Synthetic Studies on Oligomycins. Synthesis of the Oligomycin B Spiroketal and Polypropionate Portions

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(Received October 25, 1994)

The oligomycin B spiroketal portion, [2*S*,2(2*R*),3*S*,6*R*,8*S*,8(3*R*),9*S*,10*R*,11*S*]-2-[2-(*t*-butyldiphenylsilyloxy)propyl]-8-[3-(hydroxymethyl)pentyl]-3,9,11-trimethyl-1,7-dioxaspiro[5.5]undecane-5,10-diol (**2**), and polypropionate portion, ethyl (2*E*,4*S*,5*R*,6*R*,7*S*,8*S*,9*R*,10*S*,12*R*,13*S*,14*R*,16*E*)-5-(*t*-butyldimethylsilyloxy)-7,9-(isopropylidenedioxy)-12,13-(4-methoxybenzylidenedioxy)-4,6,8,10,12,14-hexamethyl-11-oxo-18-phenylsulfonyloctadeca-2,16-dienoate (**3**), have been synthesized. The C19-C21 Wittig salt, [(2*S*,3*R*)-2-ethyl-3,4-(isopropylidenedioxy)butyl]triphenylphosphonium iodide (**6**), prepared from 2-butene-1,4-diol via Sharpless epoxidation, was coupled with the C22-C27 aldehyde, benzyl 2,4-dideoxy-3-*O*-(4-methoxybenzyl)-2,4-di-*C*-methyl-α,β-L-*galacto*-hexodialdopyranoside-(1,5) (**7**), prepared from (*Z*)-2-butene-1,4-diol via Sharpless epoxidation and the Brown's crotylboration. The resulting coupling product was transformed to the C19-C27 lactone, [3*S*,4*R*,5*R*,6*S*,6(3*R*,4*R*)]-6-[3-ethyl-4,5-(isopropylidenedioxy)pentyl]-4-(4-methoxybenzyloxy)-3,5-dimethyl-3,4,5,6-tetrahydro-2*H*-pyran-2-one (**4**). The C28-C34 organostannane compound, (2*R*,4*S*,5*S*,7*RS*)-2-(*t*-butyldiphenylsilyloxy)-5-methyl-7-(tributylstannyl)-4-(triethylsilyloxy)-7-[(2-trimethylsilylethoxy)-methoxy]heptane (**5b**), was prepared from (*R*)-methyl 3-hydroxybutyrate via the Brown's crotylboration and the Still's stannylation. After lithiation of **5b** with butyllithium, the resulting α-alkoxy organolithium compound was coupled with **4** and the product was converted to the C19-C34 spiroketal, [2*S*,2(2*R*),3*S*,6*R*,8*S*,8(3*R*,4*R*),9*S*,10*R*,11*S*]-2-[2-(*t*-butyldiphenylsilyloxy)propyl]-8-[3-ethyl-4,5-(isopropylidenedioxy)pentyl]-10-(4-methoxybenzyloxy)-3,9,11-trimethyl-1,7-dioxaspiro[5.5]undecan-5-ol (**37**). The synthetic **2**, derived from **37**, was identical to the oligomycins (A, B, C mixture) degradation product in all respects, which elucidates the absolute stereochemistry of oligomycin B (**1b**). The C3-C9 aldehyde, (2-trimethylsilylethoxy)methyl 2,4,6-trideoxy-3-*O*-(4-methoxybenzyl)-2,4,6-tri-*C*-methyl-D-*glycero*-α-L-*ido*-heptodialdopyranoside-(1,5) (**9**), was prepared from (2*S*)-3-(*t*-butyldimethylsilyloxy)-2-methylpropanal via Keck's crotylstannane addition and Brown's crotylboration. The aldol coupling between the zinc enolate of the C10-C16 ketone, *t*-butyldimethylsilyl 2,3,7,8-tetradeoxy-4-*O*-(4-methoxybenzyl)-3,5-di-*C*-methyl-α-L-*xylo*-octopyranosid-6-ulose (**10**), prepared from methyl (*R*)-(+)-lactate via Brown's crotylboration and a metallated methoxyallene addition, and aldehyde **9** gave the C8-C9 *syn*, C9-C10 *syn* product, which was transformed to the oligomycin B polypropionate portion **3** through elongation of the C1-C2 and C17-C18 carbon units.

The oligomycin family of antibiotics consists of a 26-membered macrolactone ring having a spiroketal ring (Fig. 1). Oligomycins A (**1a**), B (**1b**), and C (**1c**) were isolated in 1954 from a strain of *Streptomyces diastatochromogenes*.[1] They are antifungal antibiotics[1] and potent, specific inhibitors of oxidative phosphorylation.[2] The structure of **1** was elucidated by chemical degradation studies and an X-ray crystallographic analysis.[3] Other oligomycin members, rutamycins A[4a,4b] (oligomycin D) and B,[4c] oligomycins E[4d] and F,[4e] 44-homooligomycins A and B,[4f,4g] were also isolated and the individual members have shown characteristic biological activities. Recently, Evans and his co-workers have achieved the total synthesis of rutamycin B.[5] In connection with our ongoing studies concerning the total synthesis of oligomycins, we wish to describe in this full account[6] the enantiospecific synthesis of the oligomycin B spiroketal portion **2** and the polypropionate portion **3**. The absolute stereochemistry of oligomycin B (**1b**) was unequivocally established, as depicted in Fig. 1, by a comparison of the synthetic **2** and the naturally derived **2**.

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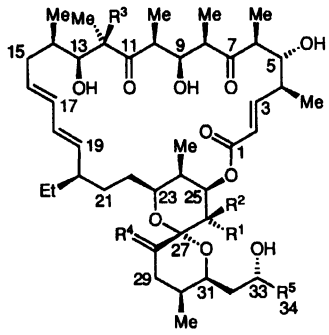
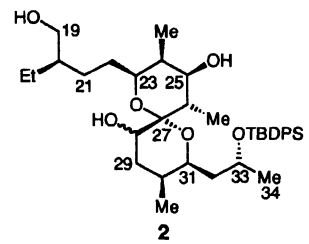


	R^1	R^2	R^3	R^4	R^5
Oligomycin A (1a)	Me	H	OH	H_2	Me
Oligomycin B (1b)	Me	H	OH	O	Me
Oligomycin C (1c)	Me	H	H	H_2	Me
Oligomycin E	Me	OH	OH	O	Me
Oligomycin F	Me	H	OH	H_2	Et
Rutamycin A (Oligomycin D)	H	H	OH	H_2	Me
Rutamycin B	H	H	H	H_2	Me
44-Homooligomycin A	Et	H	OH	H_2	Me
44-Homooligomycin B	Et	H	OH	O	Me



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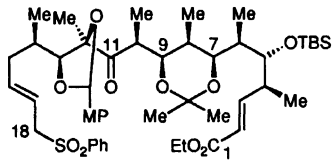

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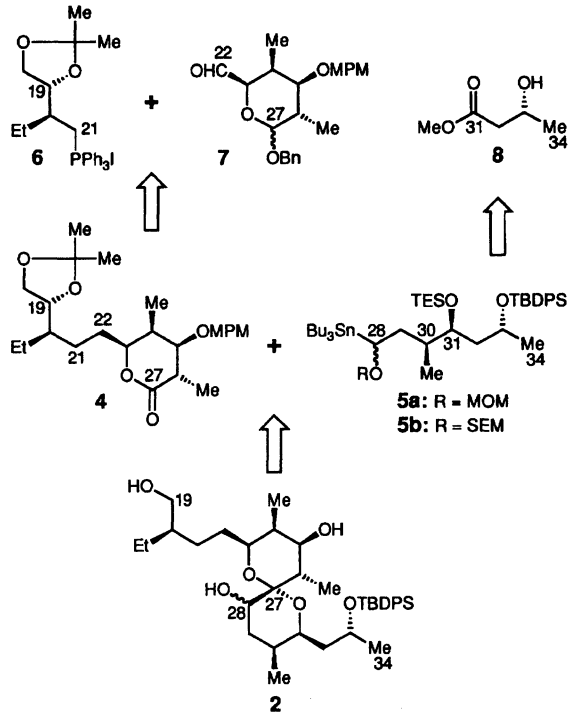
Fig. 1.

Results and Discussion

Synthetic Plan. Figure 2 reveals the plan for the synthesis of the C19-C34 spiroketal portion **2**. It could be assumed that the C27-stereogenic center[7] would be established under acidic equilibrium conditions. We anticipated that the C27-C28 bond could be formed by coupling the C19-C27 lactone **4** and the C28-C34 α-alkoxy organolithium compound derived from the α-alkoxy organostannane compound **5** using Still's methodology.[8] The reason that we adopted this approach is that the resulting coupling product would be transformed to the spiroketal portion of oligomycin B or oligomycins A and C by the oxidation or deoxygenation of the C28-hydroxyl group, respectively. Disconnection of the C21-C22 single, non-chiral bond in lactone **4** led to the C19-C21 Wittig salt **6** and the C22-C27 aldehyde **7**. The organostannane compound **5** would be prepared from (*R*)-methyl 3-hydroxybutyrate **8** by using the Brown's crotylboration[9] in order to build the C30 and the C31 stereocenters.

Figure 3 reveals the plan for the synthesis of the C1-C18 polypropionate portion **3**. Evans and his coworkers have reported on the synthesis of the polypropionate portion of rutamycin B employing a C8-C9 *syn*



5a: R = MOM
5b: R = SEM

Fig. 2.

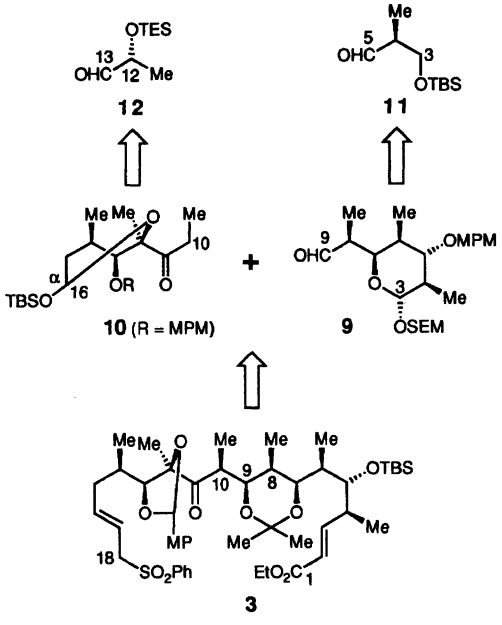
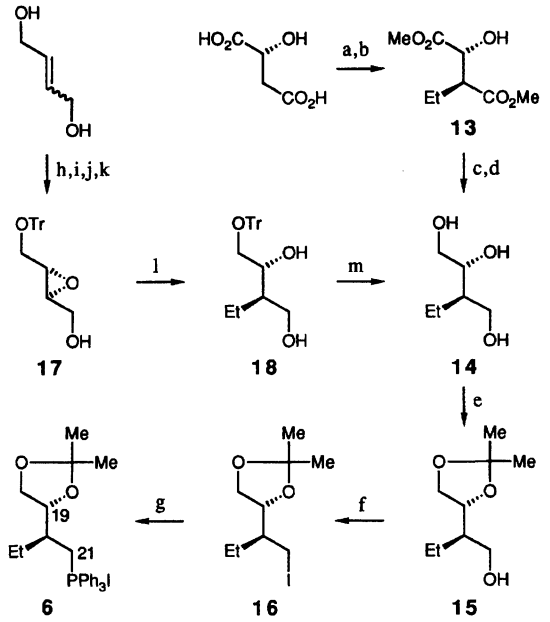


Fig. 3.

aldol coupling between a titanium enolate and an aldehyde.[5b,5c] White and his co-workers have also reported on a conceptually similar synthesis of the polypropionate portion of rutamycin B.[10] We chose a C9-C10 *syn* aldol coupling between the C3-C9 aldehyde **9** and the C10-C16 ketone **10**, both of which have a 6-membered ring in their skeletons. On the basis of molecular model studies, we anticipated that the desired product (C8-C9 *syn*, C9-C10 *syn*) would be preferentially obtained by such a substrate-controlled aldol coupling. Aldehyde **9** would be obtained from the known aldehyde **11** via Keck's crotylstannane addition[11] and Brown's crotylboration.[9] Ketone **10** would be obtained from aldehyde **12** via Brown's crotylboration[9] and a metallated methoxyallene addition.[12]

Synthesis of the C19-C21 Segment. The C19-C21 Wittig salt **6** was prepared by the two different routes shown in Scheme 1. In the first route, a diastereoselective alkylation of malate developed by Seebach[13] was used to construct the C20-stereochemistry. Lithiation of (*R*)-dimethyl malate, prepared from (*R*)-malic acid with MeOH and H_2SO_4 (87% yield), with lithium diisopropylamide (LDA) followed by ethylation with ethyl iodide afforded **13** as a 9:1 mixture of diastereomers in 80% yield.[13] Reduction of this inseparable mixture with diisobutylaluminium hydride



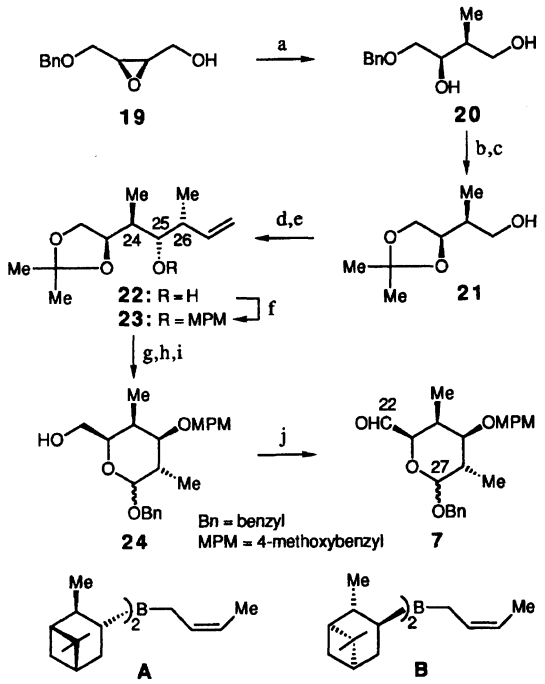
(a) MeOH, H_2SO_4, 65 °C, 8 h, 87%; (b) LDA, THF, -78 °C, 0.5 h, then EtI, -78 to 0 °C, 8 h, 80%; (c) DIBAL, toluene, 0 °C, 1 h, then Ac_2O, Et_3N, DMAP, CH_2Cl_2, 25 °C, 1.5 h, 34% (2 steps); (d) NaOMe, MeOH, 25 °C, 0.5 h; (e) $Me_2C(OMe)_2$, CSA, CH_2Cl_2, 25 °C, 1 h, 72% (2 steps); (f) I_2, Ph_3P, imidazole, CH_2Cl_2, 25 °C, 1 h, 80%; (g) Ph_3P, MeCN, 75 °C, 25 h, 86%; (h) TrCl, Et_3N, CH_2Cl_2, 0 °C, 15 min; (i) PCC, MS 4AP, CH_2Cl_2, 25 °C, 0.5 h; (j) $NaBH_4$, 1 : 4 THF-MeOH, 25 °C, 0.5 h, 66% from 2-butene-1,4-diol; (k) L-(+)-diethyl tartrate, *t*-butyl hydroperoxide in toluene, $Ti(O\text{-}i\text{-}Pr)_4$, MS 4AP, CH_2Cl_2, -20 to 0 °C, 2 h, 80%; (l) EtMgBr, CuCl, THF, 25 °C, 12 h, 98%; (m) 6% HCl-MeOH, 25 °C, 0.5 h, 100%.

Scheme 1.

(DIBAL) afforded the crude triol **14**, which was directly acetylated for convenience of isolation. The resulting triacetate (34% yield from **13**) was hydrolyzed with NaOMe in MeOH to afford **14**, which was subjected to acetonization with 2,2-dimethoxypropane (DMP) and *dl*-10-camphorsulfonic acid (CSA) in CH_2Cl_2 to provide acetonide **15** (72%), the (20*S*)-epimer, and other acetonide regioisomers. The desired acetonide **15** could be separated from others by silica-gel column chromatography. Iodination (I_2, triphenylphosphine, imidazole) of **15** gave iodide **16** in 80% yield, which was treated with triphenylphosphine in acetonitrile to afford the desired C19-C21 Wittig salt **6** in 86% yield.

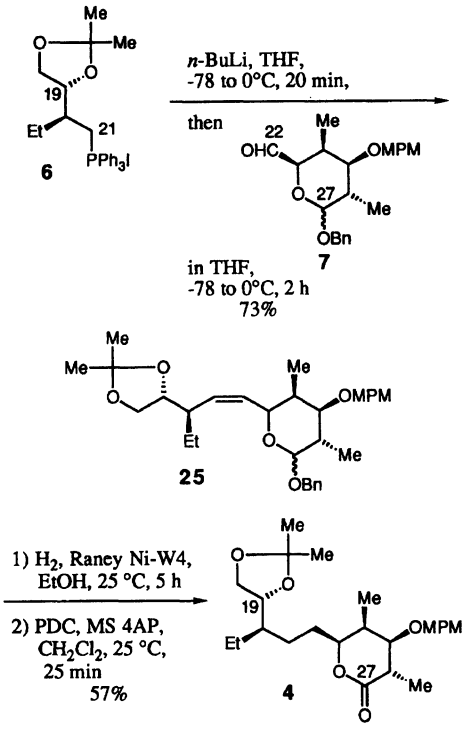
In the second route to **6**, Sharpless asymmetric epoxidation and a regioselective epoxide-opening reaction were used as the key steps. The epoxide **17**, prepared from the *E,Z*-mixture of 2-butene-1,4-diol by the modified Kitagawa's procedure[14] including Sharpless asymmetric epoxidation,[15] was treated with ethylmagnesium bromide in THF in the presence of CuCl[16] to afford a 19:1 mixture of **18** and its regioisomer in 98% combined yield. Their stereochemistries were tentatively assigned as depicted by considering the generality of this type of reaction.[16,17] Both compounds were hydrolyzed to the same triol **14**, which was transformed to the Wittig salt **6** by the same procedure as described above. The optical rotations of iodide **16** and the Wittig salt **6** prepared by the latter procedure were identical with those of iodide **16** and the Wittig salt **6** prepared by the former procedure. In light of a large-scale preparation, the second route proved to be more effective than the first route.

Synthesis of the C22-C27 Segment. The synthesis began with the readily available epoxy-alcohol **19** (94% ee),[18] which was subjected to the regioselective epoxide-opening[16,17] with lithium dimethylcuprate(I) to afford a 4.5:1 mixture of **20** and its regioisomer (Scheme 2). Since this mixture could not be separated, it was subjected to $NaIO_4$-oxidation; from the resulting mixture the inert **20** was easily isolated by silica-gel column chromatography in 66% yield. Debenzylation of **20** followed by regioselective acetonization in acetone in the presence of *p*-toluenesulfonic acid (TSA) afforded acetonide **21** in 95% yield. In this case, acetonization with DMP and CSA in CH_2Cl_2 provided a lower yield (82%) of **21**. Swern oxidation of **21** gave the crude aldehyde. It was essential to employ the *N*-ethyl-*N*-isopropylisopropylamine-workup instead of a triethylamine-workup to prevent a concomitant epimerization.[19] The C25 and C26 stereocenters were then introduced with 15:1 selectivity by coupling of this aldehyde with the Brown's (*Z*)-crotyldiisopinocampheylborane (**A**), prepared from *B*-(−)-methoxydiisopinocampheylborane.[9] The stereochemistry of the major diastereomer **22**[20] was verified by the conversion to **24**. The coupling between the same aldehyde and (*Z*)-crotyldiisopinocampheylborane (**B**), pre-



(a) Me_2CuLi, ether, -40 °C, 1 h, then $NaIO_4$, aq THF, 25 °C, 12 h, 66%; (b) H_2, $Pd(OH)_2$, MeOH, 25 °C, 2 h; (c) acetone, TSA, 25 °C, 5 h, 95% (2 steps); (d) $(COCl)_2$, DMSO, CH_2Cl_2, -78 °C, 40 min, then *i*-Pr_2NEt, -78 to -40 °C, 0.5 h; (e) **A**, THF-ether, -78 °C, 1 h, then aq NaOH, aq H_2O_2, 45 °C, 0.5 h; (f) MPMCl, NaH, DMF, 25 °C, 20 h, 28% (3 steps); (g) OsO_4, NMO, aq acetone, 25 °C, 7 h, then $NaIO_4$, THF-pH 7 phosphate buffer, 25 °C, 6 h, 80%; (h) 1 : 1 : 1 AcOH-H_2O-THF, 25 °C, 15 h, 98%; (i) BnOH, CSA, MeCN, 25 °C, 15 h, 83% (α : β=3 : 1); (j) $(COCl)_2$, DMSO, CH_2Cl_2, -78 °C, 30 min, then Et_3N, -78 to 0 °C, 0.5 h, 100%.

Scheme 2.



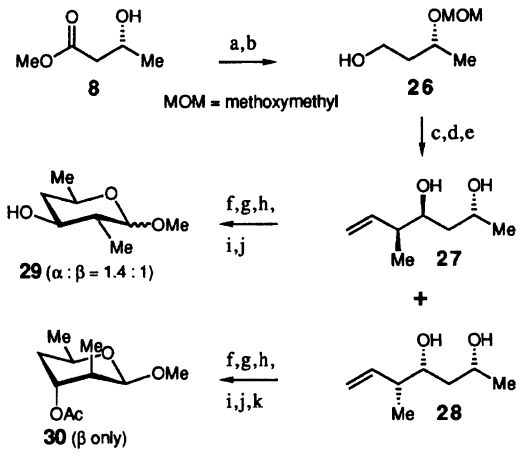
Scheme 3.

pared from *B*-(+)-methoxydiisopinocampheylborane,[9] afforded **22** and the other C25-C26 *syn* product in a 1 : 1 ratio. According to these experiments, the optical purity of **22** was determined to be 97% ee. Protection of **22** with 4-methoxybenzyl chloride (MPMCl) and NaH in DMF afforded **23** and its stereoisomer in 28 and 1.9% yields, respectively, from **21**. Cleavage of the terminal olefin in **23** was realized by osmium tetroxide and a 4-methylmorpholine *N*-oxide (NMO) treatment followed by oxidation with $NaIO_4$ to give aldehyde, which was subjected to deacetonization and subsequent benzyl glycosylation to afford **24** in 65% overall yield as a 3 : 1 mixture of α : β anomers, respectively. The ^{1}H NMR *J* analysis confirmed the complete stereochemistry in **24**α and **24**β, and hence in **22** (see Experimental). A Swern oxidation of **24** furnished the C22-C27 aldehyde **7** in quantitative yield.

Assemblage of the C19-C27 Segment. After an extensive variation of the base, solvent, and temperature, the optimized conditions for the Wittig reaction were a treatment of the Wittig salt **6** with *n*-BuLi in THF at −78 to 0 °C, followed by coupling with the C22-C27 aldehyde **7**, furnishing **25** in 73% yield as a single (*Z*)-isomer (Scheme 3). Further elaboration of **25** into the C19-C27 lactone **4** was accomplished in 57% yield by selective hydrogenolysis[21] and hydrogenation followed by a pyridinium dichromate (PDC) oxidation of the intermediate lactol.

