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Novel Oxepane Formation by $TiCl_4$-Catalyzed Nucleophilic Cleavage of 1-Alkoxymethyl-6,8-dioxabicyclo[3.2.1]octanes

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Abstract—Introduction of an alkoxymethyl group at the C1 position in the 6,8-dioxabicyclo[3.2.1]octane system enabled novel formation of oxepane compounds in $TiCl_4$-catalyzed acetal cleavage reactions.

Introduction

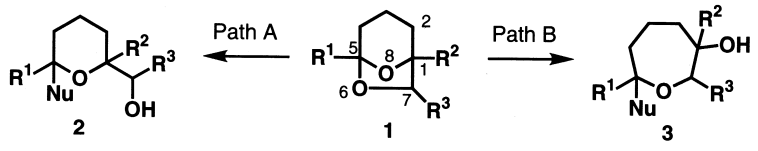
Lewis acid-catalyzed nucleophilic cleavage of the C5–O8 bond in a 6,8-dioxabicyclo[3.2.1]octane system (**1**) (path B in Scheme 1) which produces an oxepane (**3**) is an attractive method for the preparation of the segments for natural fused polycyclic ethers.[1] In fact, however, the cleavage reaction of **1** has produced exclusively an oxane (**2**) through a break of the C5–O6 bond (path A) in every case using DIBAH,[2–4] a combination of triethylsilane (Et_3SiH) with a Lewis acid,[2,3] or a combination of allyltrimethylsilane with $BF_3{\cdot}OEt_2$.[5] Recently, Rychnovsky has reported the first oxepane-selective formation in the system only under cyanation conditions.[6,7] In this context, we have developed a general procedure leading to production of oxepanes from 6,8-dioxabicyclo[3.2.1]octanes. Here, the selective formation of the oxepane derivatives by reductive and allylative cleavage of bicyclic acetals using chelation of $TiCl_4$ is described.[8]

Results and Discussion

The general concept in an exclusive cleavage reaction of the bicyclic system toward the oxepane formation is outlined in Scheme 2. We planned the selective fixation of a Lewis acid on O8 in order to enhance the cleaving ability of the C5–O8 bond rather than the C5–O6 bond by chelation of the Lewis acid between O8 and the oxygen of the alkoxymethyl function at C1. Thus, bicyclic acetals having an alkoxy-methyl group at C1 (**4a**–**e**) and a methyl group at C1 (**4f**) were designed as substrates for the cleavage reaction.

Preparation of bicyclic acetals

Acetals **4a**–**f** were prepared via diols **16a**–**f** (Scheme 3). Diol **16a** was synthesized from glycerol (**8**). Reaction of **8** with benzaldehyde gave an inseparable 4:3 mixture of acetals **9** and **10**. Methylation of the mixture followed by separation afforded **11** (49%). Acetal **11** was treated with $TiCl_4$ and Et_3SiH[9] to produce **13** selectively, which was oxidized and coupled with 4-(*tert*-butyldiphenylsilyloxy)-1-butynyl lithium to give **15** (53%). Removal of the benzyl group and reduction of the alkynyl part of **15** with Pd/C and H_2 yielded diol **16a** (70%). Diols **16b**–**e** were synthesized from the common β-hydroxy ester **20**, which was prepared in 81% yield from ϵ-caprolactone (**17**) by a 3-step process, including diastereoselective aldol reaction, reported by Abiko and Masamune.[10] Mesylation of **20** followed by DBU-mediated elimination and reduction with DIBAH produced *E*-allyl alcohol **21** in 89% yield, which was converted to **16b** (98%) by methylation and dihydroxylation and to **16d** (70%) by benzylation and dihydroxylation. On the other hand, reaction of **20** with DCC in the presence of CuCl and molecular sieves 4 Å[11] followed by reduction



Scheme 1.

