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Highly Demanding Cross-Metathesis in the Synthesis of the C16−C30 Fragment of Dolabelide C

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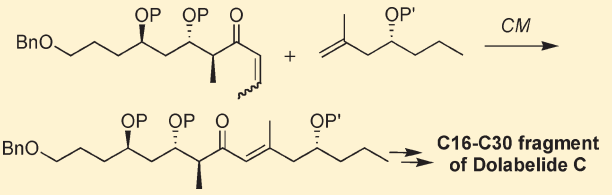
Supporting Information

ABSTRACT: A highly demanding cross-metathesis (CM) reaction for the formation of the C24−C25 trisubstituted olefin of dolabelide C has been optimized. A difference in reactivity between the *E* and *Z* enone isomers in this reaction was uncovered, and the selection of the *Z* isomer of the starting enone was critical for the success of the cross-metathesis. Application to the synthesis of the C16−C30 fragment of dolabelide C is reported.



INTRODUCTION

Dolabelides A and B, two 22-membered-ring lactones, were isolated in 1995 by Yamada and co-workers from the sea hare *Dolabella auricularia* (family Aplysiidae).[1] In 1997, Dolabelides C and D, two similar 24-membered-ring lactones, were also extracted from this marine organism.[2] These polyketides exhibit cytotoxicity against HeLa-S_3 cell lines with IC_{50} values of 6.3, 1.3, 1.9, and 1.5 μg/mL, respectively. Several groups have published synthetic approaches to these compounds,[3] and the total synthesis of dolabelide D has been achieved by Leighton and co-workers.[4]

The retrosynthesis we envisioned for dolabelide C is shown in Scheme 1. Opening the macrocycle and disconnecting the C15−C16 bond leads to compounds **1** and **2**. These two fragments would be joined by a B-alkyl Suzuki coupling between the vinyl iodide at C15 and a borane derived from the iodide at C16. A Yamaguchi macrolactonization[5] would then close the ring. The order of these two steps could also be reversed if necessary. We have already reported the synthesis of the C1−C15 fragment,[6] and we wish to describe here the completion of the C16−C30 portion of dolabelide C.

In a previous approach to compound **2**, we had planned to construct the trisubstituted C24−C25 double bond by a Wittig or Julia olefination reaction.[7] However, a more flexible route to this fragment could involve a cross-metathesis (CM) reaction to install the olefin at C24−C25, allowing the easy formation of analogues of the target molecule with various side chains (Scheme 1). Compound **2** would be prepared from allylic alcohol derivative **3** and *gem*-disubstituted olefin **4**.

RESULTS AND DISCUSSION

CM reactions have been employed in numerous syntheses of natural products for the construction of disubstituted olefins, but there are very few reports of syntheses of trisubstituted alkenes.[8] We thus decided to study this demanding CM on model systems (Scheme 2). Racemic compound **5a** (R = Me) was reacted with acetate (±)-**6a**[9] in the presence of 5 mol % of Grubbs' second-generation catalyst **G2**[10] (Figure 1). Although the secondary allylic alcohol **5a** is a type II olefin,[11] its rate of dimerization is much faster than the desired CM reaction, and only undesired homodimer **7a** was obtained as a mixture of diastereomers. The same result was observed with internal olefin **5b** (R = Pent), and CM of the PMB ether of **5a** with (±)-**6a** only led to decomposition.

We then examined CM reactions with the enone analogues of **5a**,**b**, which dimerize significantly more slowly than the corresponding allylic alcohols (Scheme 3). Cross-metathesis of vinyl ketone **8a** with (±)-**6a** only furnished homodimer **9a**,[12] but CM of the propenyl ketone **8b** (*E*/*Z* = 1/1) gave 15% of the desired product **10b**, along with the homodimer of **8b**. Use of 4 equiv of (±)-**6a** suppressed the formation of the homodimer and raised the yield to 28%.[13] This result is consistent with the trend observed by Grubbs and co-workers for the cross-metathesis between 2-methyl-1-heptene (which corresponds to compound (±)-**6a** without the acetate substituent) and ethyl vinyl or ethyl propenyl ketone, although the presence of the acetate substituent considerably lowers the yield of the CM reactions in our case. It is also interesting to note that the *E*/*Z* ratio of **10b** was higher when the reaction was performed with 4 equiv of (±)-**6a**.

Having established that the propenyl ketone was the suitable functional group for CM, we set to synthesize the metathesis partners **19a**,**b** required for the synthesis of dolabelide C (Scheme 4). Homoallylic alcohol **12** is the enantiomer of the starting compound we used for the C1−C15 portion of dolabelide C and was prepared in the same way by Jacobsen hydrolytic kinetic resolution (HKR)[14] of epoxide (±)-**11** with complex

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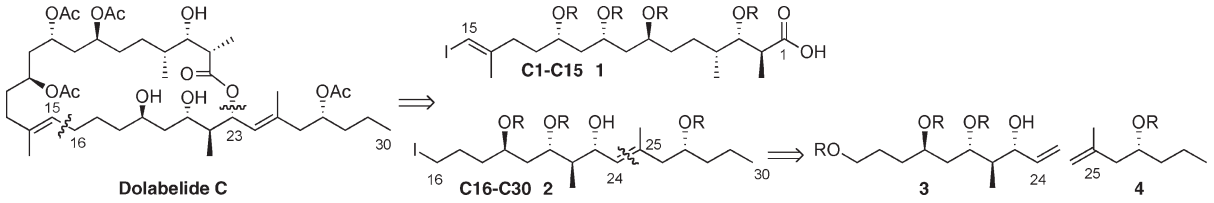
Scheme 1. Retrosynthesis of Dolabelide C



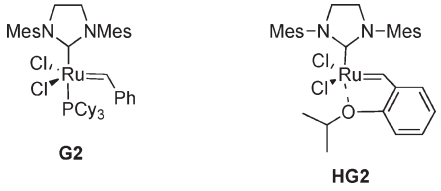
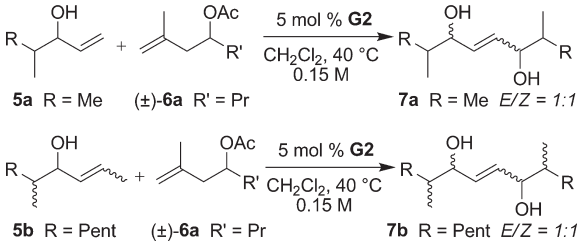
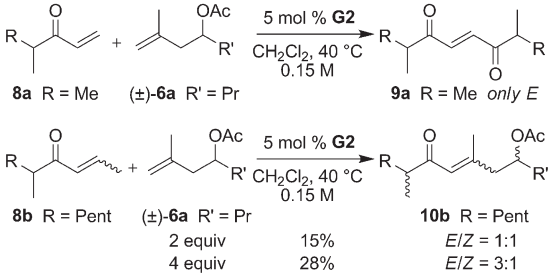


Figure 1. Metathesis catalysts.

Scheme 2. CM Reactions with Allylic Alcohol Derivatives

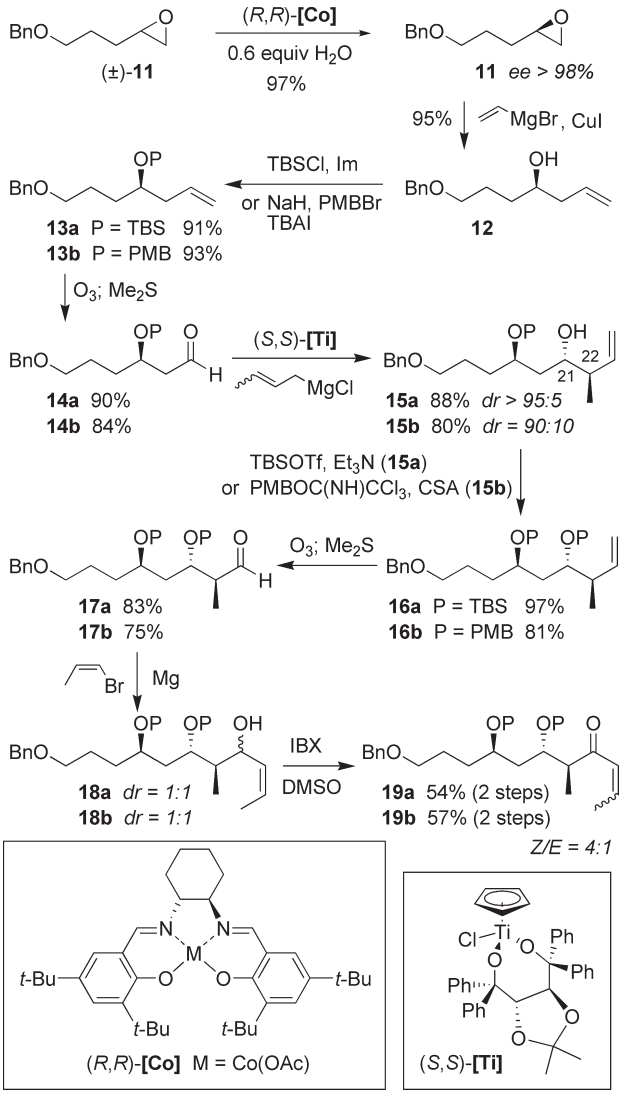


Scheme 3. CM Reactions with Enone Derivatives



(*R*,*R*)-[**Co**], followed by opening of the enantiopure **11** with a vinyl Grignard reagent.[6] Protection of the alcohol as a TBS or PMB ether gave **13a,b** in 91 and 93% yields, respectively, and subsequent ozonolysis furnished aldehydes **14a,b**. The C21 and C22 stereocenters were installed by an enantioselective Duthaler crotylation[15] of **14a,b** with the complex (*S*,*S*)-[**Ti**], which proceeded in good to excellent selectivity, and the major diastereomers **15a,b** were isolated in 88 and 80% yields, respectively.[16] After protection of the free alcohol, bis -TBS and bis-PMB ethers **16a,b** were subjected to oxidative cleavage to give aldehydes **17a,b**. These aldehydes were transformed into the corresponding propenyl ketones **19a,b** in two steps. We first employed a 1/1 mixture of (*E*)- and (*Z*)-1-bromopropene to make the Grignard reagent. Use of 5 equiv of this organometallic reagent led to a 3/1 *Z*/*E* mixture of alcohols **18a**, probably because the *Z* Grignard reagent reacts more quickly than the *E* isomer. Crude alcohols

Scheme 4. Synthesis of Enones 19a,b



18a,b were then oxidized to the desired enones **19a,b** with iodoxybenzoic acid (IBX).[17] When pure (*Z*)-1-bromopropene was used, **19a,b** were isolated as 4/1 *Z*/*E* mixtures,[18] due to isomerization of the alkene during silica gel chromatography after the oxidation reaction.