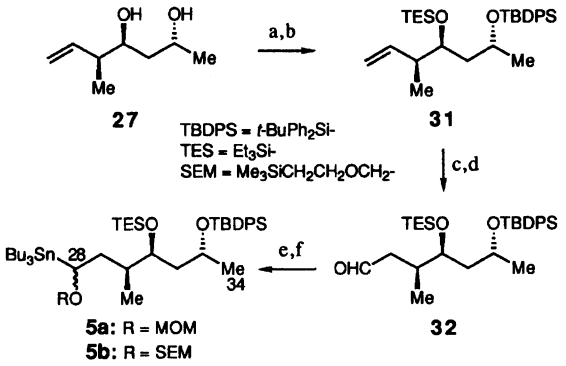
Synthesis of the C28-C34 Segment. The synthesis of the C28-C34 organostannane compound, **5a** or **5b**, began with (*R*)-methyl 3-hydroxybutylate **8** (Scheme 4). Its methoxymethylation (95% yield) with chloromethyl methyl ether (MOMCl) and *N*-ethyl-*N*-isopropylisopropylamine and subsequent $LiAlH_4$ reduction (91% yield) afforded alcohol **26**. This was oxidized with pyridinium chlorochromate (PCC) to give the crude aldehyde quantitatively, which was treated with the Brown's reagent **B** to afford a 3 : 1 mixture of the coupling product. Deprotection of this mixture gave the desired diol **27** (31% yield), which was separated from its stereoisomer **28** (10% yield) by column chromatography. The stereochemistries of both compounds were established by ^{1}H NMR *J* analyses of the 6-membered glycosides, **29** and **30**, derived from **27** and **28**, respectively, as shown in Scheme 4 (see Experimental). Selective silylation of **27** with *t*-butylchlorodiphenylsilane (TBDPSCl) and imidazole followed by a second silylation with chlorotriethylsilane (TESCl) and imidazole afforded **31** in 79% yield from **27** (Scheme 5). Hydroboration of **31** with dicyclohexylborane, followed by oxidation with Dess–Martin periodinane[22] in the presence of pyridine, afforded aldehyde **32** in 98% yield.[23] Finally, the addition of *n*-Bu_3SnLi[8] to **32** followed by etherification furnished the C28-C34 organostannane compound **5a** or **5b** in 75 or 72% yield, each of which was a 1 : 1 mixture at the C28-position.

Assemblage of the C19-C34 Segment. The



(a) MOMCl, *i*-Pr_2NEt, CH_2Cl_2, 25 °C, 42 h, 95%; (b) $LiAlH_4$, THF, 0 °C, 1 h, 91%; (c) PCC, MS 4AP, CH_2Cl_2, 25 °C, 0.5 h; (d) **B**, THF-ether, -78 °C, 3 h, then aq NaOH, aq H_2O_2, 45 °C, 0.5 h; (e) 10% HCl-MeOH, MeOH, 25 °C, 13 h, 31% for **27**, 10% for **28** (3 steps); (f) $PhCH(OMe)_2$, CSA, CH_2Cl_2, 25 °C, 1.5 h; (g) OsO_4, NMO, aq acetone, 25 °C, 2 h, 51% from **27**; (h) H_2, $Pd(OH)_2$, MeOH, 25 °C, 1.2 h; (i) $NaIO_4$, aq THF, 25 °C, 1 h, 92% for 2 steps; (j) 0.3% HCl-MeOH, 25 °C, 1 h, 84%; (k) Ac_2O, DMAP, benzene, 25 °C, 14 h, 100%.

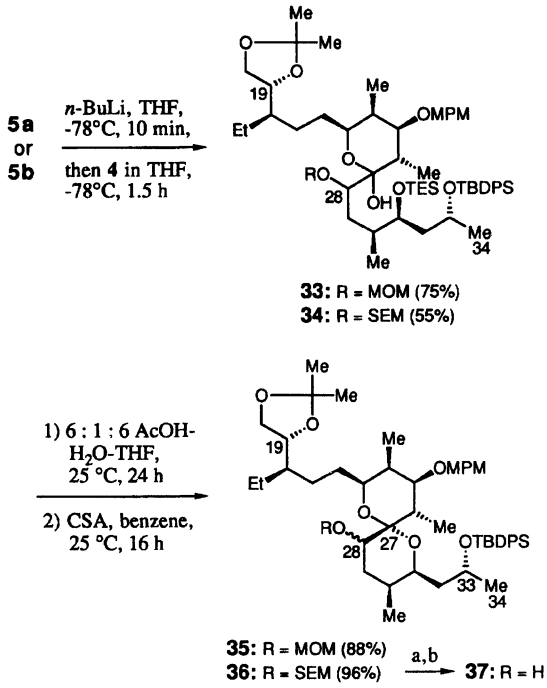
Scheme 4.



(a) TBDPSCl, imidazole, DMF, 25 °C, 14 h; (b) TESCl, imidazole, DMF, 25 °C, 20 min, 79% (2 steps); (c) dicyclohexylborane, THF, 0 °C, 40 min, then aq H_2O_2-aq NaOH, 40 °C, 20 min, 100%; (d) Dess-Martin periodinane, pyridine, CH_2Cl_2, 25 °C, 1 h, 98%; (e) *n*-Bu_3SnH, LDA, THF, 0 °C, 15 min, then **32**, -78 °C, 40 min; (f) to **5a**: MOMCl, *i*-Pr_2NEt, CH_2Cl_2, 25 °C, 19 h, 75% (2 steps). to **5b**: (2-trimethylsilylethoxy)methyl chloride (SEMCl), *i*-Pr_2NEt, CH_2Cl_2, 25 °C, 15 h, 73% (2 steps).

Scheme 5.

coupling of the C19-C27 and the C28-C34 subunits was realized by lithiation[8] of **5a** or **5b** with *n*-BuLi in THF at −78 °C, followed by an immediate addition of lactone **4** to afford the adduct **33** (75%) or **34** (55%) (Scheme 6). Selective desilylation of the each adduct with 6 : 1 : 6 acetic acid–H_2O–THF followed by cyclization with CSA in benzene afforded **35** (88%) or **36** (96%). Both **35** and **36** consisted of a 1 : 1 separable mixture at the C28-position.[24] Since selective deprotection of the MOM ether in **35** resulted in a failure, the (2-trimethylsilylethoxy)methyl (SEM) ether compound **36** was selected for further transformation. Removal[25] of both protecting groups of the C28 and C33-hydroxyl

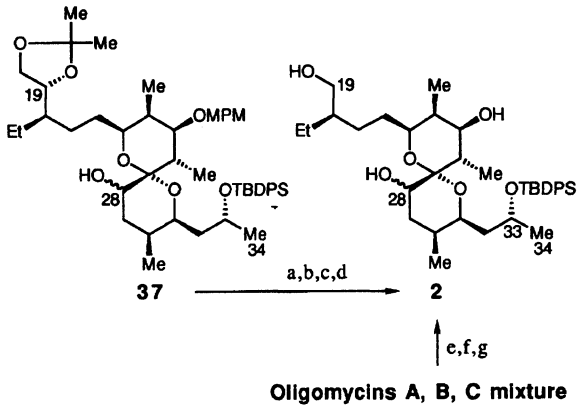


(a) *n*-Bu_4NF, MS 4AP, *N,N'*-dimethylpropyleneurea, 45 °C, 23 h, 60%; (b) TBDPSCl, imidazole, DMF, 40 °C, 5 h, 70%.

Scheme 6.

groups in each of the C28-epimers **36** followed by resilylation of the C33-hydroxyl group furnished the corresponding C28-epimers **37** in 42 and 40% yields, respectively. We believe that these compounds would be useful synthetic intermediates for the total synthesis of oligomycins.[26] The C27-configuration in the less polar epimer of **37** was confirmed by its conversion to **2** (vide infra). The C27-configuration in other compounds (**35**, **36**, and the more polar epimer of **37**) was assumed, as depicted in Scheme 6, by considering a general feature in configurational stabilities of spiroketal compounds.

Determination of the Absolute Stereochemistry of Oligomycin B. We considered that the degradation[3d,27] product **2** of oligomycins was suitable for a comparison with a synthetic material. Commercially available oligomycins A, B, and C mixture (A : B : C = 75 : 15 : 10, Aldrich) was subjected to silylation (TBDPSCl, imidazole, DMF, 33 °C, 88 h), ozonolysis (O_3/O_2, EtOAc, −78 °C, 5 min, then $NaBH_4$, THF, −78 °C to 25 °C, 21 h), and ester cleavage reaction (DIBAL, CH_2Cl_2, −78 to −40 °C, 1 h) (Scheme 7). The obtained **2** (12% yield) consisted of a 10 : 1 separable mixture at the C28-position.[24] On the other hand, the less polar epimer of our key intermediate **37** was transformed to **2** by the following four-step sequence: (1) TSA, MeOH, 25 °C, 4 h; (2) $NaIO_4$, THF-pH 7 phosphate buffer, 25 °C, 1 h; (3) $NaBH_4$, MeOH, 25 °C, 0.5 h; (4) 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ), aq CH_2Cl_2, 25 °C, 20 min,[21] 75% overall yield. The synthetic **2** was identical in all respects (^1H NMR, IR, $[\alpha]_D$, and TLC mobilities) with the naturally de-



(a) TSA, MeOH, 25 °C, 4 h; (b) $NaIO_4$, THF-pH 7 phosphate buffer, 25 °C, 1 h; (c) $NaBH_4$, MeOH, 25 °C, 0.5 h; (d) DDQ, aq CH_2Cl_2, 25 °C, 20 min, 75% from **37**; (e) TBDPSCl, imidazole, DMF, 33 °C, 88 h; (f) O_3/O_2, EtOAc, -78 °C, 5 min, then $NaBH_4$, THF, -78 to 25 °C, 21 h; (g) DIBAL, CH_2Cl_2, -78 to -40 °C, 1 h, 12% from oligomycins A, B, C mixture.

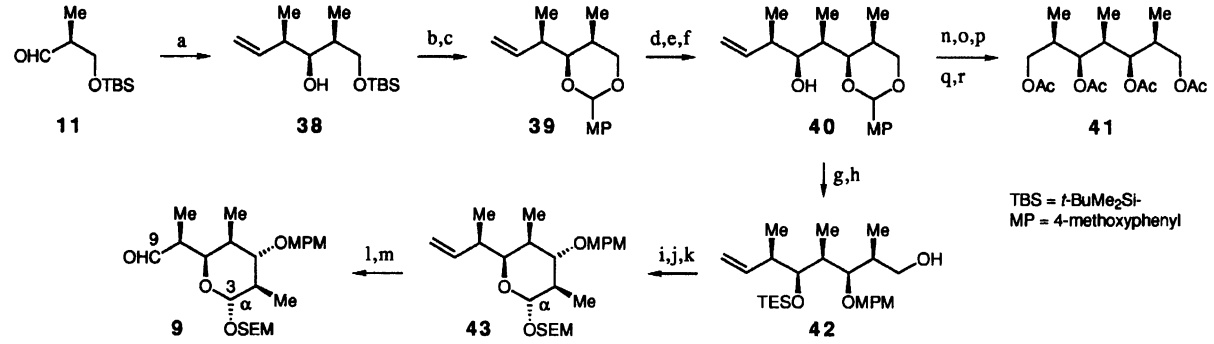
Scheme 7.

rived **2** (the major one of the 10:1 mixture), which implies that the absolute stereochemistry of oligomycin B (**1b**) is as depicted in Fig. 1.

Synthesis of the C3-C9 Segment. The synthesis of the C3-C9 aldehyde **9** began with the readily available aldehyde **11** (Scheme 8).[11] A crotylstannane addition (n-$Bu_3SnCH_2CH{=}CHCH_3$, $BF_3{\cdot}OEt_2$)[11a] to **11** afforded **38**[11] in 80% yield with 11:1 diastereoselectivity.[10,11a] Deprotection of **38** followed by methoxybenzylidenation of the resulting diol[28] afforded **39** in 83% yield. An oxidative cleavage of the olefin in **39** and the resulting aldehyde was subjected to coupling with Brown's reagent **A** to afford **40** in a 50% overall yield. Another isomer has not been fully characterized because it was contaminated with impurities. The ratio of the coupling products, therefore, has not been determined. The stereochemistry of **40** was verified by its conversion to **41**, which proved to be a meso compound by the ^{1}H NMR spectrum. Silylation of **40** with TESCl, followed by a DIBAL treatment,[29] gave alcohol **42** in 90% yield. Swern oxidation of **42** and subsequent desilylation and glycosylation afforded **43** and its β-isomer in 39 and 34% overall yields, respectively. Finally, an oxidative cleavage of the olefin in **43** furnished the C3-C9 aldehyde **9** in 91% yield. Since the β-isomer of **9**, prepared from the β-isomer of **43**, proved to be unsuitable for the next crucial aldol coupling (vide infra), it was necessary to recycle the β-isomer of **43** to **43** by the two-step sequence [(1) 9:1 (95:5 MeCN–46% aq HF)–H_2O, 25 °C, 2.5 h, 73%; (2) SEMCl, i-Pr_2NEt, CH_2Cl_2].

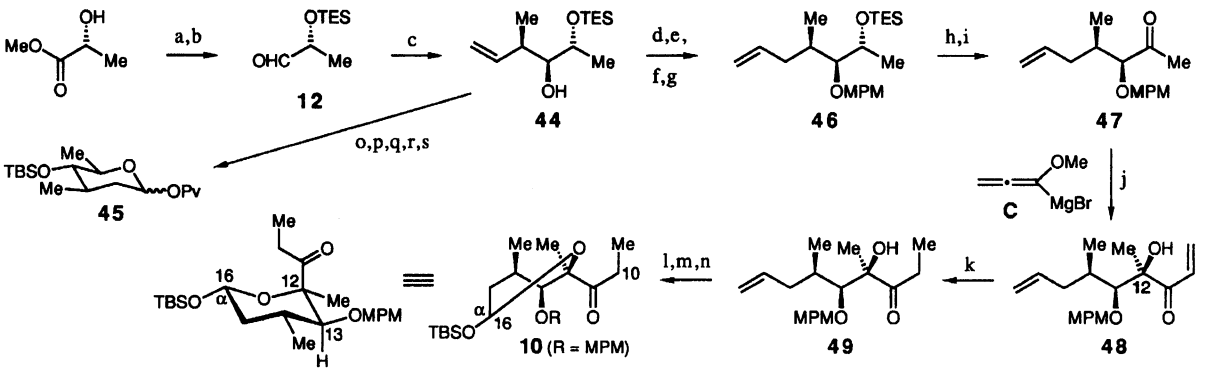
Synthesis of the C10-C16 Segment. The synthesis of the C10-C16 ketone **10** began with aldehyde **12** (Scheme 9). Aldehyde **12** was prepared from methyl (R)-(+)-lactate by silylation with TESCl (93% yield) and subsequent DIBAL reduction (100% yield), which was used without purification. The treatment of **12** with Brown's reagent **A** afforded **44** in 75% yield as the only adduct. The stereochemistry of **44** was established by its conversion to the 6-membered **45** (see Experimental). The adduct **44** was transformed to **46** by the following four-step sequence: (1) protection as its 4-methoxybenzyl ether;[30,31] (2) hydroboration and oxidative work-up; (3) Dess–Martin oxidation; (4) Wittig methylenation, 45% overall yield. Desilylation of **46** followed by oxidation gave ketone **47** in 95% yield. The C12-stereocenter was introduced by an α-chelation-controlled coupling of this ketone **47** with a metallated methoxyallene reagent **C**, prepared from lithiated methoxyallene[12] by transmetallation with $MgBr_2{\cdot}OEt_2$, to afford the adduct, which was hydrolyzed to give **48** in 70% yield as the sole product. The C12-configuration in **48** was confirmed by subsequent transformations. A selective reduction of **48** was realized with L-selectride in THF at −100 °C under high dilution conditions to afford **49** in 92% yield. Finally, an oxidative cleavage of olefin in **49** followed by silylation gave a 1:1 mixture of the α-anomer **10** and its β-isomer in 97% combined yield, which could be separated by silica-gel column chromatography. The ^{1}H NMR spectrum of **10** shows that it exists in a chair conformation. Furthermore, irradiation of the doublet at 3.09 ppm, corresponding to the signal of the H-13, caused a 3.7% NOE enhancement of the C12-Me signal at 1.46 ppm, which confirmed the C12-configuration as depicted in Scheme 9. The β-isomer of **10** could be recycled to **10** by desilylation (n-Bu_4NF, AcOH, THF, 25 °C, 1 h, 85%) and resilylation.

Aldol Coupling. With both units in hand, we turned our attention to a crucial aldol coupling. We investigated a number of conditions employing several model ethyl ketones and model aldehydes.[32] Among potassium, sodium, lithium, boron, titanium, and tin enolates derived from model ethyl ketones, potassium enolate was most satisfactory. Using potassium enolate derived from **10** and potassium bis(trimethylsilyl)-amide, aldol coupling with many kinds of aldehydes was investigated.[32] Some representative examples are displayed in Table 1. It is noteworthy that the desired C8-C9 *syn*, C9-C10 *syn* product was obtained as a major, or a sole, product in Entries 1, 2, and 6. This result indicates, as we anticipated, that the potassium enolate of **10** seems to have the ability to distinguish diastereofaces of an aldehyde. It was disappointing, however, that an aldol coupling between **10** and aldehyde **52**, which bears the whole skeleton necessary for the C1-C9 segment, afforded preferentially the undesired C8-C9 *anti*, C9-C10 *syn* product (Entries 4 and 5).[32] Since potassium enolates caused an unpleasant decomposition of aldehydes in some cases, transmetallation reactions were investigated. Among zinc, cerium, and magnesium enolates prepared by transmetallation from potassium enolate, zinc enolate[33] was most satisfactory. Although the yield was acceptable, the diastereoselectivity was disappointing (Entries 3 and 7). However,



(a) n-$Bu_3SnCH_2CH{=}CHCH_3$, $BF_3{\cdot}OEt_2$, CH_2Cl_2, -78 °C, 0.5 h, 80%; (b) n-Bu_4NF, THF, 25 °C, 2 h; (c) $MeOPhCH(OMe)_2$, CSA, CH_2Cl_2, 25 °C, 3 h, 83% (2 steps); (d) OsO_4, NMO, aq acetone, 25 °C, 20 h, 84%; (e) $NaIO_4$, aq THF, 25 °C, 1 h; (f) A, THF-ether, -78 °C, 2 h, then aq NaOH, aq H_2O_2, 52 °C, 0.5 h, 60% (2 steps); (g) TESCl, imidazole, DMF, 50 °C, 3 h, 92%; (h) DIBAL, CH_2Cl_2, 0 °C, 0.5 h, 98%; (i) $(COCl)_2$, DMSO, CH_2Cl_2, -78 °C, 0.5 h, then Et_3N, -78 to 0 °C, 0.5 h; (j) 9 : 1 (95 : 5 MeCN-46% aq HF)-H_2O, 25 °C, 0.5 h, 82% (2 steps); (k) 2-(trimethylsilyl)ethoxymethyl chloride (SEMCl), i-Pr_2NEt, CH_2Cl_2, 25 °C, 20 h, 89% (α : β=1.1 : 1); (l) OsO_4, NMO, aq acetone, 25 °C, 7 h, 95%; (m) $NaIO_4$, aq THF, 25 °C, 50 min, 96%; (n) OsO_4, NMO, aq acetone, 25 °C, 2 h, 87%; (o) $NaIO_4$, aq THF, 25 °C, 0.5 h, 71%; (p) $NaBH_4$, MeOH, 25 °C, 0.5 h, 94%; (q) H_2, $Pd(OH)_2$, EtOH, 25 °C, 1 h; (r) Ac_2O, DMAP, pyridine, 25 °C, 45 min, 90% (2 steps).

Scheme 8.



(a) TESCl, imidazole, DMF, 25 °C, 2.5 h, 93%; (b) DIBAL, CH_2Cl_2, -78 °C, 3.5 h, 100%; (c) A, THF-ether, -78 °C, 1.5 h, then aq NaOH, aq H_2O_2, 53 °C, 20 min, 75%; (d) $MPMOC(=NH)CCl_3$, CSA, hexane-CH_2Cl_2, 25 °C, 72 h, 55%; (e) dicyclohexylborane, THF, 0 °C, 1 h, then aq NaOH, aq H_2O_2, 51 °C, 20 min, 97%; (f) Dess-Martin periodinane, pyridine, CH_2Cl_2, 25 °C, 1 h; (g) $Ph_3P{=}CH_2$, benzene, 45 °C, 12 h, 85% (2 steps); (h) n-Bu_4NF, THF, 25 °C, 1.5 h; (i) Dess-Martin periodinane, CH_2Cl_2, 25 °C, 0.5 h, 95% (2 steps); (j) C, ether, -78 °C, 2 h, then 1 : 5 aq HCl (0.1 M)-THF, 25 °C, 10 min, 70%; (k) 1.1 molar amount of 0.1M cooled (-100 °C) L-selectride in THF, THF (0.006M for **48**), -100 °C, 1 h, 92%; (l) OsO_4, NMO, aq acetone, 25 °C, 12 h; (m) $NaIO_4$, aq THF, 25 °C, 1 h, 98% (2 steps); (n) TBSCl, imidazole, DMF, 40 °C, 12 h, 97% (α : β = 1 : 1); (o) TBSCl, Et_3N, DMF, 25 °C, 14 h, 86%; (p) dicyclohexylborane, THF, 0 °C, 1 h, then aq NaOH, aq H_2O_2, 40 °C, 20 min, 92%; (q) PCC, MS4AP, CH_2Cl_2, 25 °C, 0.5 h, 70%; (r) 5 : 1 : 5 AcOH-H_2O-THF, 25 °C, 9 h, 97%; (s) PvCl, DMAP, benzene, 25 °C, 3 h, 70% (α : β = 1 : 1).

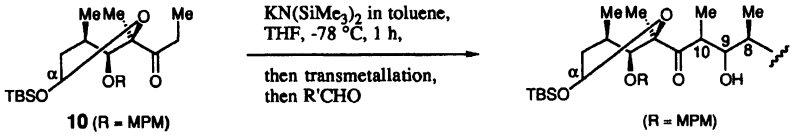
Scheme 9.

the reaction proceeded cleanly and the products could be easily recovered by silica-gel column chromatography. Although a rationale for diastereoselectivity has not been unequivocally assumed, ketone **10** and aldehyde **9** proved to be the best pair among the four possible combinations of **10**, the β-isomer of **10**, **9**, and the β-isomer of **9**.

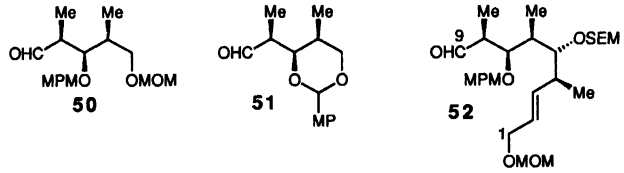
Assemblage of the C1-C18 Segment. As shown in Table 1, ketone **10** was treated with potassium bis(trimethylsilyl)amide in THF at −78 °C, and the resulting enolate was transmetallated with zinc chloride, to which was added aldehyde **9**, furnishing **53** in 48% yield along with a 37% yield of its stereoisomer (Scheme 10). The stereochemistry of **53** was verified by its conversion to **55** via **54**, which proved to be a meso compound based on the ^1H NMR spectrum (see Experimental). The transformation of **53** to the target compound **3** was realized as follows (Scheme 11). Selective desilylation of **53** followed by Wittig olefination with (ethoxycarbonylmethylene)triphenylphosphorane afforded **56** in 92% yield. Protection of the C9-hydroxyl group in **56** as its silyl ether and subsequent DIBAL reduction afforded **57** in 83% yield, which underwent chlorination and sulfonylation to give **58** in 87% yield. Desilylation of **58** and the second Wittig olefination gave **59** in 79% yield. Acetonization of **59** with DMP and CSA and the subsequent DDQ treatment and final silylation furnished **3** in 63% overall yield.