Keywords: bicyclic heterocyclic compounds; cleavage reactions; ethers; oxepanes.
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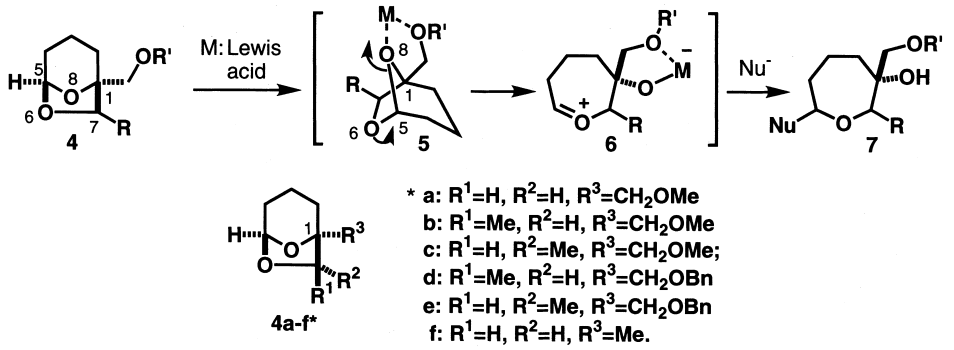
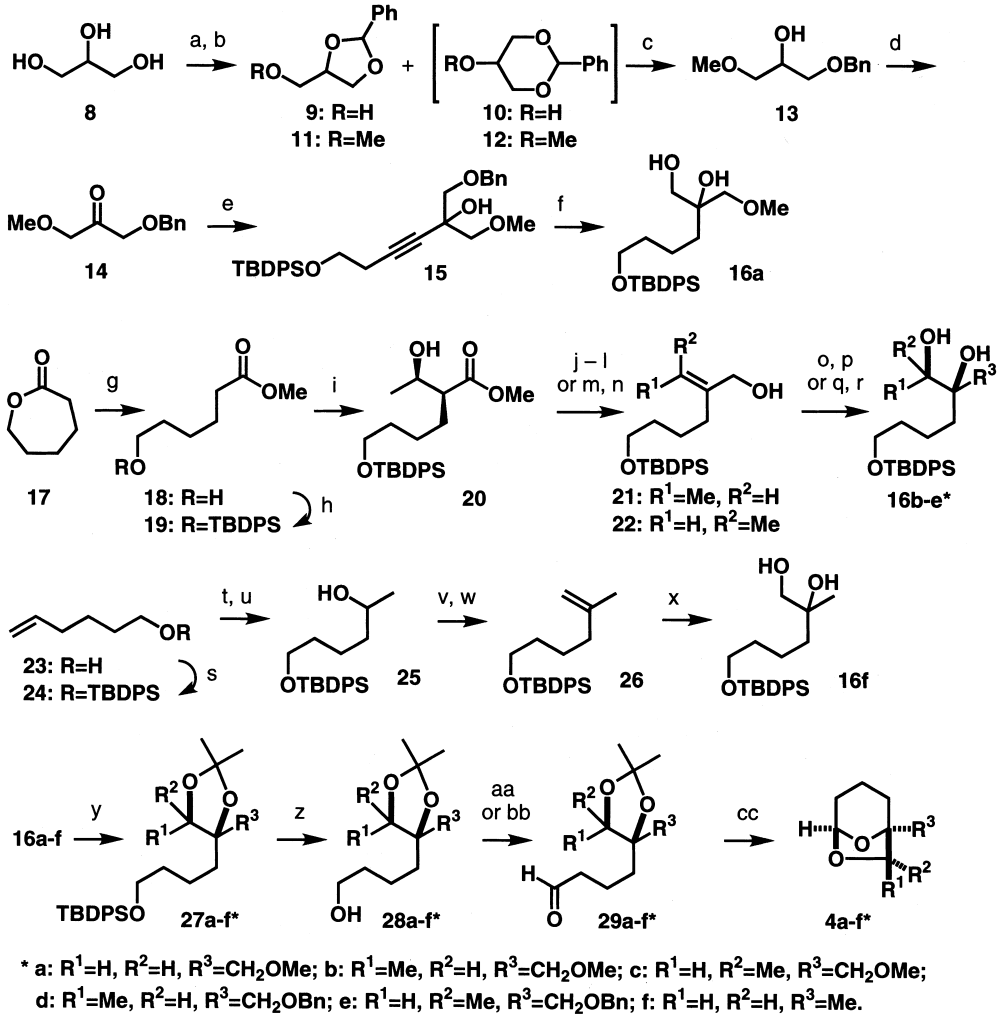
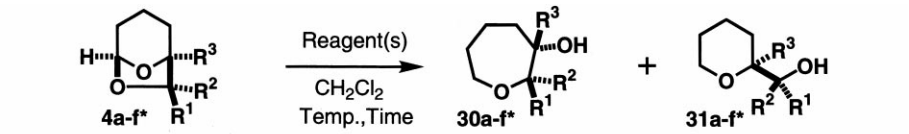


Scheme 2.



Scheme 3. Reagents and conditions: (a) benzaldehyde, PPTS, benzene, reflux, 5 h, **9**:**10**=4:3; (b) *t*-BuOK, MeI, THF, 20°C, 30 min, **11**: 49% from **8**; (c) $TiCl_4$, Et_3SiH, CH_2Cl_2, −78°C, 30 min; (d) TPAP, NMO, MS4A, CH_2Cl_2–MeCN (10:1), 20°C, 1 h; (e) $TBDPSOCH_2CH_2C{\equiv}CLi$, THF, −78°C, 20 min, 53% from **11**; (f) H_2, 10% Pd/C, 20°C, 70%; (g) NaOMe, MeOH, 20°C, 1.5 h; (h) TBDPSCl, imidazole, DMF, 20°C, 2 h, 92% from **17**; (i) Bu_2BOTf, *i*-Pr_2NEt, −78°C, 30 min, then MeCHO, −78°C, 1.5 h, 88% (*syn*:*anti*=96:4); (j) MsCl, Et_3N, CH_2Cl_2, 0°C, 1.5 h; (k) DBU, CH_2Cl_2, 20°C, 1 day; (l) DIBAH, CH_2Cl_2, −78°C, 1.5 h, **21**: 89% from **20**; (m) DCC, CuCl, MS4A, benzene, reflux 1 day; (n) DIBAH, CH_2Cl_2, −78°C, 1.5 h, **22**: 77% from **20**; (o) *t*-BuOK, MeI, THF, 20°C; (p) OsO_4, NMO, 1,4-dioxane–H_2O (3:1), 20°C, **16b**: 98% from **21**, **16c**: 89% from **22**; (q) BnBr, NaH, TBAI, THF, 20°C, 1 day; (r) OsO_4, NMO, 1,4-dioxane–H_2O (3:1), 20°C, **16d**: 70% from **21, 16e**: 78% from **22**; (s) TBDPSCl, imidazole, DMF, 0°C, 40 min, 94%; (t) *m*-CPBA, CH_2Cl_2, 20°C, 3 h, 94%; (u) $LiEt_3BH$, THF, 0°C, 1 h, 98%; (v) DMSO, $(COCl)_2$, −78°C, 30 min, then Et_3N, −78→0°C, 1 h, 76%; (w) Tebbe reagent, toluene, 20°C, 10 min, 92%; (x) OsO_4, NMO, 1,4-dioxane–H_2O (3:1), 20°C, 1.5 h, ~100%; (y) 2,2-dimethoxypropane, PPTS, CH_2Cl_2, 20°C, **27a**: 98%, **27b**: 89%, **27c**: 81%, **27d**: 96%, **27e**: 96%, **27f**: 96%; (z) TBAF, THF, 20°C, **28a**: 98%, **28b**: 92%, **28c**: ~100%, **28d**: ~100%, **28e**: ~92%, **28f**: 100%; (aa) TPAP, NMO, MS4A, CH_2Cl_2–MeCN (10:1), 20°C, **29a**: 85%, **29d**: 80%, **29e**: 81%, **29f**: 81%; (bb) DMSO, $(COCl)_2$, −78→−45°C, 30 min, then Et_3N, −45→0°C, 20 min, **29b**: 90%, **29c**: 85%; (cc) $TsOH{\cdot}H_2O$, CH_2Cl_2, 20°C, **4a**: 80%, **4b**: 79%, **4c**: 78%, **4d**: 78%, **4e**: 78%, **4f**: 66%.