The *gem*-disubstituted olefin partners **6a**−**c** were prepared in three steps from 1,2-epoxypentane ((±)-**20**) by Jacobsen HKR[14] with (*R*,*R*)-[**Co**], opening of the enantiopure epoxide **20** with isopropenylmagnesium bromide, and suitable protection of the resulting homoallylic alcohol **21** (Scheme 5).

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Scheme 5. Synthesis of *gem*-Disubstituted Olefins 6a−c

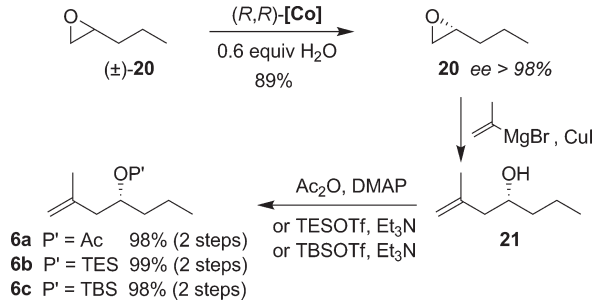
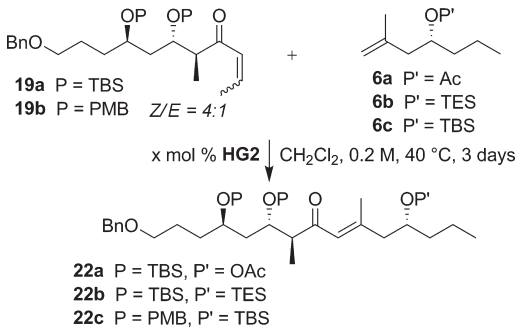


Table 1. Optimization of the CM Reaction

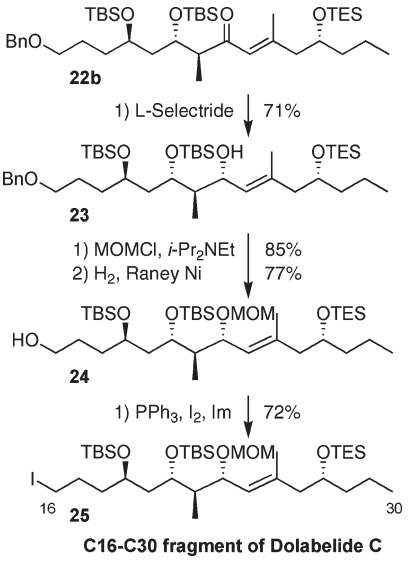


entry	P	P′	*x*	product	yield, %[a]
1	TBS	Ac	5	**22a**	[b]
2			15		26[c]
3			30[d]		39[e]
4	TBS	TES	5	**22b**	[b]
5			30		46
6			45		47
7	PMB	TBS	30	**22c**	45

[a] Refers to the pure *E* isomer. [b] Isomerization of **19a** to the *E* olefin. [c] Along with 7% of *Z* isomer of **22a**. [d] Reaction performed with **G2** catalyst. [e] Isolated as a 49% combined yield of a 4/1 mixture of *E*/*Z* isomers.

The CM reactions were performed in the presence of **G2** and **HG2**[19] complexes, and the latter catalyst, which gave sligthly better results, was used for the optimization study. When enone **19a** and 4 equiv of olefin **6a** were subjected to 5 mol % **HG2** catalyst (Figure 1), the only product was the *E* enone **19a** (Table 1, entry 1). When we increased the amount of catalyst to 15 mol %, the CM product **22a** was obtained as a 4/1 *E*/*Z* mixture, from which the desired *E* isomer could be isolated in 26% yield and the *Z* isomer in 7% yield (entry 2). Using 30 mol % of **G2** catalyst further raised the yield to 39%. The isomerized *E* enone **19a** accounted for the remaining mass balance. When this enone isomer was submitted to CM with compound **6a**, no reaction occurred, even at concentrations as high as 0.8 M, proving that it is unreactive toward cross-metathesis.[20] We also attempted slow addition of enone **19a** to a mixture of olefin **6a** and catalyst **HG2** in refluxing dichloromethane to favor the CM reaction vs the unwanted isomerization, with no success.

Scheme 6. Synthesis of the C16−C30 Fragment of Dolabelide C



Performing the CM between **19a** and **6a** at higher temperature or concentration led to greater amounts of isomerization product. In order to counteract this reactivity issue, we prepared the vinyl ketone equivalent of **19a**, but CM with this compound only led to the homodimer. Cross-metathesis between **19a** and **6b** (entries 4 and 5) or between **19b** and **6c** (entry 7) led to similar results, showing that this reaction is not sensitive to the alcohol protecting groups P and P′. The optimum amount of catalyst appeared to be 30 mol %, as use of 45 mol % gave the same yield of CM product **22b** (entry 5 vs entry 6).

We pursued the synthesis of dolabelide C with enone **22b** (Scheme 6). Diasteroselective reduction with L-Selectride[3c] led to alcohol **23** as a single diastereomer. Protection of the secondary alcohol as its MOM ether followed by deprotection of the primary benzyl ether with Raney nickel[21] furnished compound **24**. Finally, transformation of the primary alcohol of **24** into the corresponding iodide led to the C16−C30 fragment of dolabelide C **25**.

In conclusion, we have optimized a demanding CM reaction between a highly substituted enone and a *gem*-disubstituted olefin. In the process, we have uncovered the different behaviors of the *Z* and *E* enone isomers and shown that the latter was unreactive toward metathesis. We have utilized this reaction for the synthesis of the C16−C30 portion of dolabelide C. Further studies toward the synthesis of the target molecule are in progress and will be reported in due course.

EXPERIMENTAL SECTION

General Methods. See ref 22.

2,7-Dimethylocten-4-yl-3,6-diol (7a). *Z* isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 5.73−5.70 (m, 2H), 3.91 (s, 2H), 1.75 (qd, J = 6.8, 13.4 Hz, 2H), 1.45 (s, 2H), 0.94 (d, J = 6.8 Hz, 6H), 0.91 (d, J = 6.9 Hz, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 132.8, 77.2, 33.8, 18.2, 17.8; IR ($CHCl_3$, cm^{-1}) 3692, 3610, 2963, 2930, 2873, 2857, 2253, 1937, 1713, 1602, 1467, 1386, 1368, 1262, 1216, 1008; HRMS (EI, m/z) M^+ calcd for $C_{10}H_{20}O_2^+$ 172.1463, found 172.1460. *E* isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 5.68 (dd, J = 1.9, 3.9 Hz, 2H), 3.87 (s, 2H), 1.74 (qd, J = 6.8, 13.4 Hz, 2H), 1.51 (s, 2H), 0.94 (d, J = 6.8 Hz, 6H), 0.90

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(d, J = 6.9 Hz, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 133.1, 77.7, 33.8, 18.2, 18.0; IR ($CHCl_3$, cm^{-1}) 3692, 3610, 2963, 2930, 2873, 2857, 2253, 1937, 1713, 1602, 1467, 1386, 1368, 1262, 1216, 1008; HRMS (EI, m/z) M^+ calcd for $C_{10}H_{20}O_2^+$ 172.1463, found 172.1460.

6,11-Dimethylhexadecen-8-yl-7,10-diol (7b). *Z* isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 5.72−5.58 (m, 2H), 4.06−3.91 (m, 2H), 1.65−1.58 (m, 2H), 1.50−1.04 (m, 18H), 0.91−0.85 (m, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 133.3, 132.8, 132.5, 131.9, 76.4, 76.3, 76.0, 75.9, 38.9, 38.8, 32.6, 32.3, 32.1, 26.9, 26.8, 22.6, 15.0, 14.5, 14.1; IR ($CHCl_3$, cm^{-1}) 3691, 3610, 2960, 2930, 2873, 2859, 2248, 1937, 1691, 1669, 1603, 1575, 1539, 1460, 1379, 1264, 1230, 1217, 1136; HRMS (EI, m/z) M^+ calcd for $C_{18}H_{36}O_2^+$ 284.2715, found 284.2720. *E* isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 5.74−5.65 (m, 2H), 4.02−3.95 (m, 2H), 1.66−1.57 (m, 2H), 1.52−1.03 (m, 18H), 0.92−0.84 (m, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 133.5, 133.0, 132.8, 132.3, 76.6, 76.4, 76.3, 38.9, 38.8, 32.5, 32.4, 32.1, 26.9, 26.8, 26.7, 22.6, 14.9, 14.6, 14.1; IR ($CHCl_3$, cm^{-1}) 3691, 3610, 2960, 2930, 2873, 2859, 2248, 1937, 1691, 1669, 1603, 1575, 1539, 1460, 1379, 1264, 1230, 1217, 1136; HRMS (EI, m/z) M^+ calcd for $C_{18}H_{36}O_2^+$ 284.2715, found 284.2720.