Studies toward the total synthesis of oligomycins are now in progress.

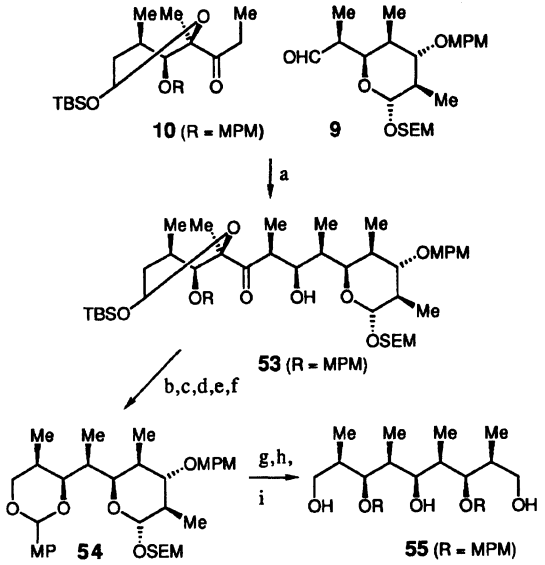
Table 1. Aldol Coupling between **10** and Aldehydes



Entry	R'CHO[a]	Transmetallation	Diastereomer ratio	Stereochemistry of the major product	Combined yield/%
1	**50**	—[b]	5 : 1	C8-C9 *syn*, C9-C10 *syn*	28
2	**51**	—[b]	Sole	C8-C9 *syn*, C9-C10 *syn*	72
3	**51**	$ZnCl_2$ in ether, −78 °C, 1 h, then **51** in ether, −78 °C, 0.5 h	2 : 1	C8-C9 *syn*, C9-C10 *syn*	70
4	**52**	—[b]	Sole	C8-C9 *anti*, C9-C10 *syn*	20
5	**52**	$ZnCl_2$ in ether, −78 to −45 °C, 0.5 h, then **52** in ether, −45 °C, 20 min	5 : 1	C8-C9 *anti*, C9-C10 *syn*	42
6	**9**	—[b]	Sole	C8-C9 *syn*, C9-C10 *syn*	36
7	**9**	$ZnCl_2$ in ether, −78 to −45 °C, 0.5 h, then **9** in THF, −45 °C, 25 min, −20 °C, 15 min	1.3 : 1	C8-C9 *syn*, C9-C10 *syn*	85

a) R'CHO= 

b) Aldehyde in THF was added at −78 °C to a potassium enolate and the mixture was stirred at −78 °C for 20 min.



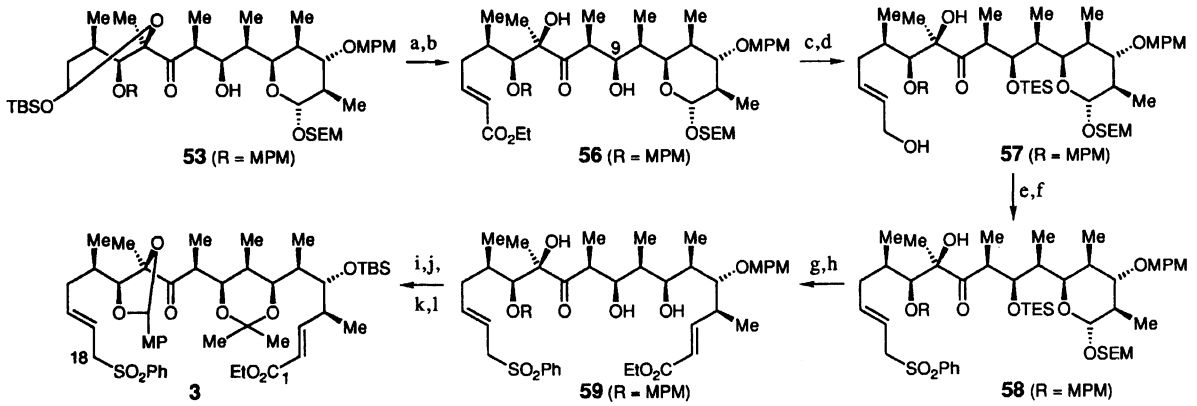
(a) **10** in THF, 0.5M $KN(SiMe_3)_2$ in toluene, -78°C, 1 h, then 1M $ZnCl_2$ in ether, -45°C, 0.5 h, then **9** in THF, -45°C, 25 min, -20°C, 15 min, 48% for **53**, 37% for its stereoisomer; (b) *n*-Bu_4NF, AcOH, THF, 25 °C, 21 h, 98%; (c) $LiBH_4$, MeOH, 25 °C, 4.5 h, 78%; (d) $NaIO_4$, 2 : 1: 1 THF-H_2O-MeOH, 25 °C, 4 h, 77%; (e) $NaBH_4$, MeOH, 25 °C, 0.5 h, 100%; (f) $MeOPhCH(OMe)_2$, CSA, CH_2Cl_2, 25 °C, 1 h, 100%; (g) DIBAL, CH_2Cl_2, -78 to -30°C, 0.5 h, 100%; (h) 9 : 1 (95 : 5 MeCN-46% aq HF)-H_2O, 25 °C, 0.5 h, 83%; (i) $LiBH_4$, MeOH, 25 °C, 3 h, 86%.

Scheme 10.

Experimental

The melting points were determined on a micro hot-stage Yanaco MP-S3 and were uncorrected. Optical rotations were measured on a JASCO DIP-360 photoelectric polarimeter in chloroform, unless otherwise noted. IR spectra were recorded on a BIO RAD DIGILAB FTS-65 spectrometer in $CHCl_3$ at 25 °C and ^1H NMR spectra were on a JEOL GSX270 spectrometer in $CDCl_3$ at 25 °C using TMS as an internal standard, unless otherwise noted. Mass spectra (EI) were recorded on a JEOL JMS-DX302 mass spectrometer. Silica-gel TLC and column chromatography were performed on a Merck TLC 60F-254 and a Fuji–Davison BW-820MH, respectively. Air- and/or moisture-sensitive reactions were carried out under an atmosphere of argon with oven-dried glassware. In general, the organic solvents were purified and dried by appropriate procedures, and evaporation and concentration were carried out under reduced pressure blow 30 °C, unless otherwise noted.

(2*R*,3*S*)-3-(Iodomethyl)-1,2-isopropylidenedioxypentane (16). To a stirred solution of **13**[13] (9.92 g, 52.2 mmol; a 9:1 mixture of diastereomers) in dry toluene (63 ml) was added at 0 °C 1.02 M DIBAL in toluene (180 ml, 184 mmol) (M=mol dm^{-3}). After 1 h at 0 °C, 1:1 MeOH–toluene (80 ml) and 1 : 1 water–MeOH (50 ml) were slowly added, and the mixture was stirred at 25 °C for 0.5 h. After concentration, the residue was suspended in dry CH_2Cl_2 (80 ml); to this were added at 0 °C triethylamine (26.0 ml, 186 mmol), acetic anhydride (29.0 ml, 307 mmol), and DMAP (20.0 g, 165 mmol). After 1.5 h at 25 °C, ethanol (18 ml) was added, and the mixture was stirred at 25 °C for 0.5 h. To this was added potassium sodium tartrate tetrahydrate (250 g) in water (600 ml), and the mixture was stirred at 25 °C for 3.5 h. The mixture was extracted with CH_2Cl_2 and the extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chro-



(a) *n*-Bu_4NF, AcOH, THF, 25 °C, 21 h, 98%; (b) $Ph_3P{=}CHCO_2Et$, benzene, 55 °C, 12 h, 94%; (c) TESOTf, 2,6-lutidine, CH_2Cl_2, -30 °C, 0.5 h, 89%; (d) DIBAL, CH_2Cl_2, -78 °C, 0.5 h, 93%; (e) LiCl, collidine, MsCl, DMF, 0 °C, 2.5 h; (f) $PhSO_2Na{\cdot}2H_2O$, DMF, 45 °C, 20 h, 87% (2 steps); (g) 9 : 1 (95 : 5 MeCN-46% aq HF)-H_2O, 25 °C, 1 h, 90%; (h) $Ph_3P{=}CHCO_2Et$, benzene, 50 °C, 48 h, 88%; (i) $Me_2C(OMe)_2$, CSA, CH_2Cl_2, 25 °C, 0.5 h, 95%; (j) DDQ, 19 : 1 CH_2Cl_2-(1 : 2 0.1M aq KH_2PO_4-0.1M aq Na_2HPO_4), 0 °C, 0.5 h; (k) DDQ, CH_2Cl_2, 0 °C, 1.5 h, 70% (2 steps); (l) TBSOTf, 2,6-lutidine, CH_2Cl_2, 25 °C, 2 h, 95%.

Scheme 11.

matographed on silica gel (400 g) with 6 : 1 benzene–ethyl acetate to afford the triacetate of **14** (4.62 g, 34% from **13**) as a colorless syrup [R_f=0.38 (6 : 1 benzene–ethyl acetate); IR 3025, 2970, 1726, 1371, 1229, and 1042 cm^{-1}; ^1H NMR δ=0.97 (3H, t, J=7.6 Hz, 3×H-5), 1.30—1.50 (2H, m, 2×H-4), 1.80—2.00 (1H, m, H-3), 2.06 and 2.07 (6H and 3H, each s, 3×OAc), 4.05—4.20 (3H, m, three of 2×CH_2OAc), 4.34 (1H, dd, J=12.0 and 3.4 Hz, one of CH_2OAc), and 5.20 (1H, ddd, J=7.0, 5.8, and 3.4 Hz, H-2). Found: C, 55.14; H, 7.80%. Calcd for $C_{12}H_{20}O_6$: C, 55.37; H, 7.74%]. This (2.21 g, 8.49 mmol) was dissolved in dry MeOH (33 ml) and to this was added at 0 °C 4.92 M NaOMe in MeOH (5.50 ml, 27.1 mmol). After 0.5 h at 25 °C, the reaction mixture was neutralized with CG50; the insoluble materials were filtered and washed with MeOH. The combined filtrate and washings were concentrated. To the residue **14** (1.14 g) dissolved in dry CH_2Cl_2 (25 ml) were added DMP (3.10 ml, 25.3 mmol) and CSA (192 mg, 1.16 mmol) and the mixture was stirred at 25 °C for 1 h. The reaction mixture was neutralized with triethylamine and the mixture was concentrated. The residue was chromatographed on silica gel (150 g) with 6 : 1 benzene–acetone to afford **15** (1.07 g, 72%) as a colorless syrup [R_f=0.41 (6 : 1 benzene–acetone); ^1H NMR δ=0.95 (3H, t, J=7.7 Hz, CH_2Me), 1.20—1.30 (2H, m, CH_2Me), 1.37 and 1.43 (each 3H, each s, CMe_2), 1.55—1.65 (1H, m, H-2), 2.78 (1H, dd, J=3.5 and 7.8 Hz, OH), 3.60—3.85 (3H, m), and 4.00—4.15 (2H, m)]. To a stirred solution of **15** (1.12 g, 6.43 mmol) in dry CH_2Cl_2 (25 ml) were added at 0 °C triphenylphosphine (2.33 g, 8.92 mmol), imidazole (1.33 g, 19.5 mmol), and iodine (2.13 g, 8.39 mmol). After 1 h at 25 °C, the reaction mixture was diluted with hexane; the new mixture was washed with saturated aqueous $Na_2S_2O_3$ and NaCl, dried, and concentrated. The residue was chromatographed on silica gel (95 g) with 12 : 1 hexane–ethyl acetate to afford **16** (1.46 g, 80%) as a colorless syrup: R_f=0.28 (12 : 1 benzene–ethyl acetate); $[\alpha]_D^{36}$ +6.9° (c 0.93); IR 2990, 2988, 2936, 1381, 1374, 1264, 1228, 910, and 851 cm^{-1}; ^1H NMR δ=0.90 (3H, t, J=7.3 Hz, 3×H-5), 1.00—1.20 (2H, m, 2×H-4), 1.36 and 1.39 (each 3H, each s, CMe_2), 3.40 (1H, dd, J=10.0 and 3.2 Hz, one of CH_2I), 3.54 (1H, dd, J=10.0 and 4.7 Hz, one of CH_2I), 3.68 (1H, dd, $J_{gem}=J_{1,2}$=7.6 Hz, H-1), 3.90 (1H, ddd, $J_{1',2}$=6.0 Hz and $J_{2,3}$=7.6 Hz, H-2), and 4.07 (1H, dd, H-1'). Found: C, 38.26; H, 5.96%. Calcd for $C_9H_{17}IO_2$: C, 38.04; H, 6.03%.

[(2*S*,3*R*)-2-Ethyl-3,4-(isopropylidenedioxy)butyl]-triphenylphosphonium Iodide (6). A mixture of **16** (464 mg, 1.63 mmol), triphenylphosphine (2.25 g, 8.58 mmol), and dry acetonitrile (12 ml) was stirred at 75 °C for 25 h. After cooling to 25 °C, the insoluble materials were filtered and washed with acetonitrile. The combined filtrate and washings were washed with hexane several times. The acetonitrile layer was concentrated and the residual solids were washed with hexane to afford **6** (769 mg, 86%) as colorless solids: R_f=0.41 (7 : 1 $CHCl_3$–MeOH); mp 211—220 °C (colorless plates from 7 : 1 $CHCl_3$–ethyl acetate); $[\alpha]_D^{31}$ −48.5° (c 0.40); IR 2940, 1439, 1234, 1111, and 723 cm^{-1}; ^1H NMR δ=0.78 (3H, t, J=7.7 Hz, CH_2Me), 1.16 and 1.22 (each 3H, each s, CMe_2), 1.25—1.45 (2H, m, CH_2Me), 1.85—2.00 (1H, m, H-2), 3.43 (1H, dd, $J_{gem}=J_{3,4}$=8.5 Hz, H-4), 3.63 (1H, ddd, J_{gem}=13.8 Hz, $J_{1,2}$=6.7 Hz, and $J_{1,P}$=15.8 Hz, H-1), 4.07 (1H, dd, $J_{3,4'}$=5.9 Hz, H-4'), 4.15 (1H, ddd, $J_{1',2}$=5.5 Hz and $J_{1',P}$=16.6 Hz, H-1'), and 4.35 (1H, ddd, $J_{2,3}$=8.5 Hz, H-3). Found: C, 59.40; H, 5.99%. Calcd for $C_{27}H_{32}IO_2P$: C, 59.35; H, 5.90%.

Preparation of 6 from 2-Butene-1,4-diol. The epoxide **17** [18.5 g, 53.4 mmol; R_f=0.50 (1 : 1 hexane–ethyl acetate); mp 107—108 °C (not recrystallized); $[\alpha]_D^{30}$ −7.0° (c 0.80); ^1H NMR δ=1.75 (1H, dd, J=5.8 and 8.0 Hz, OH), 3.09—3.23 (3H, m), 3.33—3.43 (1H, m), 3.62 (1H, ddd, J=12.2, 8.0, and 4.0 Hz, H-1), 3.93 (1H, ddd, J=12.2, 5.8, and 2.4 Hz, H-1'), and 7.20—7.48 (15H, m, Tr). Found: m/z 346.1571 (M^+). Calcd for $C_{23}H_{22}O_3$: M, 346.1569] prepared from 2-butene-1,4-diol by the Kitagawa's procedure,[14] was dissolved in dry THF (185 ml). To this were added at 0 °C CuCl (2.20 g, 22.2 mmol) and 3 M EtMgBr in ether (90.0 ml, 270 mmol) and the mixture was stirred at 25 °C for 12 h. Saturated aqueous NH_4Cl was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (550 g) with 1 : 1 hexane–ethyl acetate to afford **18** and its regioisomer (20.1 g, 98%; the ratio of **18** and its regioisomer=19 : 1) as colorless

syrups [R_f=0.51 for **18**, 0.48 for its regioisomer (1:1 hexane–ethyl acetate); ^{1}H NMR for **18** δ=0.85 (3H, t, J=7.0 Hz, Me), 1.20—1.33 (2H, m, CH_2Me), 1.38—1.50 (1H, m, H-2), 2.75 (1H, t, J=6.0 Hz, OH), 2.78 (1H, d, J=3.4 Hz, OH), 3.22 (1H, dd, J_{gem}=9.8 Hz and $J_{3,4}$=8.0 Hz, H-4), 3.29 (1H, dd, $J_{3,4'}$=3.6 Hz, H-4'), 3.62 (1H, ddd, J_{gem}=11.0 Hz and $J_{1,2}$=6.0 Hz, H-1), 3.71 (1H, ddd, $J_{1',2}$=3.0 Hz, H-1'), 3.76—3.85 (1H, m, H-3), and 7.21—7.46 (15H, m, Tr); ^{1}H NMR for the regioisomer δ=0.83 (3H, t, J=7.0 Hz, Me), 1.25—1.67 (3H, m), 2.40 (1H, br, OH), 3.19—3.26 (2H, m), 3.33 (1H, dd, J=10.0 and 3.0 Hz), 3.40—3.75 (3H, m), and 7.20—7.46 (15H, m, Tr)]. This mixture (19.5 g, 51.8 mmol) was dissolved in dry MeOH (60 ml) and to this was added 10% HCl–MeOH (90 ml) at 25 °C. After 0.5 h at 25 °C, the reaction mixture was concentrated and the residue was chromatographed on silica gel (500 g) with 6:1 $CHCl_3$–MeOH to afford **14** (6.95 g, 100%) as a colorless syrup. This was transformed to **6** via **15** and **16** by the same procedure in the first route; all data of **16** and **6** were identical with those of that prepared by the first route.

(3*R*, 4*S*, 5*S*, 6*R*)-6, 7-(Isopropyridenedioxy)-4-(4-methoxybenzyloxy)-3, 5-dimethyl-1-heptene (23). To a suspension of CuI (42.8 g, 220 mmol) in dry ether (520 ml) was added at −20 °C 1.15 M MeLi in ether (379 ml, 436 mmol). After 0.5 h at −20 °C, **19**[15,18] (8.73 g, 44.9 mmol) in dry ether (130 ml) was added at −40 °C. After 1 h at −40 °C, 2:1 saturated aqueous NH_4Cl–28% aqueous ammonia (800 ml) was added; the mixture was extracted with ether. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was dissolved in THF (284 ml) and water (94.5 ml); to this was added $NaIO_4$ (9.6 g, 45 mmol). After 12 h at 25 °C, water was added and the mixture was extracted with CH_2Cl_2. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (300 g) with 1:2 hexane–ethyl acetate to afford **20** (6.24 g, 66%) as a colorless syrup [R_f=0.30 (1:2 hexane–ethyl acetate); ^{1}H NMR δ=0.95 (3H, d, J=7.5 Hz, Me), 1.80—1.96 (1H, m), 2.28 (1H, t, J=5.5 Hz, OH), 2.58 (1H, d, J=4.0 Hz, OH), 3.54 (2H, d, J=6.0 Hz, CH_2OBn), 3.60—3.75 (2H, m), 4.01 (1H, m), 4.57 (2H, br s, OCH_2Ph), and 7.25—7.40 (5H, m, Ph)]. A mixture of **20** (6.08 g, 28.9 mmol), 20% Pd-$(OH)_2$ on carbon (1.8 g), and MeOH (250 ml) was stirred under an atmospheric pressure of H_2 (1 atm) at 25 °C for 2 h. The insoluble materials were filtered and washed with MeOH. The combined filtrate and washings were concentrated. The residue (3.47 g, 28.9 mmol) was dissolved in dry acetone (65 ml); to this was added at 25 °C TSA (51 mg, 0.29 mmol). After 5 h at 25 °C, the reaction mixture was neutralized with triethylamine. The mixture was concentrated and the residue was chromatographed on silica gel (150 g) with 1:3 hexane–ether to afford **21** (4.40 g, 95%) as a colorless syrup [R_f=0.45 (1:3 hexane–ether); ^{1}H NMR δ=0.96 (3H, d, J=7.0 Hz, Me), 1.35 and 1.42 (each 3H, each s, CMe_2), 1.86—2.01 (1H, m), 2.03 (1H, t, J=5.0 Hz, OH), 3.54—3.68 (2H, m), 3.73 (1H, dd, J=8.0 and 8.0 Hz), 4.02 (1H, dd, J=6.0 and 8.0 Hz), and 4.18 (1H, ddd, J=6.0, 6.0, and 8.0 Hz)]. A solution of DMSO (8.20 ml, 116 mmol) in dry CH_2Cl_2 (33 ml) was added at −78 °C to a stirred solution of oxalyl dichloride (4.96 ml, 57.8 mmol) in dry CH_2Cl_2 (100 ml). After 15 min at −78 °C, a solution of **21** (4.63 g, 28.9 mmol) in dry CH_2Cl_2 (46 ml) was added and the resulting suspension was stirred at −78 °C for 40 min. After the addition of *N*-ethyl-*N*-isopropylisopropylamine (30.2 ml, 173 mmol), the mixture was gradually warmed to −40 °C for 0.5 h. The reaction mixture was quenched with water and extracted with CH_2Cl_2. The extracts were washed with saturated aqueous NaCl, dried, and concentrated to afford the crude aldehyde (4.57 g, 100%). To a suspension of *t*-BuOK (3.43 g, 30.6 mmol) in dry THF (9.2 ml) was added at −35 °C (*Z*)-2-butene (5.5 ml, 62 mmol); the mixture was cooled to −78 °C. To this was added 1.63 M *n*-BuLi in hexane (18.8 ml, 30.6 mmol) and the mixture was stirred at −35 °C for 0.5 h. After cooling to −78 °C, a solution of *B*-(−)-methoxydiisopinocampheylborane (11.6 g, 36.9 mmol) in dry ether (37 ml) was added. After 0.5 h at −78 °C, BF_3·OEt_2 (5.04 ml, 41.0 mmol) was added and to this was added a solution of the above aldehyde (4.57 g, 28.9 mmol) in THF (15 ml). After 1 h at −78 °C, 3 M aqueous NaOH (41 ml) was added, and the mixture was warmed to 0 °C. 30% Aqueous H_2O_2 (8.2 ml) was slowly added, and the mixture was stirred at 45 °C for 0.5 h. After cooling to 0 °C, saturated aqueous NH_4Cl was added, and the mixture was extracted with hexane. The extracts were washed with water and saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (500 g) with 6:1 hexane–acetone to afford **22** as a colorless syrup contaminated by impurities. To a stirred solution of this sample in dry DMF (80 ml) were added at 0 °C NaH (980 mg, 41 mmol) and MPMCl (5.0 ml, 37 mmol). After 20 h at 25 °C, ethanol was added, and the mixture was stirred at 25 °C for 0.5 h. Water was added and the mixture was extracted with hexane. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (300 g) with 20:1 toluene–ethyl acetate to afford **23** (2.71 g, 28%) and its stereoisomer (183 mg, 1.9%) as colorless syrups.