Table 1.



* a: R^1=H, R^2=H, R^3=CH_2OMe; b: R^1=Me, R^2=H, R^3=CH_2OMe; c: R^1=H, R^2=Me, R^3=CH_2OMe; d: R^1=Me, R^2=H, R^3=CH_2OBn; e: R^1=H, R^2=Me, R^3=CH_2OBn; f: R^1=H, R^2=H, R^3=Me.

Entry	Substrate	Reagent(s) (equiv.)	Temp. (°C)	Time	Yield[a] (%)		**30**:**31**	**4** Recovery[a] (%)
1	**4a**	DIBAH (8)	20	2 days	81	**30a**:**31a**	0:100[b]	–
2		Et_3SiH (8) $TiCl_4$ (4)	−78	1 h	62		54:46[b]	17
3		Et_3SiH (8) $SnCl_4$ (2.4)	−78	4 h	94		0:100[c]	–
			−78→0	5 h				
4		Et_3SiH (8) $Sn(OTf)_2$ (2.4)	20	24 h	82		0:100[b]	–
5		Et_3SiH (8) $BF_3{\cdot}OEt_2$ (2.4)	20	3 h	99		0:100[b]	–
6		Et_3SiH (8) $AlMe_3$ (2.4)	20	2 days	43		59:41[b]	50
7		Et_3SiH (8) Et_2AlCl (2.4)	20	2 days	41		0:100[b]	31
8		Et_3SiH (8) $AlCl_3$ (2.4)	20	2 days	75		4:96[b]	–
9	**4b**	DIBAH (4)	20	2 days	100	**30b**:**31b**	0:100[b]	–
10		Et_3SiH (8) $TiCl_4$ (2.4)	−78	1 h	74		74:26[b]	–
11		Et_3SiH (12) $SnCl_4$ (3.6)	−78	5.5 h	43		0:100[b]	–
12	**4c**	DIBAH (4)	20	3 days	77	**30c**:**31c**	0:100[b]	–
13		Et_3SiH (8) $TiCl_4$ (2.4)	−78	1 h	98		99:1[b]	–
14		Et_3SiH (8) $SnCl_4$ (2.4)	−78	1.5 h	60		0:100[b]	–
			0	0.5 h				
15	**4d**	DIBAH (4)	20	2 days	59	**30d**:**31d**	0:100[b]	13
16		Et_3SiH (8) $TiCl_4$ (4)	−78	4 h	50		49:51[b]	35
17	**4e**	DIBAH (4)	20	2 days	50	**30e**:**31e**	2:98[b]	43
18		Et_3SiH (8) $TiCl_4$ (4)	−78	4 h	82		93:7[b]	–
19	**4f**	DIBAH (4)	20	3 days	46	**30f**:**32f**	0:100[c]	52
20		Et_3SiH (8) $TiCl_4$ (2.4)	−78	0.5 h	65		0:100[c]	–

[a] Isolated yield.
[b] Determined by GC.
[c] Determined by ^1H NMR (300 MHz).

gave *Z*-allyl alcohol **22** (77%). Diols **16c** and **16e** were derived from **22** similarly as described for **16b** and **16d**, respectively. Preparation of **16f** was commenced from 5-hexenol (**23**). Protection of **23** followed by epoxidation and regioselective reduction afforded **25** (87%), which was converted to **16f** (70%) by Swern oxidation,[12] followed by olefination with Tebbe reagent[13] and dihydroxylation. All acetals **4a**–**f** were constructed from the corresponding diols **16a**–**f** through a common 4-step sequence: protection of the diol part, desilylation, oxidation, and acidic cyclization.

Reductive cleavage of bicyclic acetals

At first, we explored the reagent system suitable for the oxepane-selective reductive cleavage of alkoxymethyl-substituted bicyclic acetals **4a**–**4e**. All reactions were carried out in CH_2Cl_2 under the conditions noted in Table 1. When DIBAH was used solely as a reductant, all the reactions of **4a**–**d** produced only the corresponding oxanes **31a**–**d**: acetals **4a**–**4c** gave the oxanes in high yield (77–100%, entries 1, 9, and 12), while the cleavage reactions of **4d**–**e** proceeded very slowly and gave oxanes in moderate yields (50–59%) with recovered substrates (entries 15 and 17). A combination of Et_3SiH with $TiCl_4$ provided satisfactory results.[14] The best selectivity of oxepane was observed in **4c** which had an α-methyl group at C7 (98%, **30c**:**31c**=99:1; entry 13). Interestingly, the selectivity in β-methyl-substituted **4b** (**30b**:**31b**=74:26; entry 10) was worse than in **4c** but better than in unsubstituted **4a** (**30a**:**31a**=54:46; entry 2).[15] The corresponding benzyloxymethyl compounds **4d** and **4e** also afforded oxepanes in comparable selectivities (**30d**:**31d**=49:51, entry 16; **30e**:**31e**=93:7, entry 18) with **4b** and **4c**. When these reactions were attempted at temperatures higher than −78°C in order to accelerate the reaction, removal of the benzyl group predominated over the normal cleavage. The