(*E*)-6,9-Dimethyl-8-oxotetradec-6-en-4-yl Acetate (10b). The second-generation Grubbs catalyst (15 mg, 3 mol %) was added to a stirred solution of ketone **8b** (100 mg, 0.59 mmol) and protected allylic alcohol (±)-**6a** (400 mg, 2.34 mmol, 4.00 equiv) in CH_2Cl_2 (4 mL). The reaction mixture was heated at reflux overnight. The mixture was then cooled to ambient temperature, concentrated in vacuo, and directly purified by silica gel chromatography (petroleum ether/ether 98/2 to 90/10) to afford the desired alkene **10b** (48.7 mg, 28%) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 6.08 (s, 1H), 5.10 (tt, J = 7.8, 5.2 Hz, 1H), 2.47 (sextet, J = 6.8 Hz, 1H), 2.38 (dd, J = 13.7, 7.8 Hz, 1H), 2.30 (dd, J = 13.7, 5.3 Hz, 1H), 2.14 (s, 3H), 2.01 (s, 3H), 2.74−1.26 (m, 12H), 1.05 (d, J = 6.8 Hz, 3H), 0.91 (t, J = 7.3 Hz, 3H), 0.87 (t, J = 6.9 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 204.7, 170.4, 153.9, 122.8, 71.5, 47.2, 45.9, 36.3, 33.1, 31.9, 27.0, 22.5, 18.6, 21.1, 19.6, 16.3, 14.0, 13.8; IR ($CHCl_3$, cm^{-1}) 2961, 2930, 2867, 2254, 1727, 1681, 1615, 1460, 1377, 1249; HRMS (EI, m/z) M^+ calcd for $C_{18}H_{32}O_3^+$ 296.2352, found 296.2359.

(*R*)-7-(Benzyloxy)hept-1-en-4-ol (12). To a stirred suspension of copper(I) iodide (2.38 g, 12.5 mmol, 0.5 equiv) in THF (100 mL) was added vinylmagnesium bromide (1 M THF solution, 125 mL, 125 mmol, 5.0 equiv) dropwise at −30 °C. After 30 min, epoxide **11**[23] (4.8 g, 25 mmol) in THF (25 mL) was slowly added to the mixture. After it was stirred at −30 °C for 2 h, the reaction mixture was quenched with saturated aqueous NH_4Cl, filtered, and extracted with ether. The combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by silica gel column chromatography (petroleum ether/ether 80/20) to afford the homoallylic alcohol **12** (5.23 g, 95%) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.25−7.37 (m, 5H), 5.78−5.89 (m, 1H), 5.12 (br d, J = 16.1 Hz, 1H), 5.12 (br d, J = 11.2 Hz, 1H), 4.52 (s, 2H), 3.63 (m, 1H), 3.52 (t, J = 6.0 Hz, 2H), 2.34 (d, J = 3.9 Hz, 1H), 2.17−2.31 (m, 2H), 1.71−1.78 (m, 2H), 1.62−1.69 (m, 1H), 1.46−1.55 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.2, 128.4, 127.7, 127.6, 138.2, 117.8, 73.0, 70.6, 70.4, 42.0, 34.0, 26.2; IR ($CHCl_3$, cm^{-1}) 3593, 3413, 3080, 3021, 3014, 3009, 2931, 2864, 1640, 1496, 1454, 1364, 1240, 1095, 1028; $[\alpha]^{25}_D$ = +6.8° (*c* 1.3, $CHCl_3$); HRMS (EI, m/z) M^+ calcd for $C_{14}H_{20}O_2^+$ 220.1463, found 220.1460.

(*R*)-7-(Benzyloxy)-4-((*tert*-butyldimethylsilyl)oxy)hex-1-ene (13a). To a stirred suspension of the alcohol **12** (3.6 g, 16 mmol) in CH_2Cl_2 (160 mL) was added imidazole (3.3 g, 49 mmol, 3.0 equiv) and TBSCl (4.9 g, 33 mmol, 2.0 equiv) at 0 °C. After it was stirred at 20 °C overnight, the reaction mixture was quenched with saturated aqueous NH_4Cl and extracted with ether. The combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by silica gel column chromatography (98/2 petroleum ether/ether) to afford the protected alcohol **13a** (5.0 g, 91%) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.27−7.34 (m, 5H), 5.81 (ddt, J = 17.6, 10.5, 7.2 Hz, 1H), 5.03 (br d, J = 16.8 Hz, 1H), 5.02 (br d, J = 10.6 Hz, 1H), 4.50 (s, 2H), 3.69−3.74 (m, 1H), 3.46 (t, J = 6.6 Hz, 2H), 2.22 (t, J = 6.4 Hz, 2H), 1.58−1.74 (m, 2H), 1.42−1.55 (m, 2H), 0.88 (s, 9H), 0.04, 0.04 (2s, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.6, 128.3, 127.6, 127.4, 135.2, 116.7, 72.8, 71.7, 70.5, 41.9, 33.2, 25.9, 25.6, 18.1, −4.4, −4.5; IR ($CHCl_3$, cm^{-1}) 3078, 3029, 3023, 3017, 2955, 2930, 2858, 1640, 1496, 1472, 1463, 1454, 1409, 1389, 1362, 1256, 1226, 1215, 1211, 1202, 1092; $[\alpha]^{25}_D$ = +13.6° (*c* 1.0, $CHCl_3$); HRMS (EI, m/z) M^+ calcd for $C_{20}H_{34}O_2Si^+$ 334.2328, found 334.2317.

(*R*)-7-(Benzyloxy)-4-((4-methoxybenzyl)oxy)hex-1-ene (13b). *tert*-Butylammonium iodide (200 mg, 0.54 mmol, 10 wt %) was added to a stirred suspension of NaH (60% dispersion in mineral oil, 783 mg, 19.6 mmol, 2.2 equiv) in THF (40 mL). After the mixture was cooled to 0 °C, the alcohol **12** (1.96 g, 8.9 mmol) was added dropwise and the mixture was stirred at 20 °C for 30 min. PMBBr (2.86 g, 14.4 mmol, 1.6 equiv) was slowly added at 0 °C, and the reaction mixture was stirred at reflux overnight. The reaction was quenched by careful addition of water, and the solution was extracted with ether. The combined organic extracts were washed with water and then brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by silica gel column chromatography (90/10 petroleum ether/ether) to afford the protected alcohol **13b** (2.52 g, 93%) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.26−7.35 (m, 5H), 7.25−7.27 (m, 2H), 6.85−6.88 (m, 2H), 5.84 (ddt, J = 17.2, 10.2, 7.1 Hz, 1H), 5.04−5.11 (m, 2H), 4.50 (d, J = 11.2 Hz, 1H), 4.49 (s, 2H), 4.41 (d, J = 11.2 Hz, 1H), 3.80 (s, 3H), 3.43−3.48 (m, 3H), 2.26−2.38 (m, 2H), 1.56−1.80 (m, 4H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 159.1, 138.6, 130.9, 129.3, 128.3, 127.6, 127.5, 113.7, 134.9, 116.9, 77.9, 72.8, 70.5, 70.4, 55.3, 38.3, 30.4, 25.7; IR ($CHCl_3$, cm^{-1}) 3006, 2937, 2863, 1640, 1612, 1514, 1465, 1454, 1442, 1362, 1302, 1249, 1174, 1091, 1036; $[\alpha]^{25}_D$ = +15.7° (*c* 1.0, $CHCl_3$); HRMS (EI, m/z) M^+ calcd for $C_{22}H_{28}O_3^+$ 340.2039, found 340.2032.

(*R*)-6-(Benzyloxy)-3-((*tert*-butyldimethylsilyl)oxy)hexanal (14a). Ozone was bubbled through a solution of the alkene **13a** (3.9 g, 12 mmol) in CH_2Cl_2 (100 mL) and methanol (25 mL) in the presence of some drops of pyridine, at −78 °C for 30 min. After flushing with oxygen, dimethyl sulfide (5 mL) was added at −78 °C and the reaction mixture was stirred overnight at 20 °C. The reaction mixture was concentrated in vacuo. The residue was purified by silica gel column chromatography (90/10 petroleum ether/ether) to afford the aldehyde **14a** (3.5 g, 90%) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 9.81 (t, J = 2.4 Hz, 1H), 7.37−7.27 (m, 5H), 4.50 (s, 2H), 4.22 (quint, J = 5.6 Hz, 1H), 3.47 (t, J = 5.9 Hz, 2H), 2.52−2.54 (m, 2H), 1.62−1.65 (m, 4H), 0.87 (s, 9H), 0.07, 0.05 (2s, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 202.1, 138.5, 128.3, 127.6, 127.5, 72.9, 70.1, 67.9, 50.8, 34.4, 25.7, 25.6, 18.0, −4.5, −4.7; IR ($CHCl_3$, cm^{-1}) 3031, 3022, 3010, 3006, 2956, 2931, 2886, 2858, 1714, 1472, 1463, 1453, 1389, 1362, 1315, 1278, 1257, 1230, 1227, 1215, 1211, 1098, 1043; $[\alpha]^{25}_D$ = −2.7° (*c* 1.5, $CHCl_3$); HRMS (EI, m/z) $(M - t\mathrm{Bu})^+$ calcd for $(C_{15}H_{23}O_3Si)^+$ 279.1417, found 279.1430.