23: R_f=0.53 (10:1 toluene–ethyl acetate); IR 2985, 1613, 1514, 1249, 1209, 1053, and 1007 cm^{-1}; ^{1}H NMR δ= 0.94 and 1.03 (each 3H, each d, J=6.6 Hz, 2×Me), 1.35 and 1.41 (each 3H, each s, CMe_2), 1.66—1.83 (1H, m, H-5), 2.38—2.54 (1H, m, H-3), 3.31 (1H, dd, J=9.4 and 3.2 Hz, H-4), 3.62 (1H, dd, J_{gem}=8.4 Hz and $J_{6,7}$=7.6 Hz, H-7), 3.79 (3H, s, OMe), 3.98 (1H, dd, $J_{6,7'}$=6.8 Hz, H-7'), 4.33 (1H, ddd, $J_{5,6}$=4.6 Hz, H-6), 4.43 and 4.56 (each 1H, ABq, J=10.4 Hz, OCH_2Ar), 5.03 (1H, dt, J=11.2, 1.7, and 1.7 Hz, H-1), 5.10 (1H, dt, J=17.6, 1.7, and 1.7 Hz, H-1'), 5.99 (1H, ddd, $J_{2,3}$=7.0 Hz, H-2), 6.86 and 7.24 (each 2H, each d-like, J=9.0 Hz, aromatic protons). Found: C, 71.58; H, 9.17%. Calcd for $C_{20}H_{30}O_4$: C, 71.82; H, 9.04%.

The Stereoisomer of 23: R_f=0.58 (10:1 toluene–ethyl acetate); ^{1}H NMR δ=0.79 and 1.13 (each 3H, each d, J=7.0 Hz, 2×Me), 1.36 and 1.40 (each 3H, each s, CMe_2), 1.73—1.89 (1H, m, H-5), 2.38—2.52 (1H, m, H-3), 3.52—3.61 and 4.00—4.09 (4H, m), 3.80 (3H, s, OMe), 4.57 and 4.61 (each 1H, ABq, J=10.0 Hz, OCH_2Ar), 4.97 (1H, dd, J_{gem}=2.0 Hz, $J_{1,2}$=10.0 Hz, H-1), 5.04 (1H, dd, $J_{1',2}$=17.0 Hz, H-1'), 5.68 (1H, ddd, $J_{2,3}$=9.0 Hz, H-2), 6.88 and 7.29 (each 2H, each d-like, J=9.0 Hz, aromatic protons).

Benzyl 2,4-Dideoxy-3-*O*-(4-methoxybenzyl)-2,4-di-*C*-methyl-α,β-L-galactopyranoside (24). To a stirred solution of **23** (1.62 g, 4.84 mmol) in acetone (73 ml) and water (7.3 ml) were added at 25 °C NMO (2.84 g, 24.2 mmol) and OsO_4 (123 mg, 0.480 mmol). After 7 h at 25

°C, saturated aqueous $Na_2S_2O_3$ was added and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. To a stirred solution of the residue in THF (53 ml) and pH 7 phosphate buffer (18 ml) was added at 0 °C $NaIO_4$ (1.55 g, 7.25 mmol). After 6 h at 25 °C, water was added, and the mixture was extracted with CH_2Cl_2. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (100 g) with 5 : 1 hexane–acetone to afford aldehyde (1.30 g, 80%) as a colorless syrup. A mixture of this sample (1.20 g, 3.57 mmol) and 1 : 1 : 1 acetic acid–water–THF (12 ml) was stirred at 25 °C for 15 h. The reaction mixture was concentrated, and the residue was chromatographed on silica gel (200 g) with 3 : 2 $CHCl_3$–acetone to afford a colorless syrup (1.04 g, 98%). To a stirred solution of this syrup (951 mg, 3.21 mmol) in dry acetonitrile (19 ml) were added at 25 °C BnOH (3.32 ml, 32.1 mmol) and CSA (37.3 mg, 0.160 mmol). After 15 h at 25 °C, the reaction mixture was neutralized with triethylamine and concentrated. The residue was chromatographed on silica gel (250 g) with 1 : 2 hexane–ether to afford the α-isomer of **24** (769 mg, 62%) and the β-isomer of **24** (248 mg, 20%) as colorless crystals.

α-Isomer of 24: R_f=0.27 (1 : 2 hexane–ether); mp 80—83 °C (not recrystallized); $[\alpha]_D^{25}$ −164° (*c* 1.50); IR 3019, 1613, 1514, 1458, 1357, 1249, 1033, and 1022 cm^{-1}; ^1H NMR δ=0.90 and 1.04 (each 3H, each d, J=7.0 Hz, 2×Me), 1.72 (1H, dd, J=8.5 and 3.6 Hz, OH), 1.99 (1H, ddq, $J_{1,2}$=3.8 Hz, $J_{2,3}$=11.4 Hz, H-2), 2.17 (1H, ddq, $J_{3,4}$=5.2 Hz, and $J_{4,5}$=2.0 Hz, H-4), 3.54 (1H, ddd, J_{gem}=12.0 Hz and $J_{5,6}$= 3.6 Hz, H-6), 3.63 (1H, dd, H-3), 3.76 (1H, ddd, $J_{5,6'}$=8.4 Hz, H-6′), 3.80 (3H, s, OMe), 4.02 (1H, ddd, H-5), 4.30 and 4.53 (each 1H, ABq, J=11.0 Hz), 4.46 and 4.71 (each 1H, ABq, J=11.8 Hz), 4.78 (1H, d, H-1), 6.87 and 7.25 (each 2H, each d-like, J=9.0 Hz, aromatic protons), and 7.29—7.40 (5H, m, Ph). Found: *m/z* 387.2184 [(M+H)$^+$]. Calcd for $C_{23}H_{31}O_5$: M+1, 387.2171.

β-Isomer of 24: R_f=0.19 (1 : 2 hexane–ether); mp 102—103 °C (not recrystallized); $[\alpha]_D^{25}$ −17.8° (*c* 0.80); IR 3019, 1613, 1513, 1458, 1362, 1249, 1090, and 1036 cm^{-1}; ^1H NMR δ=0.92 (3H, d, J=6.8 Hz, Me), 1.00 (3H, d, J=6.2 Hz, Me), 1.82 (1H, ddq, $J_{1,2}$=9.2 Hz and $J_{2,3}$=10.6 Hz, H-2), 2.09 (1H, ddq, $J_{3,4}$=4.9 Hz and $J_{4,5}$=2.0 Hz, H-4), 3.12 (1H, dd, H-3), 3.47 (1H, ddd, $J_{5,6}$=4.0 Hz and $J_{5,6'}$=8.9 Hz, H-5), 3.57 (1H, ddd, J_{gem}=11.8 Hz and $J_{6,OH}$=9.5 Hz, H-6), 3.80 (3H, s, OMe), 3.83 (1H, ddd, $J_{6',OH}$=3.2 Hz, H-6′), 4.09 (1H, d, H-1), 4.27 and 4.56 (each 1H, ABq, J=11.4 Hz), 4.63 and 4.87 (each 1H, ABq, J=11.9 Hz), 6.87 and 7.25 (each 2H, each d-like, J=9.0 Hz, aromatic protons), and 7.27—7.39 (5H, m, Ph). Found: *m/z* 386.2099 (M$^+$). Calcd for $C_{23}H_{30}O_5$: M, 386.2094.

[3*S*,4*R*,5*R*,6*S*,6(3*R*,4*R*)]-6-[3-Ethyl-4,5-(isopropylidenedioxy)pentyl]-4-(4-methoxybenzyloxy)-3,5-dimethyl-3,4,5,6-tetrahydro-2*H*-pyran-2-one (4). A solution of DMSO (0.697 ml, 9.81 mmol) in dry CH_2Cl_2 (7 ml) was added at −78 °C to a stirred solution of oxalyl dichloride (0.421 ml, 4.90 mmol) in dry CH_2Cl_2 (13 ml). After 15 min at −78 °C, a solution of **24** (632 mg, 1.64 mmol) in dry CH_2Cl_2 (6 ml) was added, and the resulting suspension was stirred at −78 °C for 0.5 h. After addition of triethylamine (1.14 ml, 8.17 mmol), the mixture was gradually warmed to 0 °C during 0.5 h. The reaction mixture was quenched with water and extracted with CH_2Cl_2. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (30 g) with 5 : 2 hexane–ethyl acetate to afford **7** (629 mg, 100%) as a colorless syrup [α-isomer of **7**: R_f=0.57 (5 : 2 hexane–ethyl acetate); ^1H NMR δ=0.93 (3H, d, J=7.3 Hz, 4-Me), 1.04 (3H, d, J=6.4 Hz, 2-Me), 2.04 (1H, ddq, $J_{1,2}$=3.8 Hz and $J_{2,3}$=11.0 Hz, H-2), 2.62 (1H, ddq, $J_{3,4}$=4.4 Hz and $J_{4,5}$=2.8 Hz, H-4), 3.66 (1H, dd, H-3), 3.80 (3H, s, OMe), 4.30 (1H, d, H-5), 4.32 and 4.54 (each 1H, ABq, J=11.2 Hz), 4.51 and 4.67 (each 1H, ABq, J=12.0 Hz), 4.90 (1H, d, H-1), 6.87 and 7.24 (each 2H, d-like, J=9.0 Hz, aromatic protons), 7.25—7.41 (5H, m, Ph), 9.61 (1H, s, H-6).

β-isomer of **7**: R_f=0.39 (5 : 2 hexane–ethyl acetate); ^1H NMR δ=0.97 (3H, d, J=7.3 Hz, 4-Me), 1.01 (3H, d, J=6.4 Hz, 2-Me), 1.89 (1H, ddq, $J_{1,2}$=8.4 Hz and $J_{2,3}$=10.7 Hz, H-2), 2.53 (1H, ddq, $J_{3,4}$=4.8 Hz and $J_{4,5}$=2.4 Hz, H-4), 3.15 (1H, dd, H-3), 3.76 (1H, d, H-5), 3.80 (3H, s, OMe), 4.13 (1H, d, H-1), 4.27 and 4.57 (each 1H, ABq, J=11.2 Hz), 4.64 and 4.97 (each 1H, ABq, J=12.1 Hz), 6.87 and 7.24 (each 2H, d-like, J=9.0 Hz, aromatic protons), 7.25—7.41 (5H, m, Ph), and 9.74 (1H, s, H-6)]. To a stirred solution of **6** (583 mg, 1.07 mmol) in dry THF (1.8 ml) was added at −78 °C 1.65 M *n*-BuLi in hexane (0.66 ml, 1.1 mmol). After 10 min, the reaction mixture was warmed to 0 °C and stirred for 20 min. This was re-cooled to −78 °C and to this was added a solution of **7** (152 mg, 0.395 mmol; α : β=3 : 1) in dry THF (0.46 ml). After 10 min at −78 °C, the reaction mixture was warmed to 0 °C and stirred for 2 h. Saturated aqueous NH_4Cl was added and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (15 g) with 5 : 1 hexane–ethyl acetate to afford **25** (151 mg, 73%; α : β=3 : 1) as a colorless syrup. A mixture of **25** (53.2 mg, 0.101 mmol), Raney Ni W4, and EtOH (0.53 ml) was stirred at 25 °C for 5 h under an atmospheric pressure of H_2 (1 atm). The insoluble materials were filtered and washed with EtOH. The combined filtrate and washings were concentrated. The residue (44.3 mg, 100%) was dissolved in CH_2Cl_2 (0.52 ml), and to this were added at 25 °C MS 4AP (30 mg) and PDC (44.8 mg, 0.119 mmol). After 25 min at 25 °C, the reaction mixture was diluted with ether, and the resulting suspension was transferred to a column filled with silica gel. The column was eluted with ether and the eluate was concentrated. The residue was chromatographed on silica gel (2.6 g) with 5 : 2 hexane–ethyl acetate to afford **4** (25.1 mg, 57%) as a colorless syrup: R_f=0.43 (5 : 2 hexane–ethyl acetate); $[\alpha]_D^{26}$ −71.7° (*c* 1.20); IR 3019, 2881, 1725, 1514, 1250, and 1068 cm^{-1}; ^1H NMR δ=0.91 (3H, t, J=7.2 Hz, CH_2*Me*), 0.95 (3H, d, J=7.0 Hz, Me), 1.35 and 1.40 (each 3H, each s, CMe_2), 1.36 (3H, d, J=7.0 Hz, Me), 1.14—1.91 (7H, m), 2.35 (1H, ddq, $J_{4,5}$=4.6 Hz and $J_{5,6}$=2.5 Hz, H-5), 2.54 (1H, dq, $J_{3,4}$=10.6 Hz, H-3), 3.47 (1H, dd, H-4), 3.58 (1H, t, J=7.5 Hz and 7.5 Hz), 3.81 (3H, s, OMe), 3.90—4.03 (1H, m), 4.04 (1H, dd, J=7.5 Hz and 6.5 Hz), 4.09—4.18 (1H, m, H-6), 4.36 and 4.60 (each 1H, ABq, J=11.2 Hz, OCH_2Ar), 6.90 and 7.26 (each 2H, d-like, J=9.0 Hz, aromatic protons). Found: *m/z* 434.2660 (M$^+$). Calcd for $C_{25}H_{38}O_6$: M, 434.2668.

(3*S*,4*S*,6*R*)-6-(*t*-Butyldiphenylsilyloxy)-3-methyl-4-(triethylsilyloxy)-1-heptene (31). To a stirred solu-

tion of **8** (10.7 g, 90.6 mmol) in dry CH_2Cl_2 (100 ml) were added at 0 °C *N*-ethyl-*N*-isopropylisopropylamine (31.6 ml, 181 mmol) and MOMCl (10.3 ml, 136 mmol). After 42 h at 25 °C, water was added, and the mixture was extracted with CH_2Cl_2. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was distilled to afford a colorless oil (13.9 g, 95%, bp 77 °C/12 mmHg, 1 mmHg=133.322 Pa). To a suspension of $LiAlH_4$ (2.57 g, 67.7 mmol) in dry THF (100 ml) was added at 0 °C a solution of the above oil (13.7 g, 84.5 mmol) in dry THF (50 ml). After 1 h at 0 °C, the reaction mixture was diluted with THF (90 ml); to this were slowly added water (2.5 ml), 3 M aqueous NaOH (3.1 ml), and water (15 ml). After 1 h at 25 °C, the insoluble materials were filtered and washed with THF. The combined filtrate and washings were concentrated. The residue was dissolved in CH_2Cl_2, this was washed with water and saturated aqueous NaCl, dried, and concentrated. The residue was distilled to afford **26** (10.3 g, 91%) as a colorless oil [R_f=0.23 (2:3 hexane–ethyl acetate); bp 76 °C/6.5 mmHg; ^{1}H NMR δ=1.22 (3H, d, J=6.2 Hz, Me), 1.68—1.86 (2H, m), 2.31—2.45 (1H, br, OH), 3.40 (3H, s, OMe), 3.67—3.87 (2H, m), 3.94 (1H, ddq, $J_{2,3}$=6.8 Hz, $J_{2',3}$=5.2 Hz, H-3), 4.63 and 4.73 (each 1H, ABq, J=7.0 Hz, OCH_2O)]. To a stirred solution of **26** (1.62 g, 12.1 mmol) in dry CH_2Cl_2 (25 ml) were added at 0 °C MS 4AP (3.6 g) and PCC (5.19 g, 24.1 mmol). After 0.5 h at 25 °C, the reaction mixture was diluted with ether; the resulting suspension was transferred to a column filled with silica gel. The column was eluted with ether and the elute was concentrated to afford aldehyde (1.60 g, 100%) as a colorless syrup. To s suspension of *t*-BuOK (1.63 g, 14.5 mmol) in dry THF (4.2 ml) was added at −35 °C (*Z*)-2-butene (2.6 ml, 29 mmol) and the mixture was cooled to −78 °C. To this was added 1.60 M *n*-BuLi in hexane (9.10 ml, 14.5 mmol) and the mixture was stirred at −35 °C for 0.5 h. After cooling to −78 °C, a solution of *B*-(+)-methoxydiisopinocampheylborane (5.27 g, 17.5 mmol) in dry ether (17.6 ml) was added. After 0.5 h at −78 °C, BF_3·OEt_2 (2.39 ml, 19.4 mmol) was added; to this was added a solution of the above aldehyde (1.60 g, 12.1 mmol) in THF (5.8 ml). After 3 h at −78 °C, a solution of 3 M aqueous NaOH (11.7 ml) was added, and the mixture was warmed to 0 °C. 30% Aqueous H_2O_2 (2.3 ml) was slowly added and the mixture was stirred at 45 °C for 0.5 h. After cooling to 0 °C, saturated aqueous NH_4Cl was added, and the mixture was extracted with hexane. The extracts were washed with water and saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (150 g) with 3:1 hexane–ethyl acetate to afford a colorless syrup (2.27 g, 100%). To a solution of this sample (2.27 g, 12.1 mmol) in MeOH (55 ml) was added at 25 °C 10% HCl–MeOH (27 ml). After 13 h at 25 °C, the mixture was concentrated and the residue was chromatographed on silica gel (100 g) with 5:6 hexane–ethyl acetate to afford **27** (540 mg, 31%) and **28** (174 mg, 10%) as colorless syrups [**27**: R_f=0.28 (5:6 hexane–ethyl acetate); ^{1}H NMR δ=1.07 (3H, d, J=7.0 Hz, Me), 1.25 (3H, d, J=6.4 Hz, Me), 1.50—1.70 (2H, m), 2.09 (1H, br d, J=3.8 Hz, OH), 2.22 (1H, br d, J=4.8 Hz, OH), 2.31 (1H, quint, J=7.0 Hz, H-5), 3.75—3.87 and 4.08—4.24 (each 1H, each m), 5.08 (1H, dt, J=1.6, 1.6, and 10.2 Hz, H-7), 5.10 (1H, dt, J=1.6, 1.6, and 16.2 Hz, H-7'), and 5.68—5.83 (1H, m, H-6).

28: R_f=0.37 (5:6 hexane–ethyl acetate); ^{1}H NMR δ=1.04 (3H, d, J=6.6 Hz, Me), 1.22 (3H, d, J=6.6 Hz, Me), 1.47 (1H, dt, J_{gem}=14.4 Hz, $J_{2,3}$=$J_{3,4}$=9.9 Hz, H-3), 1.62 (1H, dt, $J_{2,3'}$=$J_{3',4}$=2.6 Hz, H-3'), 2.28 (1H, quint, J=6.6 Hz, H-5), 2.66 (1H, br d, J=2.8 Hz, OH), 3.00 (1H, br s, OH), 3.70—3.82 and 3.96—4.12 (each 1H, each m), 5.09 (1H, dt, J=2.0, 2.0, and 17.8 Hz, H-7), 5.11 (1H, dt, J=2.0, 2.0, and 12.1 Hz, H-7'), and 5.70—5.86 (1H, m, H-6)]. To a stirred solution of **27** (540 mg, 3.74 mmol) in dry DMF (12 ml) were added at 25 °C imidazole (342 mg, 5.02 mmol) and TBDPSCl (1.03 ml, 4.02 mmol). After 14 h at 25 °C, water was added and the mixture was extracted with hexane. The extracts were washed with saturated aqueous NaCl, dried and concentrated. The residue was chromatographed on silica gel (50 g) with 12:1 hexane–acetone to afford a colorless syrup (1.29 g, 90%). To a stirred solution of this syrup (678 mg, 1.77 mmol) in dry DMF (13.5 ml) were added at 25 °C imidazole (252 mg, 3.70 mmol) and TESCl (0.44 ml, 2.6 mmol). After 20 min at 25 °C, water was added, and the mixture was extracted with hexane. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (45 g) with 30:1 hexane–ethyl acetate to afford **31** (775 mg, 88%) as a colorless syrup: R_f=0.23 (30:1 hexane–ethyl acetate); $[\alpha]_D^{30}$ −10.1° (*c* 0.87); IR 3008, 2935, 2878, 1110, 1074, 1007, and 911 cm^{-1}; ^{1}H NMR δ=0.51 (6H, q, J=7.8 Hz, 3×$SiCH_2$), 0.84 (3H, d, J=7.1 Hz, Me), 0.89 (9H, t, Si(CH_2*Me*)$_3$), 1.03 (3H, d, J=6.0 Hz, Me), 1.03 (9H, s, *t*-Bu), 1.39 (1H, ddd, J_{gem}=13.4 Hz, $J_{4,5}$=5.9 Hz and $J_{5,6}$=7.4 Hz, H-5), 1.71 (1H, ddd, $J_{4,5'}$=4.6 Hz and $J_{5',6}$=7.0 Hz, H-5'), 2.08—2.23 (1H, m, H-3), 3.73 (1H, quint, $J_{3,4}$=7.8 Hz, H-4), 3.86—4.01 (1H, m, H-6), 4.93 (1H, dt, $J_{1,2}$=17.0 Hz and J_{gem}=$J_{1,3}$=1.6 Hz, H-1), 4.97 (1H, dt, $J_{1',2}$=10.6 Hz and $J_{1',3}$=1.6 Hz, H-1'), 5.84 (1H, ddd, $J_{2,3}$=6.8 Hz, H-2), 7.28—7.46 and 7.60—7.74 (6H and 4H, each m, aromatic protons). Found: C, 72.66; H, 9.49%. Calcd for $C_{30}H_{48}O_2Si_2$: C, 72.52; H, 9.74%.

Transformation of 27 to 29. To a stirred solution of **27** (40.0 mg, 0.277 mmol) in dry CH_2Cl_2 (0.8 ml) were added at 25 °C benzaldehyde dimethyl acetal (0.125 ml, 0.832 mmol) and CSA (5.9 mg, 0.025 mmol). After 1.5 h at 25 °C, the reaction mixture was neutralized with triethylamine and the mixture was concentrated. The residue was chromatographed on silica gel (15 g) with 10:1 hexane–ether to afford a colorless syrup (64.4 mg, 100%). To a stirred solution of this syrup (64.4 mg, 0.277 mmol) in acetone (1.9 ml) and water (0.64 ml) were added at 25 °C NMO (167 mg, 1.42 mmol) and OsO_4 (26.5 mg, 0.104 mmol). After 2 h at 25 °C, saturated aqueous $Na_2S_2O_3$ was added and the mixture was extracted with CH_2Cl_2. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (2.2 g) with 1:5 hexane–ethyl acetate to afford diol (37.1 mg, 51% from **27**). A mixture of this diol (37.1 mg, 0.139 mmol), 20% $Pd(OH)_2$ on carbon (20.1 mg), and MeOH (1.4 ml) was stirred at 25 °C for 1.2 h under an atmospheric pressure of H_2 (1 atm). The insoluble materials were filtered and washed with MeOH. The combined filtrate and washings were concentrated. The residue (24.8 mg, 0.139 mmol) was dissolved in THF (0.75 ml) and water (0.25 ml); to this was added at 0 °C $NaIO_4$ (58.2 mg, 0.272 mmol). After 1 h at 25 °C, saturated aqueous NaCl was added, and the mixture was extracted with ethyl acetate. The extracts

were concentrated and the residue was chromatographed on silica gel (1 g) with 1:5 hexane–ethyl acetate to afford a colorless sample (18.7 mg, 92% for two steps), which was dissolved in MeOH (0.37 ml); to this was added at 25 °C 10% HCl–MeOH (0.01 ml), and the mixture was stirred at 25 °C for 1 h. After the reaction mixture was neutralized with triethylamine, it was concentrated. The residue was chromatographed on silica gel (2 g) with 5:4 hexane–ethyl acetate to afford the α-isomer of **29** (9.9 mg, 48.5%) and the β-isomer of **29** (7.3 mg, 35.8%) as colorless syrups.