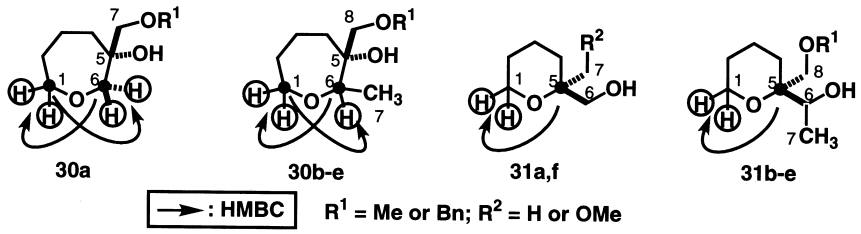


Figure 1. Observed HMBC in 6- and 7-membered cyclic ethers (**30** and **31**).

cleavage reactions of **4a**–**c** with Et_3SiH–$SnCl_4$ produced only oxanes **31a**–**c** although $SnCl_4$ is a bis-coordinating Lewis acid similar to $TiCl_4$. In the cases of Et_3SiH–$Sn(OTf)_2$ and Et_3SiH–$BF_3{\cdot}OEt_2$, only oxanes were given (entries 4 and 5). Among the aluminum Lewis acids investigated here such as $AlMe_3$, Et_2AlCl, and $AlCl_3$ (entries 6, 7, and 8), only $AlMe_3$ produced a significant amount of the oxepane **30a** as a mixture with **31a** from **4a** (**30a**:**31a**=59:41; entry 6).[16] However, reactions of the other substrates with this reagent system occurred too slowly to produce any cleavage products. Notably, $SnCl_4$, which is a bis-coordinate Lewis acid similar to $TiCl_4$ and more acidic than $AlMe_3$, could not produce an oxepane. It is deduced from the results that the strength of Lewis acidity is not essential for oxepane formation. Thus, we found that the combination of Et_3SiH and $TiCl_4$ is most effective for oxepane-selective reductive cleavage of 1-alkoxymethyl-6,8-dioxabicyclo[3.2.1]octanes.

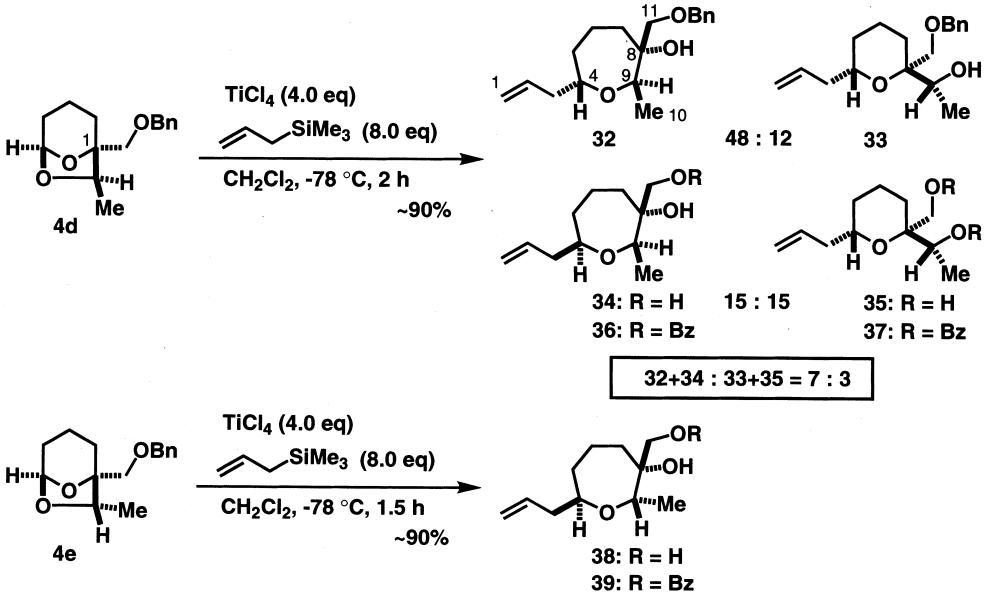
Next, the bicyclic acetal **4f** having no internal ligand was examined. Use of a mixture of Et_3SiH and $TiCl_4$ as well as of DIBAH provided only oxane **31f** but not oxepane **30f** (entries 19 and 20). This result shows that the presence of an alkoxymethyl group at C1 in the 6,8-dioxabicyclo[3.2.1]-octane skeleton is necessary for the oxepane-selective cleavage reaction.

The structures of oxepanes **30a**–**e** and oxanes **31a**–**f** were determined by their NMR analyses (Fig. 1). Both the cross-peaks between C1 and H6 and between C6 and H1 observed in all the HMBC spectra of **30a**–**e** verified the oxepane frameworks of **30a**–**e**. The oxane skeletons of **31a**–**f** were confirmed by the cross-peaks between C5 and H1 observed in all the HMBC spectra of **31a**–**f**.

Allylative cleavage of bicyclic acetals

Next, allylative cleavage of 1-alkoxymethyl-6,8-dioxabicyclo-[3.2.1]octanes was examined as an analogy of the reductive cleavage. Treatment of **4d** with allyltrimethylsilane in the presence of $TiCl_4$ in CH_2Cl_2 at −78°C gave a mixture of oxepane **32** (~48%), oxane **33** (~12%), and a small amount of **4d** (~8%) as well as a mixture of debenzylated oxepane **34** (~15%) and oxane **35** (~15%). It is to be noted that the stereochemistry of C4 of **32** was opposite to that of **34**. The ratio of oxepanes (**32**+**34**) to oxanes (**33**+**35**) amounted to 7:3 by ^1H NMR. On the other hand, the reaction of **4e** under the same conditions produced only debenzylated oxepane **38** as a single stereoisomer in ~90% yield. Interestingly, allyltrimethylsilane showed higher oxepane selectivity in the cleavage reaction of either **4d** or **4e** with $TiCl_4$ than Et_3SiH.[17] Thus, an alkoxymethyl substituent at C1 in the bicyclic acetal system induced oxepane formation also in allylative cleavage with allyltrimethylsilane catalyzed by $TiCl_4$ (Scheme 4).