(*R*)-6-(Benzyloxy)-3-(4-(methoxybenzyl)oxy)hexanal (14b). Ozone was bubbled through a solution of the alkene **13b** (2.52 g, 7.40 mmol) in CH_2Cl_2 (80 mL) and methanol (20 mL) in the presence of some drops of pyridine, at −78 °C for 30 min. After flushing with oxygen, dimethyl sulfide (3 mL) was added at −78 °C and the reaction mixture was stirred overnight at 20 °C. The reaction mixture was concentrated in vacuo. The residue was purified by silica gel column chromatography (70/30 petroleum ether/ether) to afford the aldehyde **14b** (2.13 g, 84%) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 9.77 (t, J = 2.1 Hz, 1H), 7.26−7.32 (m, 5H), 6.85−6.87 (m, 2H), 6.85−6.87 (m, 2H), 4.49 (s, 2H), 4.48 (d, J = 11.1 Hz, 1H), 4.41 (d, J = 11.1 Hz, 1H),

3.93−3.99 (m, 1H), 3.80 (s, 3H), 3.47 (t, J = 6.1 Hz, 2H), 2.67 (ddd, J = 16.3, 7.2, 2.6 Hz, 1H), 2.54 (ddd, J = 16.3, 4.8, 1.9 Hz, 1H), 1.66−1.74 (m, 4H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 201.6, 159.3, 138.5, 130.2, 129.4, 128.4, 127.6, 127.6, 113.8, 73.6, 72.9, 70.9, 70.0, 55.3, 48.3, 31.0, 25.4; IR ($CHCl_3$, cm^{-1}) 3031, 2936, 2862, 1720, 1606, 1514, 1250, 1173, 1096, 1034; $[\alpha]^{25}_D$ = −6.0° (c 1.0, $CHCl_3$); HRMS (EI, m/z) (M − H_2O)$^+$ calcd for $(C_{21}H_{24}O_3)^+$ 324.1726, found 324.1719.

(3*R*,4*S*,6*R*)-9-(Benzyloxy)-6-((*tert*-butyldimethylsilyl)oxy)-3-methylnon-1-en-4-ol (15a). Crotylmagnesium chloride in THF (773 μL of a 0.5 M solution, 0.39 mmol, 1.3 equiv) was added dropwise over 10 min at 0 °C to a solution of cyclopentadienyl[(4*S*,*trans*)-2,2-dimethyl-α,α,α′,α′-tetraphenyl-1,3-dioxolane-4,5-dimethanolato-*O*,*O*′]-titanium chloride (290 mg, 0.48 mmol, 1.6 equiv) in ether (6 mL). After it was stirred for 3 h at 0 °C, the slightly orange suspension was cooled to −78 °C, and aldehyde **14a** (100 mg, 0.30 mmol, dissolved in 1 mL of ether) was added over 2 min. Stirring at −78 °C was continued for 20 min, and the reaction mixture was then treated with 5 mL of water, stirred for 12 h at 20 °C, filtered through Celite, and extracted with ether. The combined organic phases were washed with brine, dried over $MgSO_4$, filtered, and concentrated in vacuo. The solid residue was stirred with 15 mL of pentane. Subsequent filtration furnished white crystalline (4*S*,*trans*)-2,2-dimethyl-α,α,α′,α′-tetraphenyl-1,3-dioxolane-4,5-dimethanol (TADDOL). The residue was purified by silica gel column chromatography (90/10 petroleum ether/ether) to afford the alcohol **15a** (346 mg, 88%) as a slightly yellow oil. Analysis of the ^{1}H NMR of the product showed a >98/2 ratio of diastereoisomers: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.33−7.26 (m, 5H), 5.79 (ddd, J = 17.0, 11.1, 7.8 Hz, 1H), 5.11 (br d, J = 11.1 Hz, 1H), 5.11 (br d, J = 17.0 Hz, 1H), 4.50 (s, 2H), 4.04−4.10 (m, 1H), 3.85 (ddt, J = 9.9, 5.0, 2.2 Hz, 1H), 3.52 (t, J = 6.1 Hz, 2H), 3.18 (d, J = 2.2 Hz, 1H), 2.19−2.27 (m, 1H), 1.59−1.72 (m, 5H), 1.26−1.32 (m, 1H), 1.08 (d, J = 6.9 Hz, 3H), 0.89 (s, 9H), 0.09, 0.07 (2s, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 140.7, 138.5, 128.3, 127.6, 127.5, 115.2, 72.9, 71.3, 71.2, 70.3, 44.1, 38.6, 33.0, 26.0, 25.8, 18.0, 15.7, −4.6, −4.7; IR ($CHCl_3$, cm^{-1}) 3672, 3475, 3084, 3068, 3013, 3009, 2954, 2931, 2884, 2859, 1639, 1496, 1471, 1463, 1454, 1434, 1420, 1389, 1362, 1310, 1256, 1095, 1028; $[\alpha]^{25}_D$ = −1.0° (c 1.0, $CHCl_3$); HRMS (EI, m/z) (M − *t*Bu)$^+$ calcd for $(C_{19}H_{31}O_3Si)^+$ 335.2043, found 335.2044.

(3*R*,4*S*,6*R*)-9-(Benzyloxy)-6-(4-(methoxybenzyl)oxy)-3-methylnon-1-en-4-ol (15b). Crotylmagnesium chloride in THF (12.8 mL of a 0.5 M solution, 6.40 mmol, 1.3 equiv) was added dropwise over 10 min at 0 °C to a solution of cyclopentadienyl[(4*S*,*trans*)-2,2-dimethyl-α,α,α′,α′-tetraphenyl-1,3-dioxolane-4,5-dimethanolato-*O*,*O*′]-titanium chloride (4.51 g, 7.36 mmol, 1.6 equiv) in ether (90 mL). After it was stirred for 20 min at 0 °C, the slightly orange suspension was cooled to −78 °C, and the aldehyde **14b** (1.57 g, 4.6 mmol, dissolved in 10 mL of ether) was added over 2 min. Stirring at −78 °C was continued for 4 h. The reaction mixture was then treated with water, stirred for 12 h at 20 °C, filtered through Celite, and extracted twice with ether. The combined organic phases were washed with brine, dried over $MgSO_4$, filtered, and concentrated in vacuo. The solid residue was stirred with 15 mL of pentane. Subsequent filtration furnished white crystalline (4*S*,*trans*)-2,2-dimethyl-α,α,α′,α′-tetraphenyl-1,3-dioxolane-4,5-dimethanol (TADDOL). The residue was purified by silica gel column chromatography (70/30 petroleum ether/ether) to afford the alcohol **15b** (1.47 g, 80%) as a slightly yellow oil. Analysis of the ^{1}H NMR of the product showed a 90/10 ratio of diastereoisomers: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.25−7.36 (m, 7H), 6.86−6.88 (m, 2H), 5.81 (ddd, J = 17.0, 10.8, 8.0 Hz, 1H), 5.08 (br d, J = 10.8 Hz, 1H), 5.08 (br d, J = 17.0 Hz, 1H), 4.51 (s, 2H), 4.48−4.51 (m, 2H), 3.80 (s, 3H), 3.70−3.78 (m, 2H), 3.48 (t, J = 6.0 Hz, 2H), 2.59 (br s, 1H), 2.15−2.24 (m, 1H), 1.56−1.77 (m, 6H), 1.03 (d, J = 6.9 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 159.2, 140.6, 138.6, 130.6, 129.4, 128.3, 127.6, 127.5, 113.8, 115.4, 76.4, 72.9, 71.0, 70.3, 71.4, 55.2, 44.2, 37.3, 30.3, 25.8, 15.9; IR ($CHCl_3$, cm^{-1}) 3670, 3608, 3471, 3067, 3036, 2937, 2868, 2840, 1639, 1613, 1606, 1514, 1464, 1455, 1363, 1303, 1234, 1075, 1035; HRMS (EI, m/z) M$^+$ calcd for $C_{25}H_{34}O_4^+$ 398.2457, found 398.2456.

(3*R*,4*S*,6*R*)-9-(Benzyloxy)-4,6-bis((*tert*-butyldimethylsilyl)-oxy)-3-methylnon-1-ene (16a). To a solution of the alcohol **15a** (982 mg, 2.5 mmol) in CH_2Cl_2 (25 mL) at −78 °C was added dropwise Et_3N (1.05 mL, 7.5 mmol, 3.0 equiv) and TBSOTf (1.15 mL, 5 mmol, 2.0 equiv). The reaction mixture was stirred for 1 h at −78 °C and was quenched by saturated aqueous NH_4Cl. The aqueous phase was extracted with ether, and the combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by silica gel column chromatography (98/2 petroleum ether/ether) to afford the protected alcohol **16a** (1.23 g, 97%) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.25−7.35 (m, 5H), 5.79 (ddd, J = 17.3, 10.7, 7.4 Hz, 1H), 5.01 (br d, J = 17.3 Hz, 1H), 5.01 (br d, J = 10.7 Hz, 1H), 4.51 (s, 2H), 3.71−3.76 (m, 2H), 3.46 (t, J = 6.6 Hz, 2H), 3.71−3.78 (m, 1H), 1.41−1.70 (m, 6H), 0.98 (d, J = 6.9 Hz, 3H), 0.89, 0.87 (2s, 18H), 0.08, 0.07, 0.04, 0.04 (4s, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 140.4, 138.6, 128.3, 127.6, 127.5, 114.7, 73.3, 72.8, 70.5, 69.9, 43.4, 41.5, 34.2, 25.9, 25.9, 25.3, 18.1, 18.1, 15.0, −3.9, −4.1, −4.2, −4.3; IR ($CHCl_3$, cm^{-1}) 3070, 3034, 3028, 3023, 3017, 3005, 2957, 2930, 2886, 2857, 1638, 1586, 1495, 1472, 1463, 1408, 1361, 1257, 1230, 1227, 1219, 1210, 1203, 1188, 1074, 1005; $[\alpha]^{25}_D$ = −6.0° (c 0.9, $CHCl_3$); HRMS (EI, m/z) (M − *t*Bu)$^+$ calcd for $(C_{25}H_{45}O_3Si_2)^+$ 449.2907, found 449.2912.