α-Isomer of 29: R_f=0.39 (5:4 hexane–ethyl acetate); ^{1}H NMR δ=1.03 and 1.21 (each 3H, each d, J=6.6 Hz, 2×Me), 1.26 (1H, q, $J_{gem}=J_{3,4ax}=J_{4ax,5}$=12.1 Hz, H-4ax), 1.50—1.66 (1H, m, H-2), 1.95 (1H, ddd, $J_{3,4eq}$=5.0 Hz and $J_{4eq,5}$=2.4 Hz, H-4eq), 3.32 (3H, s, OMe), 3.70 (1H, dt, $J_{2,3}$=12.1 Hz, H-3), 3.88 (1H, ddq, H-5), and 4.56 (1H, d, $J_{1,2}$=4.0 Hz, H-1).

β-Isomer of 29: R_f=0.34 (5:4 hexane–ethyl acetate); ^{1}H NMR δ=1.07 (3H, d, J=6.8 Hz, Me), 1.28 (3H, d, J=6.0 Hz, Me), 1.17—1.46 (2H, m, H-2 and H-4ax), 1.93 (1H, ddd, J_{gem}=12.6 Hz, $J_{3,4eq}$=5.0 Hz, and $J_{4eq,5}$=2.2 Hz, H-4eq), 3.36 (1H, dt, $J_{2,3}=J_{3,4ax}$=11.0 Hz, H-3), 3.49 (3H, s, OMe), 3.44—3.59 (1H, m, H-5), and 3.91 (1H, d, $J_{1,2}$=8.4 Hz, H-1).

Transformation of 28 to 30. Compound **28** was transformed to methyl glycoside by the same procedure as that described for the transformation of **27** to **29**. This methyl glycoside was acetylated with acetic anhydride (2.5 equiv) and DMAP (3.0 equiv) in benzene (25 °C, 14 h) to afford **30** (quantitatively) as a β-isomer only.

30: R_f=0.37 (5:1 hexane–ethyl acetate); ^{1}H NMR δ=0.99 (3H, d, J=7.2 Hz, Me), 1.25 (3H, d, J=6.2 Hz, Me), 1.49—1.71 (2H, m, 2×H-4), 1.88—2.01 (1H, m, H-2), 2.08 (3H, s, OAc), 3.49 (3H, s, OMe), 3.87 (1H, ddq, $J_{4ax,5}$=10.0 Hz and $J_{4eq,5}$=3.9 Hz, H-5), 4.63 (1H, d, $J_{1,2}$=3.2 Hz, H-1), and 4.95 (1H, q, $J_{2,3}=J_{3,4ax}=J_{3,4eq}$=3.2 Hz, H-3).

(2*R*, 4*S*, 5*S*, 7*RS*)- 2- (*t*- Butyldiphenylsilyloxy)- 5-methyl-7-(tributylstannyl)-4-(triethylsilyloxy)-7-[(2-trimethylsilylethoxy)methoxy]heptane (5b). To a stirred solution of 10 M BH_3·SMe_2 (0.440 ml, 4.40 mmol) in dry THF (14.5 ml) was added at 0 °C cyclohexene (0.88 ml, 8.7 mmol); the mixture was stirred at 0 °C for 2 h. To this was added at 0 °C a solution of **31** (722 mg, 1.45 mmol) in dry THF (8.0 ml). After 40 min at 0 °C, 3 M aqueous NaOH (4.4 ml) and 30% aqueous H_2O_2 (1.5 ml) were added and the mixture was stirred at 40 °C for 20 min. Water was added and the mixture was extracted with hexane. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (60 g) with 5:1 hexane–ethyl acetate to afford a colorless syrup [767 mg, 100%; R_f=0.37 (5:1 hexane–ethyl acetate); $[\alpha]_D^{31}$ −2.1° (*c* 0.56), $[\alpha]_{365}^{31}$ +2.1° (*c* 0.56); IR 3386, 2960, 2879, 1461, 1428, 1380, 1141, 1079, and 1007 cm^{-1}; ^{1}H NMR δ=0.52 (6H, q, J=8.0 Hz, 3×$SiCH_2$), 0.79 (3H, d, J=6.4 Hz, Me), 0.89 (9H, t, $Si(CH_2Me)_3$), 1.02 (9H, s, *t*-Bu), 1.06 (3H, d, J=6.0 Hz, Me), 1.23—1.41 (1H, m), 1.44—1.77 (4H, m), 2.77 (1H, br dd, J=3.6 and 7.9 Hz, OH), 3.48—3.73 (2H, m, 2×H-1), 3.81 (1H, ddd, J=2.2, 3.4, and 8.2 Hz, H-4), 3.88—4.02 (1H, m, H-6), 7.31—7.47 and 7.63—7.79 (6H and 4H, each m, aromatic protons). Found: C, 69.79; H, 9.43%. Calcd for $C_{30}H_{50}O_3Si_2$: C, 69.98; H, 9.79%]. To a stirred solution of this syrup (88.1 mg, 0.171 mmol) in dry CH_2Cl_2 (0.8 ml) were added at 0 °C pyridine (0.073 ml, 0.90 mmol) and Dess–Martin periodinane (128 mg, 0.302 mmol). After 1 h at 25 °C, saturated aqueous $Na_2S_2O_3$ and $NaHCO_3$ were added, and the mixture was extracted with ether. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (3 g) with 10:1 hexane–ethyl acetate to afford **32** (86.0 mg, 98%) as a colorless syrup [R_f=0.50 (6:1 hexane–ethyl acetate); ^{1}H NMR δ=0.49 (6H, q, J=7.6 Hz, 3×$SiCH_2$), 0.73 (3H, d, J=6.8 Hz, 6-Me), 0.88 (9H, t, $Si(CH_2Me)_3$), 1.03 (9H, s, *t*-Bu), 1.09 (3H, d, J=6.2 Hz, 3-Me), 1.48 (1H, ddd, J_{gem}=15.6 Hz, $J_{4,5}$=7.6 Hz, and $J_{5,6}$=6.8 Hz, H-5), 1.69 (1H, ddd, $J_{4,5'}$=4.8 Hz and $J_{5',6}$=6.8 Hz, H-5′), 1.98—2.11 (1H, m, H-3), 2.12 (1H, ddd, J_{gem}=16.1 Hz, $J_{1,2}$=1.9 Hz, and $J_{2,3}$=8.6 Hz, H-2), 2.53 (1H, ddd, $J_{1,2'}$=1.9 Hz and $J_{2',3}$=4.5 Hz, H-2′), 3.73 (1H, ddd, $J_{3,4}$=2.0 Hz, H-4), 3.91 (1H, sextet, H-6), 7.28—7.50 and 7.61—7.78 (6H and 4H, each m, aromatic protons), and 9.71 (1H, t, H-1)]. To a stirred solution of diisopropylamine (0.112 ml, 0.503 mmol) in dry THF (1.7 ml) was added at 0 °C 1.63 M *n*-BuLi in hexane (0.309 ml, 0.503 mmol). After 0.5 h at 0 °C, *n*-Bu_3SnH (0.135 ml, 0.501 mmol) was added and the mixture was stirred at 0 °C for 15 min. To this was added at −78 °C a solution of **32** (86.0 mg, 0.168 mmol) in dry THF (0.86 ml) and the mixture was stirred at −78 °C for 40 min. Water was added and the mixture was extracted with hexane. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was dissolved in dry CH_2Cl_2 (2 ml); to this were added *N*-ethyl-*N*-isopropylisopropylamine (0.155 ml, 0.890 mmol) and SEMCl (0.148 ml, 0.836 mmol). After 15 h at 25 °C, water was added and the mixture was extracted with hexane. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (10 g) with 20:1 hexane–ethyl acetate to afford **5b** (114 mg, 73% from **32**) as a colorless syrup: R_f=0.40 (20:1 hexane–ethyl acetate); IR 3021 and 1213 cm^{-1}; ^{1}H NMR ($CHCl_3$=7.26, a 1:1 mixture of the C7-epimers) δ=0.00 (9H, s, $SiMe_3$), 0.49 and 0.50 (total 6H, each q, J=7.6 Hz, 3×$SiCH_2$), 0.59 and 0.64 (total 3H, each d, J=6.5 Hz, Me), 0.77—0.96 (15H, m), 1.02 (9H, s, *t*-Bu), 1.06 and 1.07 (total 3H, each d, J=6.0 Hz, Me), 4.00 and 4.10 (total 1H, each dd, $J_{6,7}$=7.3 Hz, $J_{6',7}$=8.8 Hz and $J_{6,7}$=12.2 Hz, $J_{6',7}$=2.4 Hz, H-7), 4.50 and 4.57 (each 0.5H, ABq, J=7.0 Hz, OCH_2O), 4.52 (1H, s, OCH_2O), 7.28—7.44 and 7.61—7.72 (6H and 4H, each m, aromatic protons). Found: C, 61.81; H, 10.01%. Calcd for $C_{48}H_{90}O_4Si_3Sn$: C, 61.71; H, 9.71%.

[2*S*, 2(2*R*), 3*S*, 5*RS*, 6*R*, 8*S*, 8(3*R*, 4*R*), 9*S*, 10*R*, 11*S*]-2-[2-(*t*-Butyldiphenylsilyloxy)propyl]-8-[3-ethyl-4,5-(isopropylidenedioxy)pentyl]-10-(4-methoxybenzyloxy)-3, 9, 11- trimethyl- 5- [(2- trimethylsilylethoxy)-methoxy]-1,7-dioxaspiro[5.5]undecane (36). To a stirred solution of **5b** (291 mg, 0.311 mmol) in dry THF (5.8 ml) was added at −78 °C 1.62 M *n*-BuLi in hexane (0.307 ml, 0.497 mmol). After 10 min at −78 °C, a solution of **4** (67.6 mg, 0.156 mmol) in dry THF (0.68 ml) was added and the mixture was stirred at −78 °C for 1.5 h. Water was added and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (15 g) with 10:1 hexane–ethyl acetate to afford **34** (92.7 mg, 55%) as a colorless syrup. A mixture of this syrup (92.7

mg, 0.0859 mmol) and 6:1:6 acetic acid–water–THF (8.6 ml) was stirred at 25 °C for 24 h. After concentration, the residue was chromatographed on silica gel (6 g) with 4:1 hexane–ethyl acetate to afford a colorless syrup (82.9 mg, 100%). To a solution of this syrup (82.9 mg, 0.0859 mmol) in dry benzene (6 ml) was added at 25 °C CSA (2.0 mg, 0.0086 mmol). After 16 h at 25 °C, the reaction mixture was neutralized with triethylamine. The mixture was concentrated and the residue was chromatographed on silica gel (6 g) with 8:1 hexane–ethyl acetate to afford the less polar epimer of **36** (39.0 mg, 48%) and the more polar epimer of **36** (39.0 mg, 48%) as colorless syrups.

The Less Polar Epimer of 36: R_f=0.77 (4:1 hexane–ethyl acetate); $[\alpha]_D^{26}$ −22.8° (*c* 0.43); IR 3019, 2961, 1514, 1225, 1108, 1050, and 1032 cm^{-1}; ^1H NMR ($CHCl_3$=7.26) δ=0.00 (9H, s, $SiMe_3$), 0.76 (3H, d, *J*=7.0 Hz, Me), 0.79—0.96 (8H, m), 1.05 (9H, s, *t*-Bu), 1.12 (3H, d, *J*=6.3 Hz, Me), 1.17 (3H, d, *J*=6.4 Hz, Me), 1.33 and 1.36 (each 3H, each s, CMe_2), 1.59—1.80 and 1.90—2.05 (each 2H, each m), 3.36 (1H, dd, $J_{9,10}$=5.0 Hz and $J_{10,11}$=10.8 Hz, H-10), 3.79 (3H, s, OMe), 4.23 and 4.50 (each 1H, ABq, *J*=10.8 Hz), 4.55 and 4.64 (each 1H, ABq, *J*=7.0 Hz), 6.86 and 7.25 (each 2H, each d-like, *J*=9.0 Hz, aromatic protons), 7.32—7.43 and 7.63—7.72 (6H and 4H, each m, 2×Ph). Found: C, 69.28; H, 9.74%. Calcd for $C_{55}H_{86}O_9Si_2$: C, 69.72; H, 9.15%.

The More Polar Epimer of 36: R_f=0.69 (4:1 hexane–ethyl acetate); $[\alpha]_D^{28}$ −34.6° (*c* 0.26); IR 2960, 1249, 1100, 1050, and 1025 cm^{-1}; ^1H NMR ($CHCl_3$=7.26) δ=−0.02 (9H, s, $SiMe_3$), 0.69 (3H, d, *J*=7.2 Hz, Me), 0.80—0.93 (8H, m), 1.01 (3H, d, *J*=6.7 Hz, Me), 1.05 (9H, s, *t*-Bu), 1.10 (3H, d, *J*=6.1 Hz, Me), 1.32 and 1.34 (each 3H, each s, CMe_2), 3.43 (1H, dd, $J_{9,10}$=4.6 Hz and $J_{10,11}$=10.9 Hz, H-10), 3.79 (3H, s, OMe), 4.23 and 4.52 (each 1H, ABq, *J*=11.0 Hz), 4.58 and 4.64 (each 1H, ABq, *J*=7.2 Hz), 6.86 and 7.25 (each 2H, each d-like, *J*=9.0 Hz, aromatic protons), 7.32—7.43 and 7.63—7.72 (6H and 4H, each m, 2×Ph). Found: C, 69.49; H, 9.92%. Calcd for $C_{55}H_{86}O_9Si_2$: C, 69.72; H, 9.15%.

[2*S*,2(2*R*),3*S*,6*R*,8*S*,8(3*R*,4*R*),9*S*,10*R*,11*S*]-2-[2-(*t*-Butyldiphenylsilyloxy)propyl]-8-[3-ethyl-4,5-(isopropylidenedioxy)pentyl]-10-(4-methoxybenzyloxy)-3,9,11-trimethyl-1,7-dioxaspiro[5.5]undecan-5-ol (37). 1.0 M *n*-Bu_4NF in THF (0.127 ml, 0.127 mmol) was added to the less polar epimer of **36** (12.0 mg, 0.0127 mmol) at 25 °C. This was concentrated, and to the residue were added *N*,*N*′-dimethylpropyleneurea (DMPU) (0.24 ml) and MS 4AP (12 mg). After 23 h at 45 °C, water was added and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1 g) with 2:1 hexane–ethyl acetate to afford a colorless syrup (4.4 mg, 60%). This was dissolved in dry DMF (0.1 ml); to this were added at 25 °C imidazole (5.8 mg, 0.085 mmol) and TBDPSCl (0.02 ml, 0.08 mmol). After 5 h at 40 °C, water was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1 g) with 5:1 hexane–ethyl acetate to afford the less polar epimer of **37** (4.3 mg, 70%) as a colorless syrup. The more polar epimer of **36** was transformed to the more polar epimer of **37** by the same procedure as that described above.

The Less Polar Epimer of 37: R_f=0.59 (2:1 hexane–ethyl acetate); $[\alpha]_D^{26}$ −70.9° (*c* 0.11); IR 3015, 2964, 2861, 1513, 1247, 1110, 1067, and 994 cm^{-1}; ^1H NMR δ=0.82 and 0.83 (each 3H, each d, *J*=7.0 Hz, 2×Me), 0.86 (3H, t, *J*=7.2 Hz, CH_2Me), 1.06 (9H, s, *t*-Bu), 1.13 (3H, d, *J*=6.0 Hz, Me), 1.20 (3H, d, *J*=6.4 Hz, Me), 1.32 and 1.35 (each 3H, each s, CMe_2), 1.82 (1H, dq, *J*=6.4 and 10.8 Hz), 1.95—2.06 (1H, m), 2.13 (1H, dt, *J*=14.0 and 5.0 Hz), 3.36 (1H, dd, *J*=10.8 and 5.2 Hz), 3.42 (1H, ddd, *J*=7.8, 5.9, and 1.6 Hz), 3.46—3.58 (2H, m), 3.65 (1H, dt, *J*=7.2 and 3.0 Hz), 3.73—3.86 (1H, m), 3.79 (3H, s, OMe), 3.87—4.02 (2H, m), 4.23 and 4.52 (each 1H, ABq, *J*=10.8 Hz), 6.86 and 7.26 (each 2H, each d-like, *J*=9.0 Hz), 7.32—7.46 and 7.63—7.73 (6H and 4H, each m). Found: *m*/*z* 759.4264 [(M−*t*-Bu)$^+$]. Calcd for $C_{45}H_{63}O_8Si$: M−57, 759.4293.

The More Polar Epimer of 37: R_f=0.42 (2:1 hexane–ethyl acetate); $[\alpha]_D^{26}$ −52.0° (*c* 0.10); IR 3009, 2967, 2862, 1513, 1247, 1109, 1068, and 987 cm^{-1}; ^1H NMR δ=0.68, 0.88, and 0.97 (each 3H, each d, *J*=6.6, 7.3, and 6.6 Hz, 3×Me), 0.86 (3H, t, *J*=6.8 Hz, CH_2Me), 1.05 (9H, s, *t*-Bu), 1.09 (3H, d, *J*=6.6 Hz, Me), 2.14 (1H, dq, *J*=6.6 and 11.0 Hz), 3.42 (1H, dd, *J*=11.0 and 4.3 Hz), 3.59—3.82 (2H, m), 3.79 (3H, s, OMe), 3.87—4.04 (2H, m), 4.23 and 4.50 (each 1H, ABq, *J*=10.8 Hz), 6.85 and 7.24 (each 2H, each d-like, *J*=9.0 Hz), 7.31—7.45 and 7.62—7.71 (6H and 4H, each m). Found: *m*/*z* 802.4850 [(M+H−Me)$^+$]. Calcd for $C_{48}H_{70}O_8Si$: M−14, 802.4840.

Transformation of The Less Polar Epimer of 37 to 2. To a stirred solution of the less polor epimer of **37** (5.7 mg, 0.0069 mmol) in MeOH (0.6 ml) was added at 25 °C TSA·H_2O (0.7 mg, 0.003 mmol). After 4 h at 25 °C, the reaction mixture was neutralized with triethylamine, and the mixture was concentrated. The residue was chromatographed on silica gel (1 g) with 1:2 hexane–ethyl acetate to afford a colorless syrup (4.8 mg, 90%). To a stirred solution of this syrup (4.8 mg, 0.0062 mmol) in THF (0.12 ml) and pH 7 phosphate buffer (0.04 ml) was added $NaIO_4$ (2.0 mg, 0.0093 mmol). After 1 h at 25 °C, water was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was dissolved in MeOH (0.2 ml) and to this was added $NaBH_4$ (0.3 mg, 0.009 mmol) and the mixture was stirred at 25 °C for 0.5 h. The reaction mixture was treated with CO_2 and concentrated. The residue was chromatographed on silica gel (1 g) with 1:1 hexane–ethyl acetate to afford a colorless syrup (4.2 mg, 90% for two steps). This (4.2 mg, 0.0056 mmol) was dissolved in CH_2Cl_2 (0.18 ml) and water (0.012 ml) and to this was added at 25 °C DDQ (2.3 mg, 0.010 mmol). After 20 min at 25 °C, water was added and the mixture was extracted with benzene. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1 g) with 2:3 hexane–ethyl acetate to afford **2** (3.2 mg, 75% from **37**) as a colorless syrup: R_f=0.45 (2:5 $CHCl_3$–ethyl acetate); $[\alpha]_D^{30}$ −35.1° (*c* 0.08); IR 3019, 2965, 2932, 1462, 1384, 1110, and 990 cm^{-1}; ^1H NMR δ=0.82 (6H, d, *J*=6.8 Hz, 2×Me), 0.87 (3H, t, *J*=7.3 Hz, CH_2Me), 1.05 (9H, s, *t*-Bu), 1.15 (3H, d, *J*=6.0 Hz, Me), 1.22 (3H, d, *J*=6.6 Hz, Me), 1.79 (1H, ddq, *J*=6.8, 6.8, and 1.8 Hz), 2.12 (1H, ddd, *J*=13.8, 4.5, and 4.2 Hz), 3.39—3.50 (3H, m), 3.51

(1H, t-like, J=3.8 Hz), 3.59—3.69 (2H, m), 3.82 (1H, ddq, J=6.2 and 6.0 Hz), 7.32—7.46 and 7.62—7.72 (6H and 4H, each m). The ^{1}H NMR spectrum showed that this synthetic sample of **2** was contaminated with a small quantity of an inseparable byproduct.

Degradation of Oligomycins A, B, C mixture. To a stirred solution of the commercially available oligomycins A, B, and C mixture (61.0 mg; A : B : C=75 : 15 : 10, Aldrich) in dry DMF (2.4 ml) were added at 25 °C imidazole (34.6 mg, 0.508 mmol) and TBDPSCl (0.078 ml, 0.30 mmol). After 88 h at 33 °C, water was added and the mixture was extracted with 1 : 1 hexane–ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (8 g) with 5 : 3 benzene–ethyl acetate to afford a 73.1 mg of sample. A solution of this sample (73.1 mg) in ethyl acetate (3.7 ml) at −78 °C was bubbled with O_3/O_2 gas. After 5 min at −78 °C, argon gas was bubbled for a few min, and dry THF (3.6 ml) was added; to this was added $NaBH_4$ (42.7 mg, 1.13 mmol). The reaction mixture was gradually warmed to 25 °C and stirred for 21 h. Saturated aqueous NH_4Cl was added and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was dissolved in dry CH_2Cl_2 (2.2 ml); to this was added at −78 °C 1.0 M DIBAL in CH_2Cl_2 (1.4 ml, 1.4 mmol). The reaction mixture was warmed to −40 °C and stirred for 1 h. MeOH (0.28 ml) and potassium sodium tartrate tetrahydrate (1.98 g) in water (10 ml) were added. The mixture was extracted with $CHCl_3$, and the extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (5 g) with 10 : 9, 2 : 5, and 1 : 3 $CHCl_3$–ethyl acetate to afford **2** (5.7 mg, 12% from oligomycins A, B, C mixture) as a colorless syrup: $[\alpha]_D^{30}$ −54.8° (c 0.08, $CHCl_3$), −41.9° (c 0.54, $CHCl_3$). The ^{1}H NMR and IR spectra and TLC mobilities of this sample of **2** were identical of those of the synthetic sample of **2**.