The structures of the products were determined by NMR analyses. Benzyl ethers **32** and **33** were analyzed as such,



Scheme 4.

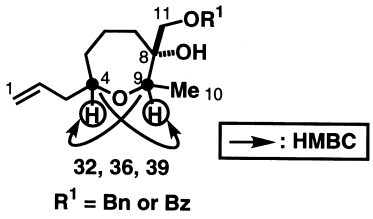


Figure 2. Observed HMBC in 7-membered cyclic ethers (**32**, **36**, **39**).

while diols **34**, **35**, and **36** were analyzed after conversion to the corresponding benzoates **36**, **37**, and **39**. The oxepane frameworks of **32**, **36**, and **39** were confirmed by the cross-peaks between C4 and H9 and between C9 and H4 observed in all the HMBC spectra of **32**, **36**, and **39** (Fig. 2). The relative configurations at C4 of these oxepanes were verified by the NOEs between H3 and H9 in **32** and between H4 and H9 in **36** as well as the NOEs between H3 and H9 and between H4 and H10 in **39** (Fig. 3). Although the cross-peak between H4 and C8 was not detected in the HMBC spectra of both **33** and **37**, the NOEs between H4 and H9 were observed in both the compounds (Fig. 3), which confirmed their oxane framework and the stereochemistry at C4.

Conclusion

In the reductive cleavage reaction catalyzed by $TiCl_4$, 6,8-dioxabicyclo[3.2.1]octanes having an alkoxymethyl group at C1 as an internal ligand led to novel oxepane formation. Benzyloxymethyl compounds **4d** and **4e** showed oxepane selectivity comparable with that of methoxymethyl compounds **4b** and **4c** in the reaction. Stereochemistry of the methyl substituent at C7 in the bicyclic acetal strongly affected the selectivity. Cleavage with allyltrimethylsilane and $TiCl_4$ in this bicyclic acetal system also disclosed the oxepane formation. Application of these reactions to the total syntheses of natural products and a detailed mechanistic study on the stereochemistry of these reactions are currently under way in our laboratory.

Experimental

General

The following general procedures were used in all reactions unless otherwise noted. Oxygen- and moisture-sensitive reactions were carried out in oven-dried (>130°C) glassware sealed under a positive pressure of dry argon from a manifold or balloon. Sensitive liquids and solutions were transferred by syringe or cannula through rubber septa. Reactions were run at noted temperature and stirred with a Teflon-covered magnetic stirring bar. All commercially available reagents were used without further purification with the following exceptions. THF was distilled from sodium-benzophenone ketyl under argon. Dichloromethane (CH_2Cl_2) and diisopropylethylamine (*i*-Pr_2NEt) were distilled from CaH_2 under argon prior to use. Analytical TLC was performed with 0.25 mm Silica Gel 60 plates with a 254 nm fluorescent indicator from Merck. Plates were developed in a covered chamber and visualized by ultraviolet light and by treatment with acidic anisaldehyde stain followed by heating. Flash chromatography was performed on YMC Silica Gel 60 (230–400 mesh) as a stationary phase. Melting points were obtained using a Yanagimoto micro melting point apparatus without calibration. NMR spectra were measured on a JEOL alpha-400 (^1H at 400 MHz, ^{13}C at 100 MHz), a JEOL FT-270 (^1H at 270 MHz), or a JEOL AL-300 (^1H at 300 MHz) magnetic resonance spectrometer. ^1H NMR spectra are reported as chemical shifts in parts-per-million (ppm) based on tetramethylsilane (0 ppm) or one of the signals of the solvent (noted in each case). ^{13}C NMR spectra are reported as chemical shifts in ppm based on one of the signals of the solvent (noted in each case) and recorded with complete heterodecoupling. Position numbering of cyclic ethers in NMR data is specified in Figs. 1–3. Infrared spectra were measured on a Hitachi model 270-30 or a JEOL Winspec-100 infrared spectrometer in noted states. Low and high resolution mass spectra were measured on a JEOL DX303 mass spectrometer under electron ionization (EI) condition, a JEOL JMS-AX500 mass spectrometer under EI condition, or a JEOL JMS-600 mass spectrometer under EI or chemical ionization (CI, isobutane was used as reagent gas) condition. Analytical gas–liquid phase chromatography was performed on a Hitachi model 163 instrument equipped with a FID-detector and a capillary column of FFAP (GASUKURO KOGYO Inc. Japan, 25000×0.25 mm) with helium as carrier gas. Preparative liquid chromatography was achieved on a JASCO 880-PU instrument equipped with a JASCO 875-UV detector and a packed column (YMC-Pack SIL-06, 250×10 mm or 250×20 mm) with hexane–EtOAc as a liquid phase.