(2*R*,3*S*,5*R*)-8-(Benzyloxy)-3,5-bis((*tert*-butyldimethylsilyl)-oxy)-2-methyloctanal (17a). Ozone was bubbled through a solution of the alkene **16a** (1.1 g, 2.2 mmol) in CH_2Cl_2 (20 mL) and methanol (5 mL) in the presence of some drops of pyridine, at −78 °C for 20 min. After flushing with oxygen, dimethyl sulfide (1 mL) was added at −78 °C and the reaction mixture was stirred overnight at 20 °C. The reaction mixture was concentrated in vacuo. The residue was purified by silica gel column chromatography (90/10 petroleum ether/ether) to afford the aldehyde **17a** (917 mg, 83%) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 9.74 (d, J = 1.9 Hz, 1H), 7.27−7.34 (m, 5H), 4.50 (s, 2H), 4.06−4.10 (m, 1H), 3.82 (qd, J = 7.2, 5.4 Hz, 1H), 3.46 (t, J = 6.6 Hz, 2H), 2.50 (qdd, J = 6.9, 3.2, 1.9 Hz, 1H), 1.51−1.67 (m, 6H), 1.10 (d, J = 6.9 Hz, 3H), 0.87, 0.88 (2s, 18H), 0.08, 0.07, 0.07, 0.06 (4s, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 204.4, 138.6, 128.3, 127.6, 127.5, 72.9, 71.3, 70.3, 69.7, 52.1, 43.1, 34.3, 25.9, 25.8, 25.2, 18.0, 18.0, 10.2, −3.9, −4.1, −4.2, −4.4; IR ($CHCl_3$, cm^{-1}) 3673, 3450, 3029, 3023, 3014, 2955, 2931, 2885, 2858, 2338, 1715, 1603, 1471, 1463, 1362, 1257, 1239, 1235, 1231, 1223, 1219, 1215, 1211, 1207, 1203, 1177, 1087, 1043, 1006; $[\alpha]^{25}_D$ = +16.0° (c 1.2, $CHCl_3$); HRMS (EI, m/z) (M − *t*Bu)$^+$ calcd for $(C_{24}H_{43}O_4Si_2)^+$ 451.2700, found 451.2680.

(2*R*,3*S*,5*R*)-8-(Benzyloxy)-3,5-bis((4-methoxybenzyl)oxy)-2-methyloctanal (17b). To a solution of the alcohol **15b** (1.3 g, 3.3 mmol) and freshly prepared *p*-methoxybenzyltrichloroacetimidate (1.8 g, 6.6 mmol, 2.0 equiv) in ether (16 mL) at 20 °C was added camphorsulfonic acid (77 mg, 0.30 mmol, 0.1 equiv) in ether (1 mL). The clear solution turned cloudy within 5 min after the addition of acid. The reaction mixture was stirred for 1 h at 20 °C and was then quenched with saturated aqueous $NaHCO_3$ and diluted with ether. The combined organic phases were washed with brine, dried over $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by silica gel column chromatography (70/30 petroleum ether/ether) to afford the protected alcohol **16b** (1.39 g, 81%) as a colorless oil. Ozone was bubbled through a solution of **16b** (1.39 g, 2.67 mmol) in CH_2Cl_2 (20 mL) and methanol (5 mL) in the presence of some drops of pyridine, at −78 °C for 45 min. After flushing with oxygen, dimethyl sulfide (2.0 mL) was added at −78 °C and the reaction mixture was stirred overnight at 20 °C. The reaction mixture was concentrated in vacuo. The residue was purified by silica gel column chromatography (60/40 petroleum ether/ether) to afford the aldehyde **17b** (1.04 g, 75%) as a colorless oil: ^{1}H NMR

($CDCl_3$, 400 MHz) δ 9.70 (d, J = 1.6 Hz, 1H), 7.26−7.35 (m, 5H), 7.16−7.23 (m, 4H), 6.83−6.87 (m, 4H), 4.50 (s, 2H), 4.50 (d, J = 11.1 Hz, 1H), 4.47 (d, J = 11.0 Hz, 1H), 4.34 (d, J = 11.0 Hz, 1H), 4.30 (d, J = 11.1 Hz, 1H), 4.00 (ddd, J = 9.4, 4.7, 2.8 Hz, 1H), 3.78 (s, 6H), 3.66−3.69 (m, 1H), 3.47 (t, J = 6.9 Hz, 2H), 2.69−2.76 (m, 1H), 1.50−1.72 (m, 6H), 1.09 (d, J = 6.7 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 204.0, 159.2, 159.1, 138.6, 130.8, 130.3, 129.3, 129.3, 128.3, 127.6, 127.5, 113.8, 113.8, 75.7, 74.7, 72.9, 71.6, 70.3, 70.1, 55.3, 49.9, 37.5, 30.3, 25.0, 9.1; IR ($CHCl_3$, cm^{-1}) 2955, 2938, 2865, 2840, 1727, 1611, 1513, 1464, 1456, 1361, 1302, 1250, 1174, 1161, 1095, 1035; HRMS (EI, m/z) M^+ calcd for $C_{32}H_{40}O_6^+$ 520.2825, found 520.2810.

(5*S*,6*S*,8*R*)-11-(Benzyloxy)-6,8-bis((*tert*-butyldimethylsilyl)-oxy)-5-methylundec-2-en-4-one (19a). A solution of (*Z*)-1-bromo-1-propene (600 μL, 7.0 mmol, 7 equiv) in THF (7 mL) was added dropwise to a solution of magnesium (190 mg, 7.7 mmol, 7.7 equiv) and a few crystals of I_2 in THF (7 mL). The reaction mixture was refluxed for 1 h and then diluted with ether (7 mL) and cooled to −78 °C. The aldehyde **17a** (509 mg, 1.0 mmol) in THF (1 mL) was added dropwise, and the mixture was stirred at −78 °C for 1 h. Saturated aqueous NH_4Cl was added, and the aqueous phase was extracted with ether. The combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was directly used in the next step without further purification. To a stirred solution of 2-iodoxybenzoic acid (840 mg, 3.0 mmol, 3.0 equiv) in DMSO (18 mL) was added a solution of the alcohol **18a** in THF (9 mL) at 20 °C. After the solution had been stirred overnight, 10 mL of water and 10 mL of ether were added. The mixture was stirred for 2 h to form a white precipitate, which was then filtered off. The aqueous phase was extracted with ether. The combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by flash chromatography on silica gel (petroleum ether/ether 95/5) to afford the two separable diastereomers of the alkene **19a** (297 mg, 54% over 2 steps, Z/E = 4/1) as two yellow oils. *Z* isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.26−7.34 (m, 5H), 6.15−6.27 (m, 2H), 4.49 (s, 2H), 4.18 (dt, J = 7.2, 3.3 Hz, 1H), 3.79 (m, 1H), 3.44 (t, J = 6.6 Hz, 2H), 2.75 (qd, J = 8.9, 5.4 Hz, 1H), 2.09 (d, J = 5.9 Hz, 3H), 1.58−1.63 (m, 2H), 1.47−1.54 (m, 3H), 1.28−1.34 (m, 1H), 1.05 (d, J = 6.8 Hz, 3H), 0.89, 0.85 (2s, 18H), 0.11, 0.10, 0.05, 0.03 (4s, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 202.3, 143.5, 138.6, 128.3, 127.6, 127.4, 72.8, 70.5, 70.1, 69.6, 54.1, 41.0, 34.6, 25.9, 25.8, 25.2, 18.0, 18.0, 16.0, 9.4, −3.8, −4.2, −4.2, −4.3; IR ($CHCl_3$, cm^{-1}) 3034, 3028, 3022, 3010, 2957, 2929, 2857, 1688, 1627, 1471, 1463, 1378, 1362, 1258, 1221, 1209, 1203, 1095, 1006; $[\alpha]^{25}_D$ = +3.9° (*c* 1.5, $CHCl_3$); HRMS (EI, m/z) M^+ calcd for $C_{31}H_{56}O_4Si_2^+$ 548.3717, found 548.3722. *E* isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.26−7.34 (m, 5H), 6.87 (dq, J = 15.4, 6.9 Hz, 1H), 6.25 (dq, J = 15.3, 1.5 Hz, 1H), 4.49 (s, 2H), 4.17 (ddd, J = 8.3, 4.3, 2.9 Hz, 1H), 3.75−3.81 (m, 1H), 3.44 (td, J = 6.5, 1.3 Hz, 2H), 2.90 (qd, J = 6.8, 4.4 Hz, 1H), 1.87 (dd, J = 6.9, 1.5 Hz, 3H), 1.46−1.62 (m, 5H), 1.30−1.38 (m, 1H), 1.05 (d, J = 6.8 Hz, 3H), 0.88, 0.84 (2s, 18H), 0.11, 0.10, 0.04, 0.03 (4s, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 200.7, 142.1, 130.8, 138.6, 128.3, 127.6, 127.4, 72.8, 70.5, 70.2, 69.6, 51.6, 41.0, 34.6, 25.8, 25.8, 25.2, 18.2, 18.0, 18.0, 9.7, −3.6, −4.1, −4.2, −4.3; IR ($CHCl_3$, cm^{-1}) 3034, 3028, 3022, 3010, 2957, 2929, 2857, 1688, 1627, 1471, 1463, 1378, 1362, 1258, 1221, 1209, 1203, 1095, 1006; HRMS (EI, m/z) M^+ calcd for $C_{31}H_{56}O_4Si_2^+$ 548.3717, found 548.3703.

