.91. **26**: $^1$H NMR (300 MHz, $CDCl_3$) 8.00 and 6.90 (4H, AB), 7.30−7.20 (5H, m), 5.08−5.02 (2H, m), 4.85 (1H, dd, *J* = 3.5, 10.0), 4.68 and 4.47 (2H, AB, *J* = 12.3), 4.63 (1H, d, *J* = 6.3), 4.04 (1H, dd, *J* = 4.3, 11.2), 3.92 (1H, dd, *J* = 4.0), 3.85 (3H, s), 3.88−3.70 (5H, m), 3.28 (1H, dd, *J* = 8.2), 2.00 (3H, s), 0.96 and 0.87 (18H, each t, *J* = 7.7), 0.70−0.50 (12H, m).

**Benzyl 2-*O*-Acetyl-3-*O*-(3,4-di-*O*-triethylsilyl-2-*O*-(4-methoxybenzoyl)-*β*-D-xylopyranosyl)-4-*O*-(triethylsilyl)-*β*-L-arabinopyranoside (29) and Benzyl 2-*O*-Acetyl-4-*O*-(3,4-di-*O*-triethylsilyl-2-*O*-(4-methoxybenzoyl)-*β*-D-xylopyranosyl)-3-*O*-triethylsilyl-*β*-L-arabinopyranoside (30).** A mixture of **25** and **26** (5.67 g, 7.30 mmol), 2,6-lutidine (4.3 mL, 36.9 mmol), and TESOTf (3.2 mL, 14.2 mmol) in $CH_2Cl_2$ (50 mL) was stirred at −20 °C for 1 h and poured into saturated $NaHCO_3$ solution. The mixture was extracted with $CH_2Cl_2$, and the organic layer was washed with brine, dried over $MgSO_4$, and concentrated in vacuo. The residue was purified with flash column chromatography (petroleum ether−EtOAc, 10:1 to 8:1) to give **29** (4.58 g, 70%) as a pale yellow syrup and **30** (1.38 g, 21%) as a white solid. **29**: $[\alpha]^{18}_D$ +94.87 (*c* 1.10 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 7.93 and 6.87 (4H, AB), 7.34−7.20 (5H, m), 5.10−4.94 (3H, m), 4.69 (1H, d, *J* = 7.5), 4.64 and 4.34 (2H, AB, *J* = 12.1), 4.10 (1H, brs), 3.95 (1H, dd, *J* = 3.0, 9.6), 3.90 (1H, dd, *J* = 3.8, 11.2), 3.83 (3H, s), 3.82−3.64 (3H, m), 3.50 (1H, dd, *J* = 3.1, 11.9), 3.21 (1H, dd, *J* = 9.0), 1.73 (3H, s), 1.00−0.45 (45H, m); $^{13}$C NMR (75 MHz, $CDCl_3$) 169.84, 164.43, 163.26, 137.57, 131.63, 128.30, 127.76, 122.92, 113.46, 102.50, 95.87, 76.03, 74.75, 74.04, 71.92, 70.72, 70.41, 69.52, 65.87, 64.33, 55.35, 20.52, 6.83, 5.17, 5.12, 4.85; EIMS *m*/*z*: 863, 495, 363, 135. Anal. Calcd for $C_{45}H_{74}O_{12}Si_3\cdot 0.5H_2O$: C, 60.03; H, 8.40. Found: C, 60.17; H, 8.52. **30**: $^1$H NMR (300 MHz, $CDCl_3$), 8.03 and 6.85 (4H, AB), 7.28 (5H, m), 5.04 (1H, d, *J* = 3.3), 5.01 (1H, t, *J* = 6.0, 7.6), 4.89 (1H, d), 4.66 and 4.25 (2H, AB, *J* = 12.4), 4.61 (1H, dd, *J* = 9.9), 4.10 (1H, dd, *J* = 2.9), 4.03 (1H, dd, *J* = 3.0, 11.5), 3.84 (3H, s), 3.84−3.66 (5H, m), 3.23 (1H, dd, *J* = 8.6), 1.88 (3H, s), 1.00−0.50 (45H, m). Anal. Calcd for $C_{45}H_{74}O_{12}Si_3$-$0.5H_2O$: C, 60.03; H, 8.40. Found: C, 60.24; H, 8.38.