2-Phenyl-4-methoxymethyl-1,3-dioxolane (11). A mixture of glycerol (2.77 g, 30.1 mmol), benzaldehyde (3.1 ml,

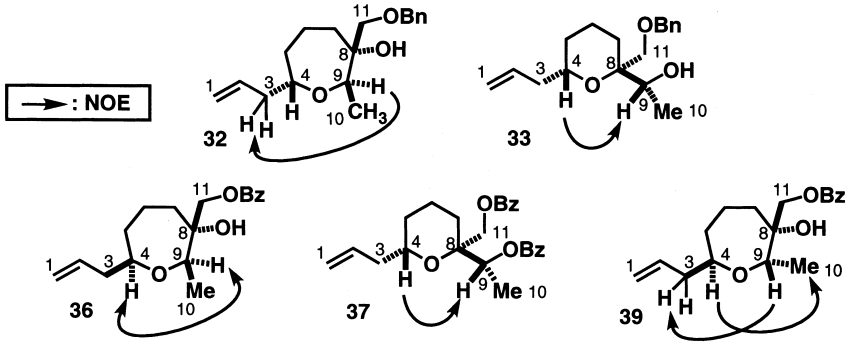


Figure 3. Observed NOEs in allyl-substituted 6- and 7-membered cyclic ethers (**32**, **33**, **36**, **37**, and **39**).

30.1 mmol), and pyridinium *p*-toluenesulfonate (PPTS) (0.38 g, 1.50 mmol) in benzene (150 ml) was refluxed for 5 h. During the reaction, water was removed by Dean–Stark trap. Then, saturated aqueous $NaHCO_3$ (50 ml) was added and the mixture was extracted with ether (150 ml). The organic layer was washed with brine (300 ml). The brine was extracted with ether (2×150 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure to provide a crude mixture of acetals **9** and **10** (5.761 g, **9**:**10**=4:3). The crude mixture and iodomethane (5.6 ml, 90.2 mmol) were dissolved in THF (100 ml) and cooled to 0°C. To the mixture, *t*-BuOK (6.75 g, 60.16 mmol) was added and the reaction mixture was warmed to 20°C, and stirred for 30 min. Then, saturated aqueous $NaHCO_3$ (50 ml) was added and the mixture was extracted with EtOAc (100 ml). The organic layer was washed with saturated $Na_2S_2O_3$ (50 ml) and brine (50 ml). The combined aqueous layers were extracted with EtOAc (2×100 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=20→5) provided acetal **11** (2.94 g, 49% from glycerol) as a pale yellow oil. **11**: a 1:1 diastereomer mixture; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.31–7.52 (10H, m), 5.95 (1H, s), 5.81 (1H, s), 4.32–4.46 (2H, m), 4.24 (1H, dd, *J*=6.6, 8.1 Hz), 4.11 (1H, dd, *J*=7.0, 8.1 Hz), 3.95 (1H, dd, *J*=5.5, 8.1 Hz), 3.83 (1H, dd, *J*=6.8, 8.3 Hz), 3.45–3.63 (4H, m), 3.44 (3H, s), 3.42 (3H, s); IR (film) ν_{max} 2984, 2932, 2884, 1458, 1396, 1220, 1200, 1108, 1072, 1028, 974, 758, 698 cm^{-1}; LR-EIMS *m*/*z* 71 (33.3%), 91 (bp), 149 (59.9%), 194 (27.0%, M); HR-EIMS calcd for $C_{11}H_{14}O_3$ [M]: 194.0943, found: 194.0927.

6-Benzyloxy-5-hydroxy-5-methoxymethyl-3-hexynyl *tert*-butyldiphenylsilyl ether (15). To a solution of acetal **11** (1.944 g, 10.01 mmol) and Et_3SiH (6.4 ml, 40 mmol) in CH_2Cl_2 (50 ml) was added $TiCl_4$ (1.65 ml, 15.0 mmol) at −78°C. The reaction mixture was stirred for 30 min, diluted with brine (30 ml) and water (30 ml), and extracted with CH_2Cl_2 (5×50 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure to provide crude alcohol **13** (2.862 g). To a mixture of the alcohol **13**, 4-methylmorpholine *N*-oxide (NMO) (1.81 g, 15.02 mmol), and molecular sieves 4 Å (2 g) in CH_2Cl_2–MeCN (10:1, 55 ml) was added tetrapropylammonium perruthenate (TPAP) (0.07 g, 0.2 mmol) at 20°C. The reaction mixture was stirred for 2 h and then subjected directly to flash chromatography (silica gel, ether) to give ketone **14** (2.095 g). To a solution of 3-butynyl *tert*-butyldiphenylsilyl ether (6.18 g, 20.02 mmol) in THF (40 ml) was added BuLi (12.5 ml, 1.60 M in hexane, 20.0 mmol) dropwise at −78°C. The mixture was stirred at −78°C for 1 h and at 0°C for 30 min, and then cooled to −78°C again. To the mixture was added **14** in THF (10 ml) dropwise at −78°C. The reaction mixture was stirred for 20 min, diluted with brine (50 ml), and extracted with ether (3×100 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=5→EtOAc) provided **15** (2.387 g, 48% from **11**) as a colorless oil. **15**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.19–7.74 (15H, m), 4.60 (2H, s), 3.76 (2H, t, *J*=7.2 Hz), 3.45–3.59 (4H, m), 3.39 (3H, s), 2.50 (2H, t, *J*=7.2 Hz), 1.04 (9H, s); IR (film) ν_{max} 3464, 3072, 2932, 2860, 1474, 1456, 1430, 1110, 824, 738, 702, 614 cm^{-1}; LR-EIMS *m*/*z* 91 (bp, [C_7H_7]), 199 (87.7%, [Ph_2SiOH]), 337 (43.0%, [TBDPSOC$_5$H$_6$O]), 459 (3.8%, [M−C_2H_7O]); HR-EIMS calcd for $C_{29}H_{35}O_3Si$ [M−C_2H_7O]: 459.2355, found: 459.2361.