(5*S*,6*S*,8*R*)-11-(Benzyloxy)-6,8-bis((4-methoxybenzyl)oxy)-5-methylundec-2-en-4-one (19b). A solution of (*Z*)-1-bromo-1-propene (850 μL, 10 mmol, 5.0 equiv) in THF (10 mL) was added dropwise to a solution of magnesium (267 mg, 11 mmol, 5.5 equiv) and a few crystals of I_2 in THF (10 mL). The reaction mixture was refluxed for 1 h and then diluted with ether (5 mL) and cooled to −78 °C. The aldehyde **17b** (1.04 g, 2.0 mmol) in THF (2 mL) was added dropwise, and the mixture was stirred at −78 °C for 1 h. Saturated aqueous NH_4Cl was added and the aqueous phase was extracted with ether. The combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was directly used in the next step without further purification. To a stirred solution of 2-iodoxybenzoic acid (1.68 g, 6.0 mmol, 3.0 equiv) in DMSO (36 mL) was added a solution of the alcohol **18b** in THF (18 mL) at 20 °C. After the solution had been stirred overnight, 20 mL of water and 20 mL of ether were added. The mixture was stirred for 2 h to form a white precipitate, which was then filtered off. The aqueous phase was extracted with ether. The combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by flash chromatography on silica gel (petroleum ether/ether 90/10) to afford the two diastereomers of alkene **19b** (639 mg, 57% for 2 steps, Z/E = 4/1) as yellow oils. *Z* isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.27−7.35 (m, 5H), 7.17−7.22 (m, 4H), 6.82−6.86 (m, 4H), 6.14−6.30 (m, 2H), 4.50 (s, 2H), 4.44−4.47 (m, 2H), 4.22−4.27 (m, 2H), 3.99 (ddd, J = 8.9, 5.8, 3.0 Hz, 1H), 3.78 (s, 3H), 3.77 (s, 3H), 3.60−3.66 (m, 1H), 3.47 (br t, J = 5.7 Hz, 2H), 2.96 (quint, J = 6.6 Hz, 1H), 2.09 (d, J = 6.2 Hz, 3H), 1.52−1.68 (m, 6H), 1.06 (d, J = 6.6 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 203.2, 143.4, 159.1, 159.0, 138.6, 131.0, 130.5, 129.3, 129.1, 128.3, 127.5, 127.5, 127.4, 113.7, 113.6, 76.3, 74.8, 72.8, 71.6, 70.4, 69.9, 55.2, 55.2, 50.3, 36.8, 30.4, 25.2, 16.0, 10.4; IR ($CHCl_3$, cm^{-1}) 3032, 2957, 2930, 2857, 1709, 1608, 1514, 1464, 1455, 1360, 1315, 1302, 1250, 1233, 1172, 1097, 1034; HRMS (EI, m/z) (M − OPMB)$^+$ calcd for $(C_{27}H_{35}O_5)^+$ 439.2484, found 439.2493. *E* isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.26−7.34 (m, 5H), 7.15−7.22 (m, 4H), 6.81−6.86 (m, 4H), 6.17−6.22 (m, 2H), 4.49 (s, 2H), 4.46 (d, J = 11.2 Hz, 1H), 4.43 (d, J = 10.9 Hz, 1H), 4.25 (d, J = 10.9 Hz, 1H), 4.24 (d, J = 11.2 Hz, 1H), 3.94−3.99 (m, 1H), 3.78 (s, 3H), 3.77 (s, 3H), 3.62−3.66 (m, 1H), 3.47 (br t, J = 5.9 Hz, 2H), 3.12 (quint, J = 6.8 Hz, 1H), 1.86 (dd, J = 6.9, 1.6 Hz, 3H), 1.54−1.68 (m, 6H), 1.06 (d, J = 6.9 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 201.7, 142.6, 159.1, 159.0, 131.2, 131.0, 130.5, 129.4, 129.1, 128.3, 127.5, 127.4, 113.7, 113.6, 76.6, 74.7, 72.8, 71.8, 70.3, 69.7, 55.2, 55.2, 47.5, 36.8, 30.4, 25.2, 18.2, 11.0; IR ($CHCl_3$, cm^{-1}) 3032, 2957, 2930, 2857, 1709, 1608, 1514, 1464, 1455, 1360, 1315, 1302, 1250, 1233, 1172, 1097, 1034; HRMS (EI, m/z) (M − OPMB)$^+$ calcd for $(C_{27}H_{35}O_5)^+$ 439.2484, found 439.2498.

(4*R*)-2-Methylhept-1-en-4-yl Acetate (6a). To a stirred suspension of copper(I) iodide (0.68 g, 3.6 mmol, 0.5 equiv) in THF (30 mL) was added isopropenylmagnesium bromide (0.5 M THF solution, 43.2 mL, 21.6 mmol, 3.0 equiv) dropwise at −30 °C. After 30 min, (*R*)-1,2-epoxypentane (**20**;[24] 0.62 g, 7.2 mmol) in THF (4 mL) was slowly added to the mixture. After it was stirred at −30 °C for 2 h, the reaction mixture was quenched with saturated aqueous NH_4Cl and filtered and the aqueous phase was extracted with ether. The combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was directly used in the next step without further purification. To a stirred solution of the previous allylic alcohol **21** with DMAP (1.1 g, 9.0 mmol) in CH_2Cl_2 (12 mL) at 0 °C was slowly added acetic anhydride (2.9 mL, 30 mmol). The reaction mixture was warmed to 20 °C and stirred overnight. The mixture was diluted by addition of ether (60 mL) and quenched with saturated aqueous $NaHCO_3$. After separation, the aqueous layer was extracted with ether. The combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by silica gel chromatography (petroleum ether and then petroleum ether/ether 98/2) to afford the protected alcohol **6a** (1.20 g, 7.1 mmol, 98%) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 5.04 (dtd, J = 7.3, 6.4, 5.7 Hz, 1H), 4.76 (s, 1H), 4.70 (s, 1H), 2.26 (dd, J = 13.9, 7.8 Hz, 1H), 2.17 (dd, J = 13.9, 5.3 Hz, 1H), 2.01 (s, 3H), 1.73 (s, 3H), 1.48−1.53 (m, 2H), 1.25−1.42 (m, 2H), 0.90 (t, J = 7.3 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 170.7, 141.9, 113.1, 71.9, 42.9, 36.2, 22.4, 21.1, 18.6, 13.9; IR ($CHCl_3$, cm^{-1}) 2963, 2935, 2875, 1728, 1651, 1465, 1376, 1255, 1023; $[\alpha]^{25}_D$ = +6.6° (*c* 0.5, $CHCl_3$); HRMS (EI, m/z) M^+ calcd for $C_{10}H_{18}O_2^+$ 170.1307, found 170.1303.

(4*R*)-2-Methyl-4-((triethylsilyl)oxy)hept-1-ene (6b). To a stirred suspension of copper(I) iodide (0.68 g, 3.6 mmol, 0.5 equiv) in THF (30 mL) was added isopropenylmagnesium bromide (0.5 M THF solution, 43.2 mL, 21.6 mmol, 3 equiv) dropwise at −30 °C. After 30 min, (*R*)-1,2-epoxypentane (**20**;[24] 0.62 g, 7.2 mmol) in THF (4 mL) was slowly added to the mixture. After it was stirred at −30 °C for 2 h, the reaction mixture was quenched with saturated aqueous NH_4Cl and filtered and the aqueous phase was extracted with ether. The combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was directly used in the next step without further purification. To a solution of the alcohol **21** in CH_2Cl_2 (70 mL) at −78 °C was added dropwise Et_3N (3.1 mL, 22 mmol, 3.0 equiv) and TESOTf (3.2 mL, 14 mmol, 2.0 equiv). The reaction mixture was stirred for 1 h at −78 °C and was quenched with saturated aqueous NH_4Cl. The mixture was warmed to 20 °C. The aqueous phase was extracted with ether, and the combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by silica gel column chromatography with a gradient of ether in petroleum ether (1/99, 5/95) to afford the product **6b** (1.70 g, 99%) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 4.76 (s, 1H), 4.70 (s, 1H), 3.78−3.84 (m, 1H), 2.14 (dd, J = 13.6, 5.8 Hz, 1H), 2.14 (dd, J = 13.4, 7.0 Hz, 1H), 1.73 (s, 3H), 1.28−1.45 (m, 4H), 0.96 (t, J = 7.9 Hz, 9H), 0.90 (t, J = 6.8 Hz, 3H), 0.60 (q, J = 7.9 Hz, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 143.0, 112.6, 70.7, 46.3, 39.2, 23.0, 18.6, 14.2, 6.9, 5.2; IR ($CHCl_3$, cm^{-1}) 3034, 3029, 3023, 3013, 2958, 2913, 2876, 1646, 1458, 1416, 1363, 1075, 1005; $[\alpha]^{25}_D$ = +5.4° (c 2.0, $CHCl_3$); HRMS (EI, m/z) (M − Et)$^+$ calcd for $(C_{12}H_{25}OSi)^+$ 213.1675, found 213.1682.