(3*R*,4*S*,5*S*)-4,6-(4-Methoxybenzylidenedioxy)-3,5-dimethyl-1-hexene (39). To a stirred solution of **38**[10,11] (866 mg, 3.35 mmol) in dry THF (12.5 ml) was added at 25 °C 1 M n-Bu_4NF in THF (4.2 ml, 4.2 mmol). After 2 h at 25 °C, water was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (48 g) with 5 : 2 $CHCl_3$–acetone to afford diol[28] (483 mg, 100%). To a stirred solution of this diol (483 mg, 3.35 mmol) in dry CH_2Cl_2 (9.8 ml) were added at 25 °C 4-methoxybenzaldehyde dimethyl acetal (0.83 ml, 5.1 mmol) and CSA (40.3 mg, 0.173 mmol). After 3 h at 25 °C, triethylamine was added, and the mixture was concentrated. The residue was chromatographed on silica gel (89 g) with 8 : 1 hexane–ethyl acetate to afford **39** (730 mg, 83%) as a colorless syrup: R_f=0.51 (8 : 1 hexane–ethyl acetate); $[\alpha]_D^{31}$ +4.9° (c 0.98), $[\alpha]_{365}^{31}$ +25.4° (c 0.98); IR 3012, 2967, 1616, 1517, 1462, 1396, 1303, 1249, 1168, 1110, 1033, 1000, and 830 cm^{-1}; ^{1}H NMR δ=1.10 (3H, d, J=6.5 Hz, Me), 1.17 (3H, d, J=7.0 Hz, Me), 1.57—1.71 (1H, m, H-5), 2.32—2.51 (1H, m, H-3), 3.52 (1H, dd, $J_{3,4}$=10.2 Hz and $J_{4,5}$=2.0 Hz, H-4), 3.80 (3H, s, OMe), 3.95—4.10 (2H, m, 2×H-6), 5.05 (1H, dd, J_{gem}=1.6 Hz and $J_{1,2}$=10.2 Hz, H-1), 5.14 (1H, br d, $J_{1',2}$=17.7 Hz, H-1′), 5.44 (1H, s, C*H*Ar), 5.64 (1H, ddd, $J_{2,3}$=9.8 Hz, H-2), 6.89 and 7.42 (each 2H, each d-like, J=9.0 Hz, aromatic protons). Found : m/z 263.1673 [(M+H)$^+$]. Calcd for $C_{16}H_{23}O_3$: M+1, 263.1647.

(3*R*,4*S*,5*R*,6*R*,7*S*)-6,8-(4-Methoxybenzylidenedioxy)-3,5,7-trimethyl-1-octen-4-ol (40). To a stirred solution of **39** (727 mg, 2.77 mmol) in acetone (22 ml) and water (7 ml) were added at 25 °C NMO (1.46 g, 12.5 mmol) and OsO_4 (74.7 mg, 0.294 mmol). After 20 h at 25 °C, saturated aqueous $Na_2S_2O_3$ was added and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (30 g) with 5 : 3 and then 1 : 1 $CHCl_3$–acetone to afford diol (690 mg, 84%). To a stirred solution of this diol (615 mg, 2.08 mmol) in THF (18 ml) and water (6 ml) was added at 0 °C $NaIO_4$ (799 mg, 3.73 mmol). After 1 h at 25 °C, water was added, and the mixture was extracted with 1 : 1 hexane–ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residual aldehyde (549 mg, 100%) was used without any purification. To a suspension of t-BuOK (595 mg, 5.30 mmol) in dry THF (1.5 ml) was added at −35 °C (Z)-2-butene (1.8 ml, 20 mmol); the mixture was cooled to −78 °C. To this was added 1.6 M n-BuLi in hexane (3.2 ml, 5.2 mmol), and the mixture was stirred at −35 °C for 35 min. After cooling to −78 °C, a solution of B-(−)-methoxydiisopinocampheylborane (2.23 g, 7.42 mmol) in dry ether (6.2 ml) was added. After 0.5 h at −78 °C, BF_3·OEt_2 (0.87 ml, 6.9 mmol) was added; to this was added a solution of the above aldehyde (549 mg, 2.08 mmol) in dry ether (3 ml). After 2 h at −78 °C, a solution of NaOH (0.89 g) in water (6.5 ml) was added and the mixture was warmed to 0 °C. 30% Aqueous H_2O_2 (2.5 ml) was slowly added and the mixture was stirred at 52 °C for 0.5 h. After cooling to 0 °C, saturated aqueous NH_4Cl was added and the mixture was extracted with 1 : 1 hexane–ethyl acetate. The extracts were washed with water and saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (67 g) with 5 : 2 hexane–ethyl acetate to afford **40** (400 mg, 60%) as a colorless syrup: R_f=0.32 (5 : 2 hexane–ethyl acetate); $[\alpha]_D^{31}$ +4.6° (c 1.05), $[\alpha]_{365}^{31}$ +15.4° (c 1.05); IR 2969, 1616, 1518, 1249, 1169, 1107, 1034, 1000, and 975 cm^{-1}; ^{1}H NMR δ=0.98 (3H, d, J=7.4 Hz, 5-Me), 1.12 and 1.15 (each 3H, each d, J=6.4 Hz, 2×Me), 1.37 (1H, br d, J=7.0 Hz, OH), 1.70—1.85 (1H, m, H-7), 1.93 (1H, ddq, $J_{4,5}$=1.9 Hz and $J_{5,6}$=9.8 Hz, H-5), 2.33 (1H, dddq, $J_{2,3}$=$J_{3,4}$=9.3 and $J_{1',3}$=1.0 Hz, H-3), 3.30—3.41 (1H, br, H-4), 3.79 (3H, s, OMe), 3.84 (1H, dd, $J_{6,7}$=2.0 Hz, H-6), 4.01 (1H, dd, J_{gem}=11.3 Hz and $J_{7,8}$=1.4 Hz, H-8), 4.09 (1H, dd, $J_{7,8'}$=2.6 Hz, H-8′), 5.00 (1H, dd, $J_{1,2}$=10.4 Hz and J_{gem}=1.8 Hz, H-1), 5.08 (1H, ddd, $J_{1',2}$=10.4 Hz, H-1′), 5.47 (1H, s, C*H*Ar), 5.60 (1H, ddd, H-2), 6.88 and 7.42 (each 2H, each d-like, J=9.0 Hz, aromatic protons). Found : m/z 321.2066 [(M+H)$^+$]. Calcd for $C_{19}H_{29}O_4$: M+1, 321.2066.

Transformation of 40 to 41. To a stirred solution of **40** (18.3 mg, 0.0571 mmol) in acetone (0.55 ml) and water (0.18 ml) were added at 25 °C NMO (33.5 mg, 0.286 mmol) and OsO_4 (3.6 mg, 0.014 mmol). After 2 h at 25 °C, saturated aqueous $Na_2S_2O_3$ was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The

residue was chromatographed on silica gel (2 g) with 3:2 $CHCl_3$–acetone to afford triol (17.6 mg, 87%). To a stirred solution of this triol (17.6 mg, 0.0500 mmol) in THF (0.53 ml) and water (0.18 ml) was added at 0 °C $NaIO_4$ (21.2 mg, 0.0990 mmol). After 0.5 h at 0 °C, water was added, and the mixture was extracted with 1:1 hexane–ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1.6 g) with 3:2 hexane–ethyl acetate to afford aldehyde (11.3 mg, 71%). This (11.3 mg, 0.0350 mmol) was dissolved in MeOH (0.34 ml) and to this was added at 0 °C $NaBH_4$ (1.7 mg, 0.046 mmol). After 0.5 h at 25 °C, saturated aqueous NH_4Cl was added and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1.1 g) with 5:2 $CHCl_3$–acetone to afford diol (10.7 mg, 94%). A mixture of this diol (3.1 mg, 0.010 mmol), 20% $Pd(OH)_2$ on carbon (3.5 mg), and EtOH (0.5 ml) was stirred under an atmospheric pressure of H_2 (1 atm) at 25 °C for 1 h. The insoluble materials were filtered and washed with EtOH. The combined filtrate and washings were concentrated and the residue was dissolved in dry pyridine (0.2 ml). To this were added Ac_2O (0.0088 ml, 0.093 mmol) and DMAP (4.6 mg, 0.038 mmol). After 45 min at 25 °C, EtOH was added, and the mixture was stirred at 25 °C for 10 min. The mixture was concentrated and the residue was chromatographed on silica gel (1 g) with 2:1 hexane–ethyl acetate to afford **41** (3.6 mg, 90%) as a colorless syrup: R_f=0.50 (1:1 hexane–ethyl acetate); ^{1}H NMR δ=0.91 (3H, d, J=6.4 Hz, Me), 0.93 (6H, d, J=6.4 Hz, 2×Me), 2.06 and 2.09 (each 6H, each s, 4×OAc), 2.00—2.15 (1H, m), 2.23 (2H, m), 3.88 (2H, dd, J=5.6 and 11.6 Hz), 3.94 (2H, dd, J=6.4 and 11.6 Hz), and 4.95 (2H, dd, J=5.8 and 5.8 Hz).

(2*S*,3*R*,4*R*,5*S*,6*R*)-3-(4-Methoxybenzyloxy)-5-(triethylsilyloxy)-2,3,6-trimethyl-7-octen-1-ol (42). To a stirred solution of **40** (1.09 g, 3.40 mmol) in dry DMF (20 ml) were added at 25 °C imidazole (696 mg, 10.2 mmol) and TESCl (1.54 ml, 9.17 mmol). After 3 h at 50 °C, water was added and the mixture was extracted with 3:1 hexane–ether. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (104 g) with 12:1 hexane–ethyl acetate to afford a colorless syrup (1.36 g, 92%). To a stirred solution of this syrup (1.32 g, 3.04 mmol) in dry CH_2Cl_2 (26 ml) was added at −25 °C 1 M DIBAL in CH_2Cl_2 (10.6 ml, 10.6 mmol). After 0.5 h at 0 °C, MeOH (0.43 ml) and potassium sodium tartrate tetrahydrate (15 g) in water (70 ml) were added and the mixture was separated. The aqueous layer was extracted with ethyl acetate and the combined organic layers were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (66 g) with 5:1 hexane–ethyl acetate to afford **42** (1.30 g, 98%) as a colorless syrup: R_f=0.30 (5:1 hexane–ethyl acetate); $[\alpha]_D^{31}$ +9.8° (*c* 1.06), $[\alpha]_{365}^{31}$ +27.5° (*c* 1.06); IR 2960, 2879, 1514, 1248, and 1034 cm^{-1}; ^{1}H NMR δ=0.65 (6H, q, J=8.0 Hz, 3×$SiCH_2$), 0.89, 1.01, and 1.03 (each 3H, each d, J=7.0, 7.2, and 7.0 Hz, 3×Me), 0.99 (9H, t, $Si(CH_2Me)_3$), 1.73 (1H, t, J=5.5 and 5.5 Hz, OH), 1.89—2.06 (2H, m, H-2 and H-4), 2.29—2.45 (1H, m, H-6), 3.47 (1H, d, J=3.4 Hz), 3.50 (1H, dd, J=1.7 and 2.1 Hz), 3.55—3.70 (2H, m, 2×H-1), 3.79 (3H, s, OMe), 4.45 and 4.53 (each 1H, ABq, J=11.0 Hz, OCH_2Ar), 4.97 (1H, ddd, $J_{7,8}$=10.3 Hz and $J_{6,8}$=1.3 Hz, and J_{gem}=2.4 Hz, H-8), 5.00 (1H, ddd, $J_{7,8'}$=17.4 Hz and $J_{6,8'}$=2.0 Hz, H-8′), 5.72 (1H, ddd, $J_{6,7}$=7.9 Hz, H-7), 6.87 and 7.26 (each 2H, each d-like, J=9.0 Hz, aromatic protons). Found: *m/z* 437.3098 [$(M+H)^+$]. Calcd for $C_{25}H_{45}O_4Si$: M+1, 437.3087.

(2-Trimethylsilylethoxy)methyl 2,4,6,7,8-Pentadeoxy-3-*O*-(4-methoxybenzyl)-2,4,6-tri-*C*-methyl-D-*glycero*-α-L-*ido*-7-octenopyranoside (43) and Its β-Isomer. A solution of DMSO (0.85 ml, 12 mmol) in dry CH_2Cl_2 (8 ml) was added at −78 °C to a stirred solution of oxalyl dichloride (0.52 ml, 6.1 mmol) in dry CH_2Cl_2 (15 ml). After 10 min at −78 °C, a solution of **42** (1.30 g, 2.98 mmol) in dry CH_2Cl_2 (11 ml) was added and the resulting suspension was stirred at −78 °C for 0.5 h. After the addition of triethylamine (2.5 ml, 18 mmol), the mixture was gradually warmed to 0 °C during 0.5 h. The reaction mixture was quenched with water and extracted with 3:1 hexane–ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. To this syrup (1.29 g, 2.98 mmol) was added 9:1 (95:5 MeCN–46% aqueous HF)–water (33 ml). After 0.5 h at 25 °C, saturated aqueous $NaHCO_3$ was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (71 g) with 3:1 hexane–ethyl acetate to afford a colorless syrup (780 mg, 82%, two steps). To a solution of this syrup (778 mg, 2.43 mmol) in dry CH_2Cl_2 (13.5 ml) were added at 0 °C *N*-ethyl-*N*-isopropylisopropylamine (2.2 ml, 13 mmol) and SEMCl (2.0 ml, 11 mmol). After 20 h at 25 °C, water was added and the mixture was extracted with 2:1 hexane–ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (82 g) with 8:1 hexane–ether to afford **43** (510 mg, 46.8%) and its β-isomer (464 mg, 42.6%) as colorless syrups:

43: R_f=0.38 (4:1 hexane–ether); $[\alpha]_D^{31}$ −98.0° (*c* 1.11); IR 2961, 2882, 1613, 1513, 1250, 1103, 1055, 997, and 971 cm^{-1}; ^{1}H NMR ($CHCl_3$=7.26) δ=0.02 (9H, s, $SiMe_3$), 0.90—1.05 (2H, m, $SiCH_2$), 1.00 and 1.09 (each 3H, each d, J=7.4 Hz, 2×Me), 1.06 (3H, d, J=7.0 Hz, 6-Me), 1.88 (1H, ddq, $J_{3,4}$=4.0 Hz and $J_{4,5}$=3.5 Hz, H-4), 2.03 (1H, ddq, $J_{1,2}$=5.4 Hz and $J_{2,3}$=7.4 Hz, H-2), 2.23—2.40 (1H, m, H-6), 3.02 (1H, dd, H-3), 3.55 (1H, dt, J=9.6 and 6.4 Hz, one of OCH_2CH_2Si), 3.77 (1H, dt, J=9.6 and 9.6 Hz, one of OCH_2CH_2Si), 3.77 (1H, dd, $J_{5,6}$=10.8 Hz, H-5), 3.81 (3H, s, OMe), 4.47 and 4.54 (each 1H, ABq, J=11.6 Hz, OCH_2), 4.64 and 4.99 (each 1H, ABq, J=7.0 Hz, OCH_2), 4.76 (1H, d, H-1), 5.00 (1H, dd, $J_{7,8}$=10.5 Hz and J_{gem}=2.0 Hz, H-8), 5.08 (1H, ddd, $J_{7,8'}$=17.0 Hz and $J_{6,8'}$=1.4 Hz, H-8′), 5.61 (1H, ddd, $J_{6,7}$=9.0 Hz, H-7), 6.87 and 7.27 (each 2H, each d-like, J=9.0 Hz, aromatic protons). Found: *m/z* 450.2804 (M^+). Calcd for $C_{25}H_{42}O_5Si$: M, 450.2801.

β-Isomer of 43: R_f=0.44 (4:1 hexane–ether); ^{1}H NMR ($CHCl_3$=7.26) δ=0.02 (9H, s, $SiMe_3$), 0.90—1.05 (2H, m, $SiCH_2$), 1.00, 1.04, and 1.10 (each 3H, each d, J=7.5, 7.5, and 6.4 Hz, 3×Me), 1.80—1.93, 2.00, 2.15, and 2.30—2.47 (each 1H, each m, H-2, H-4, and H-6), 3.38 (1H, dd, J=2.0 and 2.0 Hz), 3.50—3.80 (3H, m), 3.81 (3H, s, OMe), 4.44 (2H, s, OCH_2), 4.72 and 5.03 (each 1H, ABq, J=7.0 Hz, OCH_2), 4.98 (1H, dd, $J_{7,8}$=10.0 Hz and J_{gem}=2.0 Hz, H-8), 5.08 (1H, d, $J_{1,2}$=3.2 Hz, H-1), 5.07 (1H, dd, $J_{7,8'}$=17.0

Hz, H-8′), 5.59 (1H, ddd, $J_{6,7}$=8.4 Hz, H-7), 6.88 and 7.24 (each 2H, each d-like, J=9.0 Hz, aromatic protons).

Deprotection of the β-Isomer of 43. A solution of the β-isomer of **43** (503 mg, 1.12 mmol) in 9:1 (95:5 MeCN–46% aqueous HF)–water (40 ml) was stirred at 25 °C for 2.5 h. Saturated aqueous $NaHCO_3$ was added and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (40 g) with 5:2 hexane–ethyl acetate to afford hemiacetal (261 mg, 73%) as a colorless syrup, which was recycled to **43**.

(2-Trimethylsilylethoxy)methyl 2,4,6-Trideoxy-3-*O*-(4-methoxybenzyl)-2,4,6-tri-*C*-methyl-D-*glycero*-α-L-*ido*-heptodialdopyranoside-(1,5) (9). To a stirred solution of **43** (484 mg, 1.07 mmol) in acetone (14.5 ml) and water (4.8 ml) were added at 25 °C NMO (633 mg, 5.41 mmol) and OsO_4 (94.3 mg, 0.371 mmol). After 7 h at 25 °C, saturated aqueous $Na_2S_2O_3$ was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (42 g) with 3:1 hexane–ether and then 5:2 $CHCl_3$–ether and then 5:2 $CHCl_3$–acetone to afford a colorless syrup (495 mg, 95%). To a stirred solution of this syrup (77.4 mg, 0.160 mmol) in THF (1.55 ml) and H_2O (1.55 ml) was added at 0 °C $NaIO_4$ (73.5 mg, 0.344 mmol). After 50 min at 25 °C, water was added and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (3.6 g) with 4:1 hexane–acetone to afford **9** (69.4 mg, 96%) as a colorless syrup: R_f=0.51 (3:1 hexane–acetone); ^{1}H NMR ($CHCl_3$=7.26) δ=0.02 (9H, s, $SiMe_3$), 0.84—1.06 (2H, m, $SiCH_2$), 0.98 (3H, d, J=7.4 Hz, 6-Me), 1.11 and 1.17 (each 3H, each d, J=6.4 Hz, 2×Me), 1.93—2.11 (2H, m, H-2 and H-4), 2.65 (1H, ddq, $J_{5,6}$=9.2 Hz and $J_{6,7}$=2.8 Hz, H-6), 3.03 (1H, dd, J=5.0 and 7.8 Hz, H-3), 3.55 (1H, dt, J=10.2 and 7.0 Hz, one of OCH_2CH_2Si), 3.73 (1H, dt, J=10.2 and 7.4 Hz, one of OCH_2CH_2Si), 3.80 (3H, s, OMe), 4.24 (1H, dd, $J_{4,5}$=3.4 Hz, H-5), 4.51 (2H, s, OCH_2), 4.64 and 4.97 (each 1H, ABq, J=6.6 Hz, OCH_2), 4.74 (1H, d, $J_{1,2}$=6.0 Hz, H-1), 6.87 and 7.27 (each 2H, each d-like, J=9.0 Hz, aromatic protons), and 9.63 (1H, d, $J_{6,7}$=2.8 Hz, H-7).

(2*R*,3*S*,4*R*)-4-Methyl-2-(triethylsilyloxy)-5-hexen-3-ol (44). To a stirred solution of methyl (*R*)-lactate (5.00 g, 48.0 mmol) in dry DMF (50 ml) were added at 25 °C imidazole (3.88 g, 57.0 mmol) and TESCl (8.50 ml, 50.6 mmol). After 2.5 h at 25 °C, water was added and the mixture was extracted with pentane. The extracts were washed with saturated aqueous NaCl, dried, and concentrated (<0 °C). The residue was distilled to afford a pure sample (9.73 g, 93%; bp 59—60 °C/1.8 mmHg). To a stirred solution of this sample (4.36 g, 20.0 mmol) in dry CH_2Cl_2 (43 ml) was added at −78 °C 1.0 M DIBAL in CH_2Cl_2 (21.0 ml, 21.0 mmol). After 3.5 h at −78 °C, MeOH (3.0 ml) and potassium sodium tartrate tetrahydrate (30 g) in water (120 ml) were added, and the mixture was separated. The aqueous layer was extracted with CH_2Cl_2; the combined organic layers were washed with saturated aqueous NaCl, dried, and concentrated (<0 °C). The residual aldehyde **12** (3.76 g, 100%) was used without any purification. To a suspension of *t*-BuOK (3.32 g, 29.6 mmol) in dry THF (8.7 ml) was added at −35 °C (*Z*)-2-butene (7.4 ml, 82 mmol); the mixture was cooled to −78 °C. To this was added 1.6 M *n*-BuLi in hexane (8.7 ml, 30 mmol); the mixture was stirred at −35 °C for 30 min. After cooling to −78 °C, a solution of *B*-(−)-methoxydiisopinocampheylborane (10.5 g, 35.0 mmol) in dry ether (35 ml) was added. After 0.5 h at −78 °C, BF_3·OEt_2 (5.0 ml, 40 mmol) was added; to this was added a solution of **12** (3.76 g, 20.0 mmol) in THF (18 ml). After 1.5 h at −78 °C, a solution of NaOH (4.2 g) in water (35 ml) was added and the mixture warmed to 0 °C. 30% Aqueous H_2O_2 (11.8 ml) was slowly added and the mixture was stirred at 53 °C for 20 min. After cooling to 0 °C, saturated aqueous NH_4Cl was added, and the mixture was extracted with hexane. The extracts were washed with water and saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (250 g) with 7:1 hexane–ether to afford **44** (3.66 g, 75%) as a colorless syrup: R_f=0.39 (7:1 hexane–ether); $[\alpha]_D^{27}$ +8.2° (*c* 1.25), $[\alpha]_{365}^{27}$ +37.3° (*c* 1.25); IR 2960, 2878, 1458, 1383, 1238, 1084, 1047, 1004, and 967 cm^{-1}; ^{1}H NMR δ=0.59 (6H, q, J=8.2 Hz, 3×$SiCH_2$), 0.96 (9H, t, $Si(CH_2Me)_3$), 1.09 and 1.12 (each 3H, each d, J=6.8 Hz, 2×Me), 2.13—2.29 (1H, m, H-4), 2.39 (1H, d, J=1.6 Hz, OH), 3.34 (1H, ddd, $J_{3,4}$=8.8 Hz and $J_{2,3}$=3.6 Hz, H-3), 3.84 (1H, dq, J=6.8 Hz, H-2), 5.01 (1H, dd, $J_{5,6}$=10.3 Hz and J_{gem}=1.6 Hz, H-6), 5.06 (1H, dt, $J_{5,6'}$=17.8 Hz and $J_{4,6'}$=1.6 Hz, H-6′), and 5.66 (1H, ddd, $J_{4,5}$=8.2 Hz, H-5). Found: *m/z* 226.1752 [$(M-H_2O)^+$]. Calcd for $C_{13}H_{26}OSi$: M−18, 226.1756.