***tert*-Butyldiphenylsilyl 5,6-dihydroxy-5-methoxymethylhexyl ether (16a).** A mixture of **15** (844.2 mg, 1.686 mmol) and 10% Pd/C (100 mg) in MeOH (15 ml) was stirred at 20°C for 8–47 h under a hydrogen atmosphere, and then the catalyst was removed by filtration through Celite. Since the benzyl group of **15** resisted hydrogenolysis and the catalyst lost its activity gradually during the reaction, it was necessary for completion of the reaction to repeat the above operation for three times. The filtrate was concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=10→0.5) provided diol **16a** (491.1 mg, 70%) as a colorless oil and recovered **15** (185.0 mg, 22%). **16a**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.30–7.74 (10H, m), 3.66 (2H, t, *J*=6.2 Hz), 3.58 (2H, *J*=4.8 Hz), 3.32–3.50 (2H, m), 3.37 (3H, s), 2.67 (1H, s), 2.35 (1H, dd, *J*=4.8, 7.7 Hz), 1.36–1.49 (6H, m), 1.04 (9H, s); IR (film) ν_{max} 3420, 3072, 2936, 2896, 2860, 1474, 1464, 1430, 1112, 1062, 1008, 972, 822, 748, 702, 688, 612 cm^{-1}; LR-EIMS *m*/*z* 199 (bp, [Ph_2SiOH]), 371 (6.6%, [M−CH_2OCH_3]), 385 (6.6%, [M−CH_2OH]), 417 (0.2%, [M+H]); HR-EIMS calcd for $C_{24}H_{37}O_4Si$ [M+H]: 417.2461, found: 417.2446.

Methyl 6-(*tert*-butyldiphenylsilyloxy)hexanoate (19). To a solution of sodium methoxide in methanol, prepared from sodium (1.037 g, 45.12 mmol) and methanol (90 ml), was added ϵ-caprolactone (**17**) (5 ml, 45.12 mmol) at 0°C. The mixture was stirred at 20°C for 40 min and then cooled to 0°C. To the mixture was added 1 M aqueous HCl (90 ml) and the mixture was stirred for 20 min and extracted with ether (200 ml). The organic layer was washed with water (50 ml) and brine (50 ml), dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure to give crude methyl 6-hydroxyhexanoate (**18**) (6.737 g). The alcohol **18**, imidazole (6.758 g, 99.27 mmol), and TBDPSCl (12.9 ml, 49.6 mmol) were dissolved in DMF (7 ml) and the mixture was stirred at 20°C for 2 h. Then, the mixture was diluted with saturated aqueous $NaHCO_3$ (35 ml) and extracted with ether (3×150 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=5) provided **19** (14.901 g, 86% from ϵ-caprolactone) as a colorless oil. **19**: ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.30–7.71 (10H, m), 3.66 (3H, s), 3.61–3.69 (2H, m), 2.29 (2H, t, *J*=7.5 Hz), 1.30–1.69 (6H, m), 1.04 (9H, s); IR (film) ν_{max} 2936, 2860, 1740, 1430, 1196, 1168, 1112, 824, 740, 704, 688, 614 cm^{-1}; LR-EIMS *m*/*z* 183 (21.2%), 213 (78.4%), 327 (bp), 328 (27.9%), 353 (M−OMe, 8.3%), 383 (M, 0.09%); HR-EIMS calcd for $C_{22}H_{29}O_2Si$ [M−OMe]: 353.1937, found: 353.1922.

Methyl (2*S,1′*R**)-6-(*tert*-butyldiphenylsilyloxy)-2-(1′-hydroxyethyl)hexanoate (20).** To a solution of **19**

(1.94 g, 5.05 mmol) and *i*-Pr_2NEt (1.94 ml, 11.1 mmol) in CH_2Cl_2 (25 ml) was added Bu_2BOTf (10.1 ml, 1.0 M in CH_2Cl_2, 10.1 mmol) dropwise at −78°C, and the mixture was stirred for 30 min. Then, a solution of acetaldehyde (0.565 ml, 10.1 mmol) in CH_2Cl_2 (20 ml) was added dropwise, and the mixture was stirred for 1.5 h. Phosphate buffer (pH 7, 60 ml) and MeOH (120 ml) were added to the stirred mixture at −78°C and then 36% aqueous H_2O_2 (30 ml) and MeOH (60 ml) were added. The mixture was stirred at 0°C for 1 h and then concentrated to the residue, which was diluted with water (100 ml) and extracted with ether (3×200 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=2) provided **20** (1.896 g, 88% from **19**, *syn*/*anti*=96:4) as a colorless oil and recovered **19** (453.0 mg, 23%). **20**: ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.31–7.22 (10H, m), 3.98 (1H, dq, *J*=4.6, 6.6 Hz), 3.69 (3H, s), 3.65 (2H, t, *J*=6.5 Hz), 2.41 (1H, dt, *J*=4.6, 9.9 Hz), 2.31 (1H, d, *J*=4.6 Hz), 1.22–1.81 (6H, m), 1.18 (3H, d, *J*=6.6 Hz), 1.04 (9H, s); IR (film) ν_{max} 3460, 2936, 2860, 1738, 1430, 1200, 1166, 1112, 824, 740, 704, 688, 614 cm^{-1}; LR-EIMS *m*/*z* 95 (48.5%), 199 (bp), 213 (47.4%), 293 (91.1%), 295 (36.3%), 339 (32.0%), 371 (27.7%), 397 (M−OMe 4.7%), 429 (M+H, 0.14%); HR-EIMS calcd for $C_{24}H_{33}O_3Si$ [M−OMe]: 397.2199, found: 397.2207.