(4*R*)-4-((*tert*-Butyldimethylsilyl)oxy)-2-methylhept-1-ene (6c). To a stirred suspension of copper(I) iodide (0.68 g, 3.6 mmol, 0.5 equiv) in THF (30 mL) was added isopropenylmagnesium bromide (0.5 M THF solution, 43.2 mL, 21.6 mmol, 3.0 equiv) dropwise at −30 °C. After 30 min, (*R*)-1,2-epoxypentane (**20**;[24] 0.62 g, 7.2 mmol) in THF (4 mL) was slowly added to the mixture. After it was stirred at −30 °C for 2 h, the reaction mixture was quenched with saturated aqueous NH_4Cl and filtered and the aqueous phase was extracted with ether. The combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was directly used in the next step without further purification. To a solution of the alcohol **21** in CH_2Cl_2 (70 mL) at −78 °C were added dropwise Et_3N (3.1 mL, 22 mmol, 3.0 equiv) and TBSOTf (3.3 mL, 14 mmol, 2.0 equiv). The reaction mixture was stirred for 1 h at −78 °C and was quenched with saturated aqueous NH_4Cl. The mixture was warmed to 20 °C. The aqueous phase was extracted with ether, and the combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by silica gel column chromatography with a gradient of ether in petroleum ether (1/99, 5/95) to afford the product **6c** (1.70 g, 98%) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 4.76 (s, 1H), 4.72 (s, 1H), 3.77−3.83 (m, 1H), 2.20 (dd, J = 13.5, 5.8 Hz, 1H), 2.13 (dd, J = 13.5, 6.8 Hz, 1H), 1.73 (s, 3H), 1.35−1.42 (m, 4H), 0.88−0.90 (m, 12H), 0.05 (s, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 143.0, 112.7, 70.8, 46.2, 39.2, 25.9, 23.0, 18.6, 18.1, 14.2, −4.4, −4.5; IR ($CHCl_3$, cm^{-1}) 2959, 2931, 2858, 1472, 1463, 1376, 1362, 1255, 1125, 1107, 1088, 1039, 1006; $[\alpha]^{25}_D$ = +13.2° (c 2.0, $CHCl_3$); HRMS (EI, m/z) M$^+$ calcd for $C_{14}H_{30}OSi^+$ 242.2066, found 242.2057.

(1*R*,6*S*,7*S*,9*R*)-12-(Benzyloxy)-7,9-bis((*tert*-butyldimethylsilyl)oxy)-3,6-dimethyl-5-oxo-1-propyldodec-3-enyl Acetate (22a). The Hoveyda−Grubbs second-generation catalyst (17 mg, 15 mol %) was added to a stirred solution of enone **19a** (100 mg, 0.18 mmol) and acetate **6a** (153 mg, 0.90 mmol, 5.0 equiv) in degassed CH_2Cl_2 (1 mL) under argon. The reaction mixture was heated at reflux for 3 days. The mixture was then cooled to 20 °C, concentrated in vacuo, and directly purified by silica gel column chromatography with a gradient of ether in petroleum ether (2/98, 5/95, 10/90) to afford 32 mg of the *E* isomer of **22a** (26%) and 8 mg of *Z* isomer (7%) as two colorless oils. *E* isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.25−7.36 (m, 5H), 6.19 (s, 1H), 5.06−5.09 (m, 1H), 4.50 (s, 2H), 4.10 (dt, J = 8.0, 4.0 Hz, 1H), 3.79−3.82 (m, 1H), 3.45 (t, J = 6.4 Hz, 2H), 2.68 (qd, J = 6.9, 4.6 Hz, 1H), 2.41 (dd, J = 13.6, 7.0 Hz, 1H), 2.28 (dd, J = 13.6, 6.2 Hz, 1H), 2.14 (s, 3H), 2.03 (s, 3H), 1.24−1.65 (m, 10H), 1.05 (d, J = 6.9 Hz, 3H), 0.91 (t, J = 7.3 Hz, 3H), 0.88, 0.84 (2s, 18H), 0.11, 0.10, 0.04, 0.04 (4s, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 201.7, 170.5, 154.2, 138.6, 128.3, 127.6, 127.4, 125.4, 72.8, 71.7, 70.6, 70.4, 69.6, 54.1, 46.1, 41.5, 36.1, 34.4, 25.9, 25.2, 21.2, 19.8, 18.5, 18.1, 18.0, 13.8, 10.5, −3.9, −4.1, −4.2, −4.2; IR ($CHCl_3$, cm^{-1}) 2930, 2957, 2857, 1728, 1683, 1614, 1495, 1471, 1463, 1377, 1363, 1256, 1219, 1093, 1027, 1006; $[\alpha]^{25}_D$ = +13.0° (c 0.5, $CHCl_3$); HRMS (EI, m/z) M$^+$ calcd for $C_{38}H_{68}O_6Si_2^+$ 676.4555, found 676.4567. *Z* isomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.25−7.36 (m, 5H), 6.22 (s, 1H), 5.08−5.12 (m, 1H), 4.50 (s, 2H), 4.16 (dt, J = 7.6, 3.4 Hz, 1H), 3.79−3.82 (m, 1H), 3.45 (t, J = 6.4 Hz, 2H), 3.04 (dd, J = 13.1, 8.4 Hz, 1H), 2.76 (dd, J = 13.1, 4.4 Hz, 1H), 2.70 (qd, J = 6.9, 4.3 Hz, 1H), 1.99 (s, 3H), 1.91 (s, 3H), 1.18−1.60 (m, 10H), 1.04 (d, J = 6.9 Hz, 3H), 0.85−0.91 (m, 21H), 0.11, 0.10, 0.06, 0.04 (4s, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) 201.0, 170.7, 154.8, 138.7, 128.4, 127.6, 127.5, 125.8, 73.1, 72.9, 70.5, 70.3, 69.7, 54.2, 41.1, 38.0, 36.6, 34.5, 26.0, 25.9, 25.3, 21.3, 18.7, 18.1, 18.0,14.1, 9.9, −3.6, −4.1, −4.2, −4.2.

(4*R*,9*S*,10*S*,12*R*,*E*)-15-(Benzyloxy)-10,12-bis((*tert*-butyldimethylsilyl)oxy)-4-((triethylsilyl)oxy)-6,9-dimethylpentadec-6-en-8-one (22b). The Hoveyda−Grubbs second-generation catalyst (51 mg, 45 mol %) was added to a stirred solution of enone **19a** (100 mg, 0.18 mmol) and alkene **6b** (218 mg, 0.90 mmol, 5.0 equiv) in degassed CH_2Cl_2 (1 mL) under argon. The reaction mixture was heated at reflux for 3 days. The mixture was then cooled to 20 °C, concentrated in vacuo, and directly purified by silica gel column chromatography with a gradient of ether in petroleum ether (1/99, 3/97, 5/95) to afford *E* isomer **22b** (47%, 64 mg) as a colorless oil: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.26−7.34 (m, 5H), 6.16 (s, 1H), 4.49 (s, 2H), 4.10−4.15 (m, 1H), 3.78−3.906 (m, 2H), 3.44 (t, J = 6.4 Hz, 2H), 2.66−2.74 (m, 1H), 2.34 (dd, J = 12.8, 5.3 Hz, 1H), 2.22 (dd, J = 12.8, 7.8 Hz, 1H), 2.12 (s, 3H), 1.26−1.63 (m, 10H), 1.04 (dd, J = 6.9, 1.6 Hz, 3H), 0.96 (t, J = 7.9 Hz, 9H), 0.89 (m, 21H), 0.64 (q, J = 7.9 Hz, 6H), 0.10, 0.07, 0.05 (3s, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 201.6, 156.0, 138.7, 128.3, 127.6, 127.4, 125.2, 72.8, 70.6, 70.6, 70.5, 69.7, 54.2, 50.1, 41.2, 39.2, 34.6, 25.9, 25.9, 25.3, 20.2, 18.5, 18.0, 18.0, 14.1, 10.0, 6.9, 5.1, −4.3, −4.2; IR ($CHCl_3$, cm^{-1}) 3010, 2958, 2932, 2878, 2858, 1722, 1679, 1608, 1472, 1463, 1412, 1379, 1257, 1238, 1092, 1035; $[\alpha]^{25}_D$ = +11.5° (c 1.0, $CHCl_3$); HRMS (EI, m/z) M$^+$ calcd for $C_{40}H_{80}O_5Si_3^+$ 750.5470, found 750.5473.

(4*R*,9*S*,10*S*,12*R*,*E*)-15-(Benzyloxy)-4-((*tert*-butyldimethylsilyl)oxy)-10,12-bis((4-methoxybenzyl)oxy)-6,9-dimethylpentadec-6-en-8-one (22c). The Hoveyda−Grubbs second-generation catalyst (34 mg, 30 mol %) was added to a stirred solution of the enone **19b** (101 mg, 0.18 mmol) and the alkene **6c** (218 mg, 0.18 mmol, 5 equiv) in degassed CH_2Cl_2 (1 mL) under argon. The reaction mixture was heated at reflux for 3 days. The mixture was then cooled to 20 °C, concentrated in vacuo, and directly purified by silica gel column chromatography with a gradient of ether in petroleum ether (2/98, 10/90, 80/:20) to afford *E* isomer **22c** (61 mg, 45%) as a colorless oil (slightly contaminated by the *Z* isomer): ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.26−7.34 (m, 5H), 7.15−7.21 (m, 4H), 6.80−6.85 (m, 4H), 6.11 (s, 1H), 4.48 (s, 2H), 4.42−4.46 (m, 2H), 4.23−4.27 (m, 2H), 3.94−3.98 (m, 1H), 3.81−3.86 (m, 1H), 3.77, 3.76 (2s, 6H), 3.62−3.65 (m, 1H), 3.45 (br t, J = 5.9 Hz, 2H), 2.86−2.93 (m, 1H), 2.27 (dd, J = 12.9, 6.0 Hz, 1H), 2.19 (dd, J = 12.9, 6.7 Hz, 1H), 2.12 (d, J = 0.9 Hz, 3H), 1.54−1.66 (m, 6H), 1.39−1.54 (m, 4H), 1.05 (d, J = 7.0 Hz, 3H), 0.88−0.90 (m, 12H), 0.04, 0.02 (2s, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 202.4, 156.6, 159.0, 159.0, 141.9, 138.7, 132.3, 129.3, 129.1, 128.3, 127.6, 127.5, 125.5, 113.8, 113.7, 74.9, 72.8, 71.7, 70.7, 70.5, 69.9, 55.2, 50.7, 49.6, 39.3, 30.6,

25.9, 25.3, 22.3, 20.3, 18.4, 18.1, 14.2, 11.1, −4.4, −4.5; IR ($CHCl_3$, cm^{-1}) 2958, 2932, 2877, 2858, 1731, 1679, 1603, 1496, 1471, 1463, 1412, 1379, 1362, 1257, 1095, 1072, 1040; HRMS (EI, *m*/*z*) M^+ calcd for $C_{46}H_{68}O_7Si^+$ 760.4734, found 760.4730.