Transformation of 44 to 45. To a stirred solution of **44** (28.3 mg, 0.116 mmol) in dry DMF (0.28 ml) were added at 25 °C triethylamine (0.0323 ml, 0.232 mmol) and TBSCl (26.2 mg, 0.174 mmol). After 14 h at 25 °C, water was added and the mixture was extracted with hexane. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (4 g) with hexane to afford a colorless syrup (35.6 mg, 86%). To a stirred solution of BH_3·SMe_2 (0.153 ml, 1.53 mmol) in dry THF (2.7 ml) was added at 0 °C cyclohexene (0.310 ml, 3.06 mmol); the mixture was stirred at 0 °C for 2 h. A portion of this solution (0.80 ml, 0.384 mmol) was added at 0 °C to a stirred solution of the above syrup (34.3 mg, 0.0960 mmol) in dry THF (0.34 ml). After 1 h at 0 °C, 3 M aqueous NaOH and 30% aqueous H_2O_2 were added, and the mixture was stirred at 25 °C for 15 min and 40 °C for 20 min. Water was added and the mixture was extracted with hexane. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (4 g) with 6:1 hexane–ethyl acetate to afford a colorless syrup (33.2 mg, 92%). To a stirred solution of this syrup (33.2 mg, 0.0880 mmol) in dry CH_2Cl_2 (0.66 ml) were added at 25 °C MS 4AP (44.1 mg) and PCC (38.9 mg, 0.176 mmol). After 0.5 h at 25 °C, the reaction mixture was diluted with ether; the resulting suspension was transferred to a column filled with silica gel. The column was eluted with ether and the eluate was concentrated to afford aldehyde (23.2 mg, 70%) as a colorless syrup. A mixture of this aldehyde (23.2 mg, 0.0619 mmol) and 5:1:5 acetic acid–water–THF (0.46 ml) was stirred at 25 °C for 9 h. The reaction mixture was neutralized with 10% aqueous NaOH and extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried,

and concentrated. The residue was chromatographed on silica gel (2 g) with 4:1 hexane–ethyl acetate to afford a free sugar (15.6 mg, 97%). To a stirred solution of this sample (15.6 mg, 0.0601 mmol) in dry benzene (0.32 ml) were added at 25 °C DMAP (25.7 mg, 0.210 mmol) and PvCl (0.0222 m, 0.0180 mmol). After 3 h at 25 °C, EtOH was added, and the mixture was extracted with hexane. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (2 g) with 35:1 benzene–ethyl acetate to afford the α-isomer of **45** (7.2 mg, 35%) and the β-isomer of **45** (7.2 mg, 35%) as colorless syrups.

α-Isomer of 45: R_f=0.38 (35:1 benzene–ethyl acetate); ^{1}H NMR ($CHCl_3$=7.26) δ=0.09 (6H, s, $SiMe_2$), 0.92 (9H, s, *t*-Bu), 0.97 and 1.20 (each 3H, each d, J=6.0 Hz, 2×Me), 1.24 (9H, s, *t*-Bu), 1.54 (1H, ddd, J_{gem}=13.6 Hz, $J_{2ax,3}$=9.0 Hz and $J_{1,2ax}$=2.8 Hz, H-2ax), 1.80 (1H, ddd, $J_{2eq,3}$=3.6 Hz and $J_{1,2eq}$=1.0 Hz, H-2eq), 1.80—1.95 (1H, m, H-3), 2.96 (1H, dd, $J_{3,4}=J_{4,5}$=9.0 Hz, H-4), 3.66 (1H, dq, H-5), and 6.03 (1H, dd, H-1).

β-Isomer of 45: R_f=0.43 (35:1 benzene–ethyl acetate); ^{1}H NMR ($CHCl_3$=7.26) δ=0.08 (6H, s, $SiMe_2$), 0.90 (9H, s, *t*-Bu), 1.00 and 1.26 (each 3H, each d, J=6.0 Hz, 2×Me), 1.21 (9H, s, *t*-Bu), 1.40 (1H, ddd, $J_{gem}=J_{2ax,3}$=12.4 Hz and $J_{1,2ax}$=10.0 Hz, H-2ax), 1.60—1.77 (1H, m, H-3), 2.87 (1H, ddd, $J_{2eq,3}$=3.8 Hz and $J_{1,2eq}$=2.0 Hz, H-2eq), 2.95 (1H, dd, $J_{3,4}=J_{4,5}$=9.0 Hz, H-4), 3.40 (1H, dq, H-5), and 5.68 (1H, dd, H-1).

(4*R*,5*S*,6*R*)-5-(4-Methoxybenzyloxy)-4-methyl-6-(triethylsilyloxy)-1-heptene (46). To a stirred solution of **44** (2.53 g, 10.3 mmol) in dry CH_2Cl_2 (24 ml) were added at 25 °C 2.0 M (4-methoxybenzyl) trichloroacetimidate in hexane (25 ml, 50 mmol) and CSA (607 mg, 2.61 mmol). After 72 h at 25 °C, triethylamine (0.4 ml) was added and the insoluble materials were filtered and washed with hexane; the combined filtrate and washings were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (151 g) with 16:1 hexane–ethyl acetate to afford a colorless syrup [2.08 g, 55%; $[\alpha]_D^{26}$ −11.7° (*c* 1.13). Found: *m/z* 364.2412 (M^+). Calcd for $C_{21}H_{36}O_3Si$: M, 364.2433]. To a stirred solution of 10 M BH_3·SMe_2 (0.482 ml, 4.82 mmol) in dry THF (10 ml) was added at 0 °C cyclohexene (0.97 ml, 9.6 mmol); the mixture was stirred at 0 °C for 2 h. To this was added at 0 °C a solution of the above syrup (503 mg, 1.38 mmol) in dry THF (5.0 ml). After 1 h at 0 °C, 3 M aqueous NaOH (4.8 ml) and 30% aqueous H_2O_2 (1.63 ml) were added, and the mixture was stirred at 51 °C for 20 min. Water was added and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (52 g) with 5:2 hexane–ethyl acetate to afford alcohol (512 mg, 97%) as a colorless syrup [$[\alpha]_D^{27}$ −9.5° (*c* 1.05), $[\alpha]_{365}^{27}$ −33.5° (*c* 1.05). Found: *m/z* 381.2443 [$(M-H)^+$]. Calcd for $C_{21}H_{37}O_4Si$: M−1, 381.2461]. To a stirred solution of the above alcohol (116 mg, 0.303 mmol) in dry CH_2Cl_2 (2.3 ml) were added at 25 °C pyridine (0.049 ml, 0.61 mmol) and Dess–Martin periodinane (184 mg, 0.431 mmol). After 1 h at 25 °C, saturated aqueous $NaHCO_3$ and $Na_2S_2O_3$ were added, and the mixture was extracted with ether. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residual aldehyde (115 mg, 0.303 mmol) was dissolved in dry benzene (2.3 ml); to this was added at 25 °C $Ph_3P{=}CH_2$ (254 mg, 0.920 mmol). After 12 h at 45 °C, the reaction mixture was concentrated and the residue was chromatographed on silica gel (10 g) with 13:1 hexane–ethyl acetate to afford **46** (97.2 mg, 85%) as a colorless syrup: R_f=0.59 (7:1 hexane–ethyl acetate); $[\alpha]_D^{28}$ −19.8° (*c* 0.97); IR 3019, 1514, 1247, 1227, and 1099 cm^{-1}; ^{1}H NMR δ=0.60 (6H, q, J=8.2 Hz, 3×$SiCH_2$), 0.93 (3H, d, J=6.4 Hz, 4-Me), 0.96 (9H, t, $Si(CH_2Me)_3$), 1.23 (3H, d, J=5.9 Hz, 6-Me), 1.78—2.07 and 2.11—2.26 (2H and 1H, each m, 2×H-3 and H-4), 3.16 (1H, dd, $J_{4,5}$=4.8 Hz and $J_{5,6}$=5.9 Hz, H-5), 3.79 (3H, s, OMe), 3.91 (1H, dq, H-6), 4.49 and 4.67 (each 1H, ABq, J=11.0 Hz, OCH_2Ar), 4.96—5.07 (2H, m, 2×H-1), 5.78 (1H, ddt, $J_{1,2}$=17.5 Hz, $J_{1',2}$=11.0 Hz, and $J_{2,3}=J_{2,3'}$=7.0 Hz, H-2), 6.86 and 7.29 (each 2H, each d-like, J=9.0 Hz, aromatic protons). Found: *m/z* 378.2630 (M^+). Calcd for $C_{22}H_{38}O_3Si$: M, 378.2590.

(3*S*,4*R*)-3-(4-Methoxybenzyloxy)-4-methyl-6-hepten-2-one (47). To a stirred solution of **46** (403 mg, 1.06 mmol) in dry THF (8 ml) was added at 25 °C 1.0 M *n*-Bu_4NF in THF (1.33 ml, 1.33 mmol). After 1.5 h at 25 °C, water was added and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (8.4 g) with 3:1 hexane–ethyl acetate to afford a colorless syrup (281 mg, 100%). To a stirred solution of this syrup (274 mg, 1.04 mmol) in dry CH_2Cl_2 (5.4 ml) was added at 25 °C Dess–Martin periodinane (549 mg, 1.28 mmol). After 0.5 h at 25 °C, saturated aqueous $NaHCO_3$ and $Na_2S_2O_3$ were added and the mixture was extracted with ether. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (13 g) with 6:1 hexane–ethyl acetate to afford **47** (258 mg, 95%) as a colorless syrup: R_f=0.50 (5:1 hexane–ethyl acetate); $[\alpha]_D^{28}$ −50.8° (*c* 1.11); IR 3019, 1723, 1709, 1612, 1515, 1250, and 1035 cm^{-1}; ^{1}H NMR δ=0.91 (3H, d, J=6.7 Hz, 4-Me), 1.87—2.04 and 2.06—2.24 (2H and 1H, m, H-4 and 2×H-5), 2.16 (3H, s, 3×H-1), 3.67 (1H, d, $J_{3,4}$=4.6 Hz, H-3), 3.81 (3H, s, OMe), 4.31 and 4.54 (each 1H, ABq, J=11.3 Hz, OCH_2Ar), 4.92—5.06 (2H, m, 2×H-7), 5.72 (1H, dddd, $J_{6,7}$=16.6 Hz, $J_{6,7'}$=10.0 Hz, and $J_{5,6}=J_{5',6}$=7.3 Hz, H-6), 6.88 and 7.27 (each 2H, each d-like, J=9.0 Hz, aromatic protons). Found: *m/z* 262.1579 (M^+). Calcd for $C_{16}H_{22}O_3$: M, 262.1569.

(4*R*,5*S*,6*R*)-4-Hydroxy-5-(4-methoxybenzyloxy)-4,6-dimethyl-1,8-nonadien-3-one (48). To a stirred solution of α-methoxyallene (0.136 ml, 1.63 mmol) in dry ether (6.5 ml) was added at −44 °C 1.6 M *n*-BuLi in hexane (0.97 ml, 1.6 mmol); the mixture was stirred at −44 °C for 5 min. After cooling to −65 °C, a solution of $MgBr_2$·OEt_2 (398 mg, 1.54 mmol) in dry benzene (0.61 ml) and dry ether (3.0 ml) was added; the mixture was stirred for 15 min. After cooling to −78 °C, a solution of **47** (113 mg, 0.431 mmol) in dry ether (0.56 ml) was added. After 2 h at −78 °C, the reaction mixture was warmed to −45 °C for 7 min. MeOH (0.3 ml) and saturated aqueous NH_4Cl (5 ml) were added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was dissolved in 1:5 aqueous HCl (0.10 M)–THF (2.85 ml) and this was stirred at 25 °C for 10 min. The reaction mixture was neutralized

with 0.1 M aqueous NaOH; to this was added water. The mixture was extracted with ethyl acetate, and the extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (13 g) with 30:1 $CHCl_3$–ethyl acetate and then 6:1 hexane–ethyl acetate to afford **48** (96.0 mg, 70%) as a colorless syrup: R_f=0.34 (6:1 hexane–ethyl acetate); $[\alpha]_D^{28}$ −14.8° (*c* 0.99); IR 3014, 1686, 1612, 1514, 1249, 1079, and 1040 cm^{-1}; ^1H NMR δ=0.93 (3H, d, J=7.0 Hz, 6-Me), 1.33 (3H, s, 4-Me), 1.98 (1H, dddq, $J_{5,6}$=2.0 Hz and $J_{6,7}=J_{6,7'}$=7.0 Hz, H-6), 2.03—2.29 (2H, m, 2×H-7), 3.79 (1H, d, H-5), 3.81 (3H, s, OMe), 3.90 (1H, s, OH), 4.41 and 4.53 (each 1H, ABq, J=11.0 Hz, OCH_2Ar), 4.98—5.11 (2H, m, 2×H-9), 5.73 (1H, dd, $J_{1,2}$=10.2 Hz and J_{gem}=2.0 Hz, H-1), 5.78 (1H, dddd, $J_{8,9}$=16.8 Hz, $J_{8,9'}$=11.0 Hz, and $J_{7,8}=J_{7,8'}$=6.7 Hz, H-8), 6.43 (1H, dd, $J_{1',2}$=17.0 Hz, H-1′), 6.87 and 7.21 (each 2H, each d-like, J=9.0 Hz, aromatic protons), and 7.01 (1H, dd, H-2). Found: m/z 301.1808 [$(M-OH)^+$]. Calcd for $C_{19}H_{25}O_3$: M−17, 301.1803.

(4*R*,5*S*,6*R*)-4-Hydroxy-5-(4-methoxybenzyloxy)-4,6-dimethyl-8-nonen-3-one (49). To a stirred solution of **48** (198 mg, 0.622 mmol) in dry THF (100 ml) was added at −100 °C 0.1 M L-selectride in THF (6.9 ml, 0.69 mmol) during 10 min. After 1 h at −100 °C, MeOH (0.29 ml) and saturated aqueous NH_4Cl were added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (14 g) with 6:1 hexane–ethyl acetate to afford **49** (184 mg, 92%) as colorless crystals: R_f=0.34 (6:1 hexane–ethyl acetate); mp 44—45 °C (pentane); $[\alpha]_D^{28}$ −27.6° (*c* 1.06); IR 3022, 1711, 1587, 1515, 1250, 1175, 1113, 1035, and 918 cm^{-1}; ^1H NMR δ=0.93 (3H, d, J=6.8 Hz, 6-Me), 1.04 (3H, t, J=7.1 Hz, 3×H-1), 1.29 (3H, s, 4-Me), 1.96 (1H, dddq, $J_{6,7}=J_{6,7'}$=6.8 Hz and $J_{5,6}$=2.0 Hz, H-6), 2.03—2.29 (2H, m, 2×H-7), 2.51 and 2.80 (each 1H, dq, J_{gem}=19.2 Hz, 2×H-2), 3.74 (1H, s, OH), 3.76 (1H, d, H-5), 3.81 (3H, s, OMe), 4.35 and 4.55 (each 1H, ABq, J=11.5 Hz, OCH_2Ar), 4.99—5.11 (2H, m, 2×H-9), 5.78 (1H, dddd, $J_{8,9}$=16.1 Hz, $J_{8,9'}$=11.4 Hz, and $J_{7,8}=J_{7',8}$=7.7 Hz, H-8), 6.88 and 7.21 (each 2H, each d-like, J=9.0 Hz, aromatic protons). Found: m/z 320.1980 (M^+). Calcd for $C_{19}H_{28}O_4$: M, 320.1988.

***t*-Butyldimethylsilyl 2,3,7,8-Tetradeoxy-4-*O*-(4-methoxybenzyl)-3,5-di-*C*-methyl-α-L-*xylo*-octopyranosid-6-ulose (10) and Its β-Isomer.** To a stirred solution of **49** (354 mg, 1.10 mmol) in acetone (11 ml) and water (3.5 ml) were added at 25 °C NMO (664 mg, 5.67 mmol) and OsO_4 (28 mg, 0.11 mmol). After 12 h at 25 °C, saturated aqueous $Na_2S_2O_3$ was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. To a stirred solution of the residue (392 mg, 1.10 mmol) in THF (12 ml) and water (4 ml) was added at 0 °C $NaIO_4$ (342 mg, 1.60 mmol). After 1 h at 25 °C, water was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (14 g) with 5:2 hexane–ethyl acetate to afford a colorless syrup (349 mg, 98%). To a stirred solution of this syrup (240 mg, 0.744 mmol) in dry DMF (6 ml) were added at 25 °C imidazole (119 mg, 1.75 mmol) and TBSCl (222 mg, 1.47 mmol). After 12 h at 40 °C, water was added and the mixture was extracted with 1:1 hexane–ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (33 g) with 5:1 hexane–ether to afford **10** (158 mg, 48.5%) as a colorless syrup and its β-isomer (158 mg, 48.5%) as colorless crystals.

10: R_f=0.38 (5:1 hexane–ether); $[\alpha]_D^{29}$ −75.1° (*c* 1.01); IR 2958, 2934, 1712, 1613, 1515, 1463, 1251, 1117, 1099, 1077, 1038, and 841 cm^{-1}; ^1H NMR ($CHCl_3$=7.26) δ=0.13 and 0.14 (each 3H, each s, $SiMe_2$), 0.89 (9H, s, *t*-Bu), 0.97 (3H, t, J=7.7 Hz, 3×H-8), 1.02 (3H, d, J=6.6 Hz, 3-Me), 1.32 (1H, ddd, $J_{1,2ax}$=9.0 Hz and $J_{2ax,3}=J_{gem}$=13.8 Hz, H-2ax), 1.46 (3H, s, 5-Me), 1.75—1.95 (2H, m, H-2eq and H-3), 2.58 (2H, q, 2×H-7), 3.09 (1H, d, $J_{3,4}$=9.8 Hz, H-4), 3.81 (3H, s, OMe), 4.55 (2H, s, OCH_2Ar), 5.30 (1H, dd, $J_{1,2eq}$=3.3 Hz, H-1), 6.87 and 7.24 (each 2H, each d-like, J=9.0 Hz, aromatic protons). Found: m/z 436.2622 (M^+). Calcd for $C_{24}H_{40}O_5Si$: M, 436.2645.

β-Isomer of 10: R_f=0.32 (5:1 hexane–ether); mp 65.5 °C (plates from hexane); $[\alpha]_D^{30}$ +55.4° (*c* 0.88); IR 2959, 2934, 1713, 1613, 1514, 1464, 1251, 1157, 1069, 1039, 1003, and 831 cm^{-1}; ^1H NMR ($CHCl_3$=7.26) δ=0.10 and 0.12 (each 3H, each s, $SiMe_2$), 0.89 (9H, s, *t*-Bu), 0.95 (3H, t, J=7.4 Hz, 3×H-8), 1.38 (3H, s, 5-Me), 1.45 (1H, ddd, $J_{1,2eq}$=2.7 Hz, $J_{2eq,3}$=4.8 Hz, and J_{gem}=13.9 Hz, H-2eq), 1.92 (1H, ddd, $J_{1,2ax}$=7.6 Hz and $J_{2ax,3}$=5.6 Hz, H-2ax), 2.26—2.43 (1H, m, H-3), 2.57 and 2.80 (each 1H, each dq, J_{gem}=19.6 Hz, 2×H-7), 3.19 (1H, d, $J_{3,4}$=4.2 Hz, H-4), 3.79 (3H, s, OMe), 4.27 and 4.37 (each 1H, ABq, J=11.0 Hz, OCH_2Ar), 5.20 (1H, dd, H-1), 6.83 and 7.16 (each 2H, each d-like, J=9.0 Hz, aromatic protons). Found: m/z 435.2589 [$(M-H)^+$]. Calcd for $C_{24}H_{39}O_5Si$: M−1, 435.2567.

[1(2*R*,3*S*,4*R*,6*S*),2*S*,3*S*,4*R*,4(2*S*,3*S*,4*S*,5*R*,6*R*)]-1-[6-(*t*-Butyldimethylsilyloxy)-3-(4-methoxybenzyloxy)-2,4-dimethyltetrahydropyran-2-yl]-3-hydroxy-4-[4-(4-methoxybenzyloxy)-3,5-dimethyl-6-[(2-trimethylsilylethoxy)methoxy]tetrahydropyran-2-yl]-2-methyl-1-pentanone (53). To a stirred solution of **10** (32.2 mg, 0.0737 mmol) in dry THF (0.74 ml) was added at −78 °C 0.5 M $KN(SiMe_3)_2$ in toluene (0.162 ml, 0.0811 mmol). After 1 h at −78 °C, 1 M $ZnCl_2$ in ether (0.0811 ml, 0.0811 mmol) was added, and the mixture was stirred at −45 °C for 0.5 h. To this was added a solution of **9** (25.2 mg, 0.0557 mmol) in dry THF (0.15 ml). After 25 min at −45 °C and 15 min at −20 °C, saturated aqueous NH_4Cl was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (5 g) with 6:1 and then 7:2 hexane–ethyl acetate to afford **53** (23.8 mg, 48%) and its stereoisomer (18.3 mg, 37%) as colorless syrups.

53: R_f=0.33 (3:1 hexane–ethyl acetate); $[\alpha]_D^{27}$ −73.3° (*c* 0.82); IR 2958, 2934, 1700, 1613, 1514, 1463, 1250, 1076, 996, 969, and 838 cm^{-1}; ^1H NMR ($CHCl_3$=7.26) δ=0.01 (9H, s, $SiMe_3$), 0.12 (6H, s, $SiMe_2$), 0.88 (9H, s, *t*-Bu), 0.89 (3H, s, Me), 0.91 (3H, d, J=7.0 Hz, Me), 1.00 (3H, d, J=7.3 Hz, Me), 1.07 (3H, d, J=7.0 Hz, Me), 1.08 (3H, d, J=6.8 Hz, Me), 1.09 (3H, d, J=5.7 Hz, Me), 1.35 (1H, ddd, J=13.4 Hz, 9.6 Hz, and 7.2 Hz), 3.01 (1H, dd, J=8.2 and 4.3 Hz), 3.21 (1H, d, J=7.4 Hz), 3.43 (1H, quint like, J=7.3 Hz), 3.53 (1H, dt, J=10.0, 10.0, and 6.8 Hz), 3.77 (1H, dt, J=10.0, 10.0, and 7.5 Hz), 3.70—3.83 (1H, m), 3.80 and 3.81 (each

3H, each s, 2×OMe), 4.01 (1H, dd, J=9.7 and 3.6 Hz), 4.43 and 4.47 (each 1H, ABq, J=11.2 Hz), 4.49 and 4.53 (each 1H, ABq, J=11.4 Hz), 4.61 and 4.95 (each 1H, ABq, J=6.8 Hz), 4.71 (1H, d, J=5.4 Hz), 5.37 (1H, dd, J=7.2 and 3.6 Hz), 6.84, 6.88, 7.19, and 7.28 (each 2H, each m, aromatic protons). Found: C, 65.21; H, 9.02%. Calcd for $C_{48}H_{80}O_{11}Si_2$: C, 64.83; H, 9.07%.