**2-*O*-Acetyl-3-*O*-(3,4-di-*O*-triethylsilyl-2-*O*-(4-methoxybenzoyl)-*β*-D-xylopyranosyl)-4-*O*-(triethylsilyl)-*β*-L-arabinopyranose (31).** A suspension of **29** (2.60 g, 2.91 mmol), 10% Pd/C (3 g), and triethylamine (1.5 mL) in EtOAc (20 mL) and EtOH (20 mL) was stirred under $H_2$ atmosphere (50 atm) and 50 °C for 3 d and filtered. The filtrate was concentrated in vacuo to give a residue, which was purified by flash column chromatography to give **31** (1.17 g, 50%) as a syrup, mainly as the α anomer, and recovered starting material **29** (0.92 g, 36%). **31**: $[\alpha]^{29}_D$ +13.27 (*c* 1.27 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 7.96 and 6.90 (4H, AB, *J* = 9.9), 5.21 (1H, brs), 5.00 (1H, t, *J* = 7.6, 7.6), 4.91 (1H, dd, *J* = 3.0, 8.8), 4.68 (1H, d, *J* = 7.1), 4.05 (1H, brs), 3.86 (3H, s), 4.00−3.64 (5H, m), 3.54 (1H, dd, *J* = 4.5, 11.7), 3.21 (1H, dd, *J* = 8.5, 11.3), 1.86 (3H, s), 1.00−0.80 (27H, m), 0.70−0.40 (18H, m); $^{13}$C NMR (75 MHz, $CDCl_3$) 169.98, 164.56, 163.31, 131.66, 122.74, 113.48, 102.06, 90.97, 75.57, 74.50, 73.86, 71.69, 70.91, 65.60, 64.27, 55.36, 20.64, 6.80, 5.07, 4.90, 4.78; EIMS *m*/*z*: 772, 495, 135. Anal. Calcd for $C_{38}H_{68}O_{12}Si_3$: C, 56.97; H, 8.55. Found: C, 57.05; H, 8.91.

**2-*O*-Acetyl-3-*O*-(3,4-di-*O*-triethylsilyl-2-*O*-(4-methoxybenzoyl)-*β*-D-xylopyranosyl)-4-*O*-(triethylsilyl)-*β*-L-ara-**

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**binopyranosyl trichloroacetimidate (3).** A solution of **31** (139 mg, 0.174 mmol), $CCl_3CN$ (0.2 mL, 2 mmol), and DBU (one drop) in $CH_2Cl_2$ (5 mL) was stirred at room temperature for 6 h, the solution was concentrated in vacuo, and the resulting residue was purified by flash column chromatography (petroleum ether−EtOAc with 1% of triethylamine, 15:1 to 10:1) to give **3** (106 mg, 65%) as a syrup. Imidate **3** was found to quickly decompose in the NMR tube and therefore was immediately used in the next glycosylation without further identification.