(5*R*,9*R*,10*R*,11*S*,13*R*,*E*)-13-(3-(Benzyloxy)propyl)-11-((*tert*-butyldimethylsilyl)oxy)-2,2,3,3,7,10,15,15,16,16-decamethyl-5-propyl-4,14-dioxa-3,15-disilaheptadec-7-en-9-ol (23). To a solution of *E* ketone **22b** (50 mg, 0.067 mmol) in THF (2 mL) was added L-Selectride (1 M in THF, 120 μL, 0.12 mmol, 1.8 equiv). After it was stirred for 5 h at −78 °C, the reaction mixture was quenched by successive addition of methanol and saturated aqueous NH_4Cl. The aqueous phase was extracted with ether, and the combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by silica gel column chromatography with a gradient of ether in petroleum ether (2/98, 5/95) to afford the secondary alcohol **23** (36 mg, 71%) as a colorless oil as a single diastereomer: ^1H NMR ($CDCl_3$, 400 MHz) δ 7.26−7.34 (m, 5H), 5.19 (br d, *J* = 8.8 Hz, 1H), 4.51 (s, 2H), 4.10−4.16 (m, 2H), 3.79−3.86 (m, 2H), 3.47 (t, *J* = 6.4 Hz, 2H), 2.23 (dd, *J* = 13.2, 5.3 Hz, 1H), 2.15 (dd, *J* = 13.2, 7.9 Hz, 1H), 1.84 (br s, 1H), 1.69 (s, 3H), 1.24−1.74 (m, 11H), 0.96 (t, *J* = 7.9 Hz, 9H), 0.89 (m, 21H), 0.73 (d, *J* = 6.9 Hz, 3H), 0.60 (q, *J* = 7.9 Hz, 6H), 0.09, 0.08, 0.07 (3s, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.7, 128.3, 127.6, 127.4, 135.8, 129.9, 72.9, 71.2, 70.8, 70.6, 70.6, 70.5, 48.3, 45.5, 41.0, 39.0, 34.9, 26.0, 25.9, 25.4, 18.4, 18.1, 18.1, 17.4, 14.2, 10.9, 6.9, 5.2, −3.9, −4.1, −4.2, −4.2; IR ($CHCl_3$, cm^{-1}) 3616, 3478, 2958, 2932, 2877, 2858, 1685, 1610, 1471, 1463, 1413, 1379, 1362, 1256, 1073; $[\alpha]^{25}_D$ = +4.5° (*c* 1.5, $CHCl_3$); HRMS (EI, *m*/*z*) M^+ calcd for $C_{42}H_{82}O_5Si_3^+$ 750.5470, found 750.5473.

(4*R*,6*S*,7*R*,8*R*,12*R*)-4,6-Bis((*tert*-butyldimethylsilyl)oxy)-8-(methoxymethoxy)-7,10-dimethyl-12-(triethylsilyloxy)-pentadec-9-en-1-ol (24). The secondary alcohol **23** (63 mg, 84 μmmol) was dissolved in DCE (420 μL) followed by the addition of diisopropylethylamine (150 μL, 840 μmol, 10 equiv) and MOMCl (32 μL, 420 μmol, 5.0 equiv) at 20 °C. After it was stirred for 5 h at 50 °C, the reaction mixture was quenched with successive addition of ether and 10% aqueous HCl solution. The aqueous phase was extracted with ether, and the combined organic extracts were washed with brine, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by silica gel column chromatography with a gradient of ether in petroleum ether (5/95, 10/90) to afford the desired protected alcohol (57 mg, 85%) as a slightly yellow oil. A solution of the preceding benzyl ether (20 mg, 25 μmmol) and an excess of Raney nickel in absolute ethanol (1 mL) was stirred at 20 °C under 1 atm of H_2. After the reaction was complete, the catalyst was removed by filtration and the solution concentrated in vacuo. The residue was purified by silica gel column chromatography with a gradient of ether in petroleum ether (10/90, 20/80) to afford the protected alcohol **24** (14 mg, 77%) as a colorless oil: ^1H NMR ($CDCl_3$, 400 MHz) δ 4.98 (br d, *J* = 9.6 Hz, 1H), 4.62 (d, *J* = 6.5 Hz, 1H), 4.42 (d, *J* = 6.5 Hz, 1H), 4.10−4.17 (m, 2H), 3.88−3.93 (m, 1H), 3.80−3.85 (m, 1H), 3.58−3.66 (m, 2H), 3.34 (s, 3H), 2.27 (dd, *J* = 13.2, 4.6 Hz, 1H), 2.17 (dd, *J* = 13.2, 8.3 Hz, 1H), 1.78−1.86 (m, 1H), 1.63 (s, 3H), 1.26−1.73 (m, 10H), 0.96 (t, *J* = 7.9 Hz, 9H), 0.89 (m, 21H), 0.76 (d, *J* = 7.1 Hz, 3H), 0.60 (q, *J* = 7.9 Hz, 6H), 0.09, 0.08, 0.07 (3s, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 137.6, 127.1, 93.4, 73.4, 70.7, 70.5, 70.3, 63.2, 55.7, 48.3, 44.0, 39.4, 38.7, 34.7, 28.1, 26.0, 18.4, 18.2, 18.1, 17.4, 14.2, 10.9, 7.0, 5.1, −3.9, −4.1, −4.2, −4.3; IR ($CHCl_3$, cm^{-1}) 3690, 3623, 3397, 2957, 2932, 2884, 2858, 1664, 1602, 1471, 1463, 1412, 1387, 1362, 1256, 1144, 1086, 1034; $[\alpha]^{25}_D$ = −25.0° (*c* 0.5, $CHCl_3$); HRMS (EI, *m*/*z*) M^+ calcd for $C_{37}H_{80}O_6Si_3^+$ 704.5263, found 704.5191.

(5*R*,9*R*,10*R*,11*S*,13*R*)-11-((*tert*-Butyldimethylsilyl)oxy)-3,3-diethyl-13-(3-iodopropyl)-9-(methoxymethoxy)-7,10,15,15,16,16-hexamethyl-5-propyl-4,14-dioxa-3,15-disilaheptadec-7-ene (25). The primary alcohol **24** (10 mg, 13.6 μmmol) was stirred in THF (300 μL) at 20 °C, followed by the addition of imidazole (2.3 mg, 34 μmol, 2.5 equiv) and Ph_3P (8 mg, 30 μmol, 2.2 equiv). The reaction mixture was cooled to 0 °C, and I_2 (7 mg, 27 μmol, 2.0 equiv) was added. The reaction mixture was stirred for 45 min, concentrated, and purified by flash chromatography (99/1 petroleum ether/ether) to afford the primary iodide **25** (8 mg, 72%): ^1H NMR ($CDCl_3$, 400 MHz) δ 4.98 (br d, *J* = 9.6 Hz, 1H), 4.62 (d, *J* = 6.4 Hz, 1H), 4.43 (d, *J* = 6.4 Hz, 1H), 4.11−4.17 (m, 2H), 3.81−3.90 (m, 2H), 3.35 (s, 3H), 3.16−3.21 (m, 2H), 2.27 (dd, *J* = 13.2, 4.4 Hz, 1H), 2.17 (dd, *J* = 13.3, 8.3 Hz, 1H), 1.69 (s, 3H), 1.28−1.93 (m, 11H), 0.97 (t, *J* = 7.9 Hz, 9H), 0.90, 0.88 (2s, 18H), 0.87 (t, *J* = 6.7 Hz, 3H), 0.77 (d, *J* = 7.1 Hz, 3H), 0.61 (q, *J* = 7.9 Hz, 6H), 0.09, 0.09, 0.08, 0.07 (4s, 12H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 137.7, 127.1, 93.4, 73.3, 70.7, 70.4, 69.5, 55.7, 48.3, 44.0, 39.9, 39.2, 38.7, 29.1, 26.0, 18.4, 18.1, 18.1, 17.4, 14.2, 10.9, 7.3, 6.9, 5.1, −3.9, −4.0, −4.2, −4.2; IR ($CHCl_3$, cm^{-1}) 3690, 3623, 3397, 2957, 2932, 2884, 2858, 1664, 1602, 1471, 1463, 1412, 1387, 1362, 1256, 1144, 1086, 1034; $[\alpha]^{25}_D$ = −22.0° (*c* 0.5, $CHCl_3$); HRMS (EI, *m*/*z*) $(M - I)^+$ calcd for $(C_{37}H_{79}O_5Si_3)^+$ 682.5735, found 682.5739.

■ ASSOCIATED CONTENT

Supporting Information. Figures giving ^1H and ^{13}C NMR spectra for all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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