Stereoisomer of 53: R_f=0.60 (3:1 hexane–ethyl acetate); IR 2958, 2934, 1694, 1613, 1514, 1463, 1250, 1177, 1075, 1036, 1002, 968, and 838 cm^{-1}; ^1H NMR ($CHCl_3$=7.26) δ=0.02 (9H, s, $SiMe_3$), 0.11 and 0.13 (each 3H, each s, $SiMe_2$), 0.72 (3H, d, J=6.6 Hz, Me), 0.89 (9H, s, *t*-Bu), 0.98 (3H, d, J=6.0 Hz, Me), 1.00 (3H, d, J=6.0 Hz, Me), 1.06 (3H, d, J=6.4 Hz, Me), 1.08 (3H, d, J=7.0 Hz, Me), 1.50 (3H, s, Me), 2.95 (1H, dd, J=9.0 and 4.0 Hz), 3.16 (1H, d, J=9.0 Hz), 3.29 (1H, d, J=2.0 Hz), 3.34 (1H, br q, J=7.0 Hz), 3.45—3.60 (2H, m), 3.77 and 3.80 (each 3H, each s, 2×OMe), 4.01 (1H, dd, J=6.2 and 4.2 Hz), 4.43 and 4.54 (each 1H, ABq, J=12.0 Hz), 4.45 (2H, s), 4.56 and 4.91 (each 1H, ABq, J=6.6 Hz), 4.69 (1H, d, J=5.8 Hz), 5.39 (1H, dd, J=8.2 and 4.0 Hz), 6.80—6.90 (4H, m), and 7.15—7.30 (4H, m).

Transformation of 53 to 55. To a stirred solution of **53** (27.5 mg, 0.0309 mmol) in THF (0.5 ml) and AcOH (0.020 ml) was added at 25 °C 1 M *n*-Bu_4NF (0.34 ml, 0.34 mmol). After 21 h at 25 °C, water was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (2 g) with 3:1 and then 5:3 hexane–acetone to afford a colorless syrup (25.6 mg, 98%). To a stirred solution of this syrup (18.1 mg, 0.0234 mmol) in dry MeOH (0.72 ml) was added at 25 °C $LiBH_4$ (20.0 mg, 0.918 mmol). After 4.5 h at 25 °C, saturated aqueous NH_4Cl was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (2 g) with 3:1 and then 1:1 $CHCl_3$–acetone to afford a colorless syrup (14.0 mg, 78%). To a solution of this syrup (14.0 mg, 0.0180 mmol) in 2:1:1 THF–H_2O–MeOH (0.56 ml) was added at 25 °C $NaIO_4$ (38.4 mg, 0.180 mmol). After 4 h at 25 °C, water was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1.5 g) with 4:1 benzene–ethyl acetate to afford a colorless syrup (7.1 mg, 77%). To a stirred solution of this syrup (7.1 mg, 0.014 mmol) in dry MeOH (0.28 ml) was added at 25 °C $NaBH_4$ (1.5 mg, 0.040 mmol). After 0.5 h at 25 °C, saturated aqueous NH_4Cl was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1 g) with 4:1 $CHCl_3$–acetone to afford a colorless syrup (7.4 mg, 100%). To a stirred solution of this syrup (6.4 mg, 0.012 mmol) in dry CH_2Cl_2 (0.32 ml) were added at 25 °C 4-methoxybenzaldehyde dimethyl acetal (0.0029 ml, 0.019 mmol) and CSA (0.3 mg, 0.001 mmol). After 1 h at 25 °C, triethylamine was added, and the mixture was concentrated. The residue was chromatographed on silica gel (1 g) with 7:1 and then 5:1 hexane–ethyl acetate to afford **54** (8.2 mg, 100%) as a colorless syrup [R_f=0.55 (3:1 hexane–ethyl acetate); ^1H NMR ($CHCl_3$=7.26) δ=0.03 (9H, s, $SiMe_3$), 1.08, 1.11, 1.13, and 1.17 (each 3H, each d, J=7.0 Hz, 4×Me), 3.08 (1H, dd, J=9.8 and 7.0 Hz), 3.80 and 3.81 (each 3H, each s, 2×OMe), 4.55 (2H, s), 4.60 and 4.96 (each 1H, ABq, J=6.2 Hz), 4.77 (1H, d, J=6.0 Hz), 5.43 (1H, s), 6.85—6.95 and 7.25—7.45 (each 4H, each m)]. To a stirred solution of **54** (5.6 mg, 0.0089 mmol) in dry CH_2Cl_2 (0.40 ml) was added at −78 °C 1.0 M DIBAL in CH_2Cl_2 (0.08 ml, 0.08 mmol). After 0.5 h at −30 °C, MeOH and potassium sodium tartrate tetrahydrate (100 mg) in water (1 ml) were added, and the mixture was separated. The aqueous layer was extracted with CH_2Cl_2, the combined organic layers were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1 g) with 4:1 and then 5:2 hexane–ethyl acetate to afford a colorless syrup (5.6 mg, 100%). To this syrup (3.7 mg, 0.0058 mmol) was added at 25 °C 9:1 (95:5 acetonitrile–46% aqueous HF)–water (0.39 ml); the mixture was stirred at 25 °C for 0.5 h. Saturated aqueous $NaHCO_3$ was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1 g) with 3:1 and then 1:1 $CHCl_3$–ethyl acetate to afford a colorless syrup (2.4 mg, 83%). To a stirred solution of this syrup (2.2 mg, 0.0044 mmol) in dry MeOH (0.22 ml) was added at 25 °C $LiBH_4$ (4.5 mg, 0.207 mmol). After 3 h at 25 °C, saturated aqueous NH_4Cl was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1 g) with 3:1 and then 2:1 $CHCl_3$–acetone to afford **55** (1.9 mg, 86%) as a colorless syrup: R_f=0.38 (2:1 $CHCl_3$–acetone); ^1H NMR δ=0.97 (6H, d, J=6.6 Hz, 2×Me), 1.03 (6H, d, J=6.6 Hz, 2×Me), 1.40—1.74 (3H, br s, 3×OH), 1.84—1.96 (2H, m), 1.97—2.21 (2H, m), 3.48 (1H, dd, J=4.4 and 3.2 Hz), 3.54 (2H, dd, J=10.3 and 5.0 Hz), 3.58 (2H, dd, J=10.3 and 5.0 Hz), 3.64 (2H, dd, J=10.3 and 6.6 Hz), 3.80 (6H, s, OMe), 4.46 and 4.56 (each 2H, ABq, J=11.2 Hz), 6.88 and 7.26 (each 4H, d-like, J=8.8 Hz).

Ethyl [2*E*,5*R*,6*S*,7*R*,9*S*,10*R*,11*R*,11(2*S*,3*S*,4*S*,5*R*,6*R*)]-7,10-Dihydroxy-11-[4-(4-methoxybenzyloxy)-3,5-dimethyl-6-[(2-trimethylsilylethoxy)methoxy]-tetrahydropyran-2-yl]-6-(4-methoxybenzyloxy)-5,7,9-trimethyl-8-oxododec-2-enoate (56). To a stirred solution of **53** (55.1 mg, 0.0620 mmol) in THF (1.1 ml) and AcOH (0.039 ml, 0.682 mmol) was added at 25 °C 1 M *n*-Bu_4NF (0.68 ml, 0.68 mmol). After 21 h at 25 °C, water was added, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (5 g) with 3:1 and the 5:3 hexane–acetone to afford a colorless syrup (47.0 mg, 98%). To a stirred solution of this syrup (155 mg, 0.200 mmol) in dry benzene (3.8 ml) was added at 25 °C Ph_3P=$CHCO_2Et$ (232 mg, 0.660 mmol). After 12 h at 55 °C, the reaction mixture was concentrated and the residue was chromatographed on silica gel (13 g) with 4:3 hexane–ethyl acetate to afford **56** (159 mg, 94%) as a colorless syrup: R_f=0.47 (5:4 hexane–ethyl acetate); $[\alpha]_D^{28}$ −56.6° (c 0.94); IR 3010, 2938, 1707, 1613, 1514, 1459, 1250, 1176, 1096, 1038, 993, 969, and 836 cm^{-1}; ^1H NMR ($CHCl_3$=7.26) δ=0.00 (9H, s, $SiMe_3$), 0.93 (2H, ddd, J=10.0, 7.6, and 4.6 Hz, $SiCH_2$), 0.97—1.13 (15H, m, 5×Me), 1.20—1.28 (1H, m), 1.28 (3H, t, J=7.3 Hz), 1.68

(1H, br d, J=6.2 Hz, OH), 1.92—2.12 (3H, m), 2.13—2.43 (2H, m), 3.05 (1H, dd, J=7.9, and 3.9 Hz), 3.22 (1H, s, OH), 3.54 (1H, dt, J=10.0 and 6.4 Hz, OCH_2), 3.63 (1H, dq, J=9.0 and 6.7 Hz), 3.76 (1H, dt, J=10.0 Hz, OCH_2), 3.79 and 3.80 (each 3H, each s, 2×OMe), 3.76—3.89 (1H, m), 4.03 (1H, dd, J=9.2 and 3.5 Hz), 4.08 (1H, d, J=2.1 Hz), 4.18 (2H, q, J=7.3 Hz), 4.31 and 4.44 (each 1H, ABq, J=10.9 Hz), 4.51 and 4.57 (each 1H, ABq, J=11.0 Hz), 4.62 and 4.94 (each 1H, ABq, J=6.6 Hz), 4.73 (1H, d, J=5.6 Hz), 5.82 (1H, d, J=15.8 Hz), 6.92 (1H, dd, J=15.8 and 7.6 Hz), 6.85, 6.87, 7.17, and 7.28 (each 2H, each m, aromatic protons). Found: C, 65.46; H, 8.54%. Calcd for $C_{46}H_{72}O_{12}Si$: C, 65.37; H, 8.59%.

[2*S*,2(2*R*,3*S*,4*S*,5*R*,6*R*),3*R*,4*S*,6*R*,7*S*,8*R*,10*E*]-3-(Triethylsilyloxy)-6,12-dihydroxy-2-[4-(4-methoxybenzyloxy)-3,5-dimethyl-6-[(2-triethylsilylethoxy)methoxy]tetrahydropyran-2-yl]-7-(4-methoxybenzyloxy)-4,6,8-trimethyl-10-dodecen-5-one (57). To a stirred solution of **56** (159 mg, 0.188 mmol) in dry CH_2Cl_2 (4.7 ml) were added at −30 °C 2,6-lutidine (0.065 ml, 0.56 mmol) and TESOTf (0.106 ml, 0.469 mmol). After 0.5 h at −30 °C, saturated aqueous $NaHCO_3$ was added, and the mixture was extracted with 1:1 hexane–acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (18 g) with 3:2 hexane–ethyl acetate to afford a colorless syrup (153 mg, 89%). To a stirred solution of this syrup (89.3 mg, 0.0931 mmol) in dry CH_2Cl_2 (1.8 ml) was added at −78 °C 1.0 M DIBAL in CH_2Cl_2 (0.33 ml, 0.33 mmol). After 0.5 h at −78 °C, MeOH was added, and the mixture was warmed to 25 °C. To this was added potassium sodium tartrate tetrahydrate (480 mg) in water (3 ml); the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (6 g) with 2:1 hexane–ethyl acetate to afford **57** (79.4 mg, 93%) as a colorless syrup: R_f=0.35 (3:2 hexane–ethyl acetate); $[\alpha]_D^{29}$ −30.8° (c 0.90); IR 3010, 2959, 2879, 1702, 1613, 1514, 1460, 1249, 1174, 1000, 971, and 835 cm^{-1}; ^1H NMR ($CHCl_3$=7.26) δ=0.01 (9H, s, $SiMe_3$), 0.64 (6H, q, J=7.9 Hz, 3×$SiCH_2$), 0.94 (9H, t, J=7.9 Hz, $Si(CH_2Me_3)_3$), 1.31 (1H, t, J=5.6 and 5.6 Hz, OH), 1.34 (1H, m), 1.78—2.37 (5H, m), 3.01 (1H, dd, J=8.0 and 3.6 Hz), 3.19 (1H, s, OH), 3.52 (1H, dt, J=10.2, 10.2, and 6.5 Hz, OCH_2), 3.66 (1H, dq, J=6.8 and 11.2 Hz), 3.77 (1H, dt, J=10.2, 10.2, and 7.2 Hz), 3.80 and 3.81 (each 3H, each s, 2×OMe), 3.90 (1H, dd, J=10.5 and 3.2 Hz), 3.96 (1H, br d, J=0 Hz), 4.03—4.19 (3H, m), 4.31 and 4.49 (each 1H, ABq, J=10.7 Hz), 4.47 and 4.59 (each 1H, ABq, J=11.6 Hz), 4.59 and 4.97 (each 1H, ABq, J=6.7 Hz), 4.72 (1H, d, J=5.4 Hz), 5.59—5.76 (2H, m), 6.86, 6.87, 7.19, and 7.28 (each 2H, each m). Found: C, 65.58; H, 9.15%. Calcd for $C_{50}H_{84}O_{11}Si_2$: C, 65.46; H, 9.23%.

(2-Trimethylsilylethoxy)methyl 2,4,6,8,12,13,14,15,16-Nonadeoxy-3,11-di-*O*-(4-methoxybenzyl)-2,4,6,8,10,12-hexa-*C*-methyl-16-phenylsulfonyl-7-*O*-triethylsilyl-(14*E*)-D-*threo*-D-*gluco*-α-L-*ido*-hexadec-14-enos-9-uloside-(1,5) (58). To a stirred solution of **57** (56.4 mg, 0.0615 mmol) in dry DMF (1.1 ml) were added at 0 °C LiCl (16.2 mg, 0.382 mmol), 2,4,6-collidine (0.0284 ml, 0.215 mmol), and MsCl (0.0145 ml, 0.187 mmol). After 2.5 h at 0 °C, water was added, and the mixture extracted with 1:1 hexane–ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was dissolved in dry DMF (1.2 ml); to this was added at 25 °C $PhSO_2Na{\cdot}2H_2O$ (63.4 mg, 0.307 mmol). After 20 h at 45 °C, water was added, and the mixture was extracted with 1:1 hexane–ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (6 g) with 5:2 and then 2:1 hexane–ethyl acetate to afford **58** (55.7 mg, 87%) as a colorless syrup: R_f=0.53 (2:1 hexane–ethyl acetate); $[\alpha]_D^{29}$ −28.9° (c 0.80); IR 2959, 1703, 1613, 1514, 1460, 1305, 1249, 1146, 1035, 1000, and 970 cm^{-1}; ^1H NMR ($CHCl_3$=7.26) δ=0.02 (9H, s, $SiMe_3$), 0.64 (6H, q, J=7.4 Hz, 3×$SiCH_2$), 1.33—1.48 (1H, m), 1.64—1.82 (1H, m), 1.91—2.27 (4H, m), 3.02 (1H, dd, J=8.0 and 3.3 Hz), 3.14 (1H, s, OH), 3.52 (1H, dt, J=10.2, 10.2, and 6.5 Hz, OCH_2), 3.65 (1H, dq, J=7.3 and 9.2 Hz), 3.72—3.85 (3H, m), 3.81 (6H, s, 2×OMe), 3.90 (1H, dd, J=10.4 and 3.1 Hz), 3.95 (1H, br d, J=0 Hz), 4.03 (1H, d, J=2.2 Hz), 4.28 and 4.39 (each 1H, ABq, J=10.7 Hz), 4.47 and 4.58 (each 1H, ABq, J=11.4 Hz), 4.59 and 4.97 (each 1H, ABq, J=6.7 Hz), 4.72 (1H, d, J=6.2 Hz), 5.35—5.59 (2H, m), 6.87 (4H, m), 7.16 and 7.28 (each 2H, m), 7.50—7.67 and 7.83—7.92 (3H and 2H, each m). Found: C, 64.70; H, 8.50; S, 3.13%. Calcd for $C_{56}H_{88}O_{12}SSi_2$: C, 64.58; H, 8.52; S, 3.08%.

Ethyl (2*E*,4*S*,5*R*,6*R*,7*S*,8*S*,9*R*,10*S*,12*R*,13*S*,14*R*,16*E*)-7,9,12-Trihydroxy-5,13-di-(4-methoxybenzyloxy)-4,6,8,10,12,14-hexamethyl-11-oxo-18-phenylsulfonyloctadeca-2,16-dienoate (59). A solution of **58** (76.7 mg, 0.0736 mmol) in 9:1 (95:5 MeCN–46% aqueous HF)–water (4.6 ml) was stood at 25 °C for 1 h. Saturated aqueous $NaHCO_3$ was added at 0 °C, and the mixture was extracted with ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (4.7 g) with 7:2 and then 5:2 $CHCl_3$–acetone to afford a colorless syrup (52.8 mg, 90%). To a stirred solution of this syrup (52.8 mg, 0.0662 mmol) in benzene (1.7 ml) was added at 25 °C $Ph_3P{=}CHCO_2Et$ (105 mg, 0.302 mmol). After 48 h at 50 °C, the reaction mixture was concentrated and the residue was chromatographed on silica gel (5 g) with 5:1 and then 2:1 $CHCl_3$–acetone to afford **59** (50.5 mg, 88%) as a colorless syrup: R_f=0.51 (3:1 $CHCl_3$–acetone); $[\alpha]_D^{31}$ −6.8° (c 0.47), $[\alpha]_{365}^{31}$ −43.4° (c 0.47); IR 3534, 1707, 1613, 1515, 1462, 1305, 1250, 1178, 1147, and 1036 cm^{-1}; ^1H NMR ($CHCl_3$=7.26) δ=0.88—0.98 (9H, m), 1.05 (3H, d, J=7.1 Hz, Me), 1.17 (3H, d, J=6.5 Hz, Me), 1.12 (3H, s, Me), 1.29 (3H, t, J=7.4 Hz, Me), 1.61—1.89 (3H, m), 1.97—2.25 (2H, m), 2.49 (1H, br d, J=3.4 Hz, OH), 2.64—2.80 (1H, m), 2.97 (1H, d, J=3.1 Hz), 3.32 (1H, dd, J=8.0 and 2.4 Hz), 3.37 (1H, s, OH), 3.59 (1H, dq, J=7.4 and 7.4 Hz), 3.70—3.83 (3H, m), 3.80 (6H, s, 2×OMe), 3.84 (1H, d, J=2.3 Hz, OH), 3.89—3.99 (1H, m), 4.19 (2H, q, J=7.4 Hz), 4.28 and 4.39 (each 1H, ABq, J=11.0 Hz), 4.42 and 4.54 (each 1H, ABq, J=10.7 Hz), 5.35—5.62 (2H, m), 5.84 (1H, dd, J=15.7 and 1.3 Hz), 6.94 (1H, dd, J=15.7 and 8.2 Hz), 6.81—6.91 (4H, m), 7.16 and 7.26 (each 2H, each m), 7.49—7.68 and 7.83—7.92 (3H and 2H, each m). Found: C, 66.39; H, 7.47; S, 3.69%. Calcd for $C_{48}H_{66}O_{12}S$: C, 66.49; H, 7.67; S, 3.70%.

Ethyl (2*E*,4*S*,5*R*,6*R*,7*S*,8*S*,9*R*,10*S*,12*R*,13*S*,14*R*,16*E*)-5-(*t*-Butyldimethylsilyloxy)-7,9-(isopropylidenedioxy)-12,13-(4-methoxybenzylidenedioxy)-4,

6,8,10,12,14-hexamethyl-11-oxo-18-phenylsulfonyloctadeca-2,16-dienoate (3). To a stirred solution of **59** (25.2 mg, 0.0291 mmol) in dry CH_2Cl_2 (0.5 ml) were added at 25 °C DMP (0.036 ml, 0.29 mmol) and CSA (0.7 mg, 0.003 mmol). After 0.5 h at 25 °C, triethylamine was added and the mixture was concentrated. The residue was chromatographed on silica gel (3 g) with 2:1 and then 4:3 hexane–ethyl acetate to afford a colorless foam (25.1 mg, 95%). To a stirred solution of this syrup (4.9 mg, 0.0054 mmol) in CH_2Cl_2 (0.19 ml) and 1:2 0.1 M aqueous KH_2PO_4–0.1 M aqueous Na_2HPO_4 (0.01 ml) was added at 0 °C DDQ (2.6 mg, 0.012 mmol). After 0.5 h at 0 °C, saturated aqueous $NaHCO_3$ was added, and the mixture was extracted with benzene. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1 g) with 3:2 and then 1:1 hexane–ethyl acetate to afford a colorless syrup (4.2 mg). To a stirred solution of this syrup (4.2 mg) in dry CH_2Cl_2 (0.17 ml) was added at 0 °C DDQ (4.1 mg, 0.0181 mmol). After 1.5 h at 0 °C, saturated aqueous $NaHCO_3$ was added and the mixture was extracted with benzene. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1 g) with 3:2 hexane–ethyl acetate to afford a colorless syrup (3.0 mg, 70% for two steps). To a stirred solution of this syrup (4.6 mg, 0.0059 mmol) in dry CH_2Cl_2 (0.23 ml) were added at 0 °C 2,6-lutidine (0.0024 ml, 0.021 mmol) and *t*-butyldimethylsilyl trifluoromethanesulfonate (TBSOTf) (0.004 ml, 0.02 mmol). After 2 h at 25 °C, saturated aqueous $NaHCO_3$ was added, and the mixture was extracted with 1:1 hexane–ethyl acetate. The extracts were washed with saturated aqueous NaCl, dried, and concentrated. The residue was chromatographed on silica gel (1 g) with 2:1 hexane–ethyl acetate to afford **3** (5.0 mg, 95%) as a colorless foam: R_f=0.50 (2:1 hexane–ethyl acetate); $[\alpha]_D^{31}$ −0.05° (*c* 0.52), $[\alpha]_{365}^{31}$ −69.2° (*c* 0.52); IR 2995, 2936, 1708, 1517, 1463, 1380, 1308, 1253, 1084, 1035, and 973 cm^{-1}; ^1H NMR ($CHCl_3$=7.26) δ=0.04 and 0.09 (each 3H, each s, $SiMe_3$), 0.83 (3H, d, J=7.0 Hz, Me), 0.84 (3H, d, J=6.8 Hz, Me), 0.93 (3H, d, J=6.8 Hz, Me), 1.03 (3H, d, J=6.8 Hz, Me), 1.20 (3H, d, J=7.2 Hz, Me), 1.25 (3H, t, J=6.8 Hz, Me), 1.32 (3H, s, Me), 1.39 (6H, s, CMe_2), 1.34—1.48 (1H, m), 1.52—1.93 (3H, m), 2.18—2.32 (1H, m), 2.41—2.57 (1H, m), 3.46 (1H, br d, J=7.9 and 0 Hz), 3.58 (1H, dq, J=6.8 and 10.2 Hz), 3.64 (1H, dd, J=9.8 and 1.7 Hz), 3.72 (1H, d, J=8.0 Hz), 3.77 (2H, d, J=6.4 Hz), 3.82 (3H, s, OMe), 3.96 (1H, dd, J=10.2 and 1.6 Hz), 4.16 (2H, q, J=6.8 Hz), 5.35—5.57 (2H, m), 5.75 (1H, dd, J=16.0 and 1.0 Hz), 5.86 (1H, s, C*H*Ar), 6.93 (1H, dd, J=8.1 and 16.0 Hz), 6.93 and 7.41 (each 2H, each m), 7.50—7.68 and 7.82—7.91 (3H ans 2H, each m). Found: C, 65.59; H, 8.32%. Calcd for $C_{49}H_{74}O_{11}SSi$: C, 65.45; H, 8.29%.

We would like to thank Emeritus Professor Mitsuhiro Kinoshita (Keio University) for helpful discussion and Nippon Kayaku Co., Ltd. for a generous gift of 44-homooligomycin B. We are grateful to the Institute of Microbial Chemistry for the generous support of our program.

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