**Protected OSW-1 (32)**. A solution of donor **3** (96 mg, 0.10 mmol), aglycone **2** (50 mg, 0.085 mmol), and 4 Å MS (200 mg) in dry $CH_2Cl_2$ (2 mL) was stirred at room temperature for 15 min and then cooled to −20 °C, and a solution of TMSOTf (1 mL, 0.0045 M) in $CH_2Cl_2$ was slowly added to the reaction. After being stirred for another 20 min, the reaction was quenched with triethylamine (0.1 mL) and filtered. The filtrates were concentrated in vacuo to give a residue, which was purified by flash column chromatography (petroleum ether−EtOAc, 9:1 to 6:1) to afford **32** (80 mg, 69%) as a white foam: $[\alpha]^{25}_D$ −41.62 (*c* 0.78 $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) 8.03 and 6.98 (4H, AB), 5.30 (1H, d, $J$ = 4.5), 5.11 (1H, dd, $J$ = 0.9, 3.4), 4.98 (1H, brs), 4.90 (1H, brs), 4.55 (1H, brs), 3.68 (3H, s), 2.64 (1H, q, $J$ = 7.4), 2.01 (3H, s), 0.054 (6H, s); $^{13}$C NMR (75 MHz, $CDCl_3$) 168.45, 164.62, 163.33, 141.34, 132.06, 122.81, 121.24, 116.52, 113.29, 100.96, 87.16, 72.62, 71.05, 69.21, 68.99, 64.18, 62.43, 55.38, 49.80, 48.12, 48.01, 42.85, 37.23, 36.50, 35.24, 33.32, 32.45, 32.09, 31.89, 29.67, 28.18, 25.93, 22.28, 21.67, 20.87, 20.72, 19.26, 18.24, 12.77, 12.35, 6.94, 6.76, 5.04, 4.90, 4.77, −4.58; ESIMS *m/z*: 1420 (M + 2Na + 2), 1393. Anal. Calcd for $C_{73}H_{128}O_{16}Si_4 \cdot 2H_2O$: C, 62.18; H, 9.43. Found: C, 62.05; H, 9.34.

**OSW-1 (1).** A solution of **32** (36 mg, 0.026 mmol) and $Pd(MeCN)_2Cl_2$ (∼2 mg) in acetone and water (2 mL, v:v, 20:1) was stirred overnight at room temperature, and then the solution was directly concentrated in vacuo to give a residue, which was purified by flash column chromatography ($CH_2Cl_2$−MeOH, 15:1) to give **1** (18 mg, 79%) as a pale yellow solid: $R_f$ 0.56 ($CH_2Cl_2$−MeOH, 15:1); $[\alpha]^{26}_D$ −45.2 (*c* 0.25 MeOH), lit.[3] −43.2 (*c* 0.25 MeOH); $^1$H NMR (600 MHz, $C_5D_5N$) 8.31 (2H, d), 7.07 (2H, d), 5.67 (1H, dd, $J$ = 8.0, 9.2), 5.55 (1H, t, $J$ = 6.3, 7.5), 5.37 (1H, d, $J$ = 3.6), 5.11 (1H, d, $J$ = 8.0), 4.79 (1H, s), 4.57 (1H, d, $J$ = 6.0), 4.39 (1H, brs), 4.31 (1H, dd, $J$ = 5.2, 11.1), 4.26−4.20 (2H, m), 4.20−4.12 (3H, m), 3.81 (1H, brs), 3.73 (3H, s), 3.18 (1H, q, $J$ = 7.4), 1.96 (3H, s), 1.27 (3H, d, $J$ = 7.5), 1.06 (3H, s), 0.98 (3H, s), 0.87 (3H, d, $J$ = 6.4), 0.84 (3H, d, $J$ = 6.4); $^{13}$C NMR (75 MHz, $C_5D_5N$) 218.96, 169.27, 165.47, 163.91, 141.95, 132.45, 121.13, 114.15, 103.68, 100.86, 88.36, 85.72, 80.99, 76.35, 75.15, 72.05, 71.31, 70.75, 67.85, 67.06, 65.59, 55.52, 50.20, 48.58, 46.57, 46.33, 43.55, 39.29, 37.80, 36.90, 34.64, 32.73, 32.28, 32.08, 27.76, 22.85, 22.51, 20.93, 19.64, 13.64, 11.91; IR (KBr) 3467, 2957, 2934, 1726, 1695, 1607, 1513, 1465, 1373, 1258, 1232, 1170, 1044, 988, 972; FABMS *m/z*: 896 (M + 1 + Na); ESIMS *m/z*: 895 (M + $Na^+$), 919 (M + 1 + 2$Na^+$), 1769 (2 × (M + 1) + $Na^+$).

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**Supporting Information Available:** Reproductions of $^1$H NMR spectra for compounds **1**, **2**, **6**−**11**, **13**−**15**, **18**, **20**, and **23**−**32**, $^{13}$C NMR spectra for compounds **1**, **2**, **7**, **8**, **10**, **11**, **13**−**15**, **25**, **29**, **31**, **32** (36 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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