(*E*)-2-[4-(*tert*-Butyldiphenylsilyloxy)butyl]-2-butenol (21). A mixture of **20** (2.040 g, 4.764 mmol), Et_3N (1.99 ml, 14.3 mmol), and MsCl (0.55 ml, 7.15 mmol) in CH_2Cl_2 (20 ml) was stirred at 0°C for 2 h. Then, the mixture was diluted with saturated aqueous $NaHCO_3$ (40 ml) and extracted with CH_2Cl_2 (3×100 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=3) provided methyl (2*S**,1′*R**)-6-(*tert*-butyldiphenylsilyloxy)-2-(1′-methanesulfonyloxyethyl)hexanoate (**20-1**) (2.333 g, 97%) as a pale yellow oil. **20-1**: ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.31–7.76 (10H, m), 4.92 (1H, qn, *J*=6.6 Hz), 3.70 (3H, s), 3.64 (2H, t, *J*=6.1 Hz), 3.00 (3H, s), 2.65 (1H, ddd, *J*=3.9, 6.6, 10.4 Hz), 1.44 (3H, d, *J*=6.6 Hz), 1.19–1.80 (6H, m), 1.04 (9H, s); IR (film) ν_{max} 2936, 2860, 1740, 1430, 1388, 1360, 1202, 1178, 1112, 974, 914, 822, 742, 704, 688, 614 cm^{-1}; LR-EIMS *m*/*z* 95 (47.0%), 213 (51.5%), 277 (33.0%), 353 (bp), 354 (27.8%), 475 (M−OMe, 1.88%); HR-EIMS calcd for $C_{25}H_{35}O_5SiS$ [M−OMe]: 475.1974, found: 475.1977. Next, a mixture of **20-1** (2.437 g, 4.810 mmol) and DBU (2.45 ml, 16.36 mmol) in CH_2Cl_2 (12 ml) was stirred at 20°C for 15 h. Then, the mixture was diluted with 0.5 M aqueous HCl (50 ml) and extracted with CH_2Cl_2 (3×100 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=2) provided methyl (*E*)-2-[4-(*tert*-butyldiphenylsilyloxy)butyl]-2-butenoate (**20-2**) (1.847 g, 94%) as a colorless oil. **20-2**: ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.31–7.73 (10H, m), 6.85 (1H, q, *J*=7.3 Hz), 3.71 (3H, s), 3.66 (2H, t, *J*=6.0 Hz), 2.30 (2H, t, *J*=7.5 Hz), 1.77 (3H, d, *J*=7.3 Hz), 1.17–1.66 (4H, m), 1.04 (9H, s); IR (film) ν_{max} 2948, 2860, 1716, 1430, 1280, 1258, 1192, 1134, 1112, 742, 704 cm^{-1}; LR-EIMS *m*/*z* 181 (31.1%), 213 (63.9%), 353 (bp), 379 (M−OMe, 2.95%); HR-EIMS calcd for $C_{24}H_{31}O_2Si$ [M−OMe]: 379.2093, found: 379.2100. To a solution of **20-2** (1.471 g, 3.582 mmol) in CH_2Cl_2 (20 ml) was added DIBAH (9.63 ml, 0.93 M in hexane, 8.96 mmol) at −78°C, and the mixture was stirred for 2.5 h. MeOH (6 ml) was added dropwise at −78°C and then saturated aqueous potassium sodium tartrate (10 ml) was added at 20°C. The mixture was stirred for 1 h and extracted with EtOAc (3×100 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=2) provided **21** (1.274 g, 93%) as a colorless oil. **21**: ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.30–7.74 (10H, m), 5.51 (1H, q, *J*=6.6 Hz), 4.01 (2H, t, *J*=6.1 Hz), 2.10 (2H, t, *J*=7.4 Hz), 1.61 (3H, d, *J*=6.6 Hz), 1.13–1.58 (4H, m), 1.04 (9H, s); IR (film) ν_{max} 3336, 3072, 3052, 2936, 2860, 1474, 1464, 1430, 1392, 1106, 1028, 998, 824, 740, 702, 686, 614 cm^{-1}; LR-EIMS *m*/*z* 67 (53.0%), 81 (20.2%), 109 (bp), 199 (62.1%), 325 (M−*t*-Bu, 1.61%); HR-EIMS calcd for $C_{20}H_{25}O_2Si$ [M−*t*-Bu]: 325.1624, found: 325.1640.

(*Z*)-2-[4-(*tert*-Butyldiphenylsilyloxy)butyl]-2-butenol (22). A mixture of **20** (1.510 g, 3.526 mmol), DCC (873.0 g, 4.231 mmol), CuCl (453.8 mg, 4.584 mmol), and molecular sieves 4 Å (1.0 g) in benzene (36 ml) was refluxed for 14 h. The mixture was cooled to room temperature and filtered through Celite. Brine (50 ml) was added to the filtrate, and the mixture was extracted with EtOAc (3×100 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=5) provided methyl (*Z*)-2-[4-(*tert*-butyldiphenylsilyloxy)butyl]-2-butenoate (**20-3**) (1.395 g, 96%) as a colorless oil. **20-3**: ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.32–7.73 (10H, m), 5.94 (1H, q, *J*=6.9 Hz), 3.72 (3H, s), 3.65 (2H, t, *J*=6.1 Hz), 2.23 (2H, t, *J*=7.0 Hz), 1.94 (3H, d, *J*=6.9 Hz), 1.15–1.83 (4H, m), 1.04 (9H, s); IR (film) ν_{max} 2936, 2860, 2120, 1722, 1430, 1256, 1234, 1192, 1148, 1112, 824, 740, 702, 614 cm^{-1}; LR-EIMS *m*/*z* 183 (21.6%), 213 (65.2), 353 (M−*t*-Bu, bp); HR-EIMS calcd for $C_{21}H_{25}O_3Si$ [M−*t*-Bu]: 353.1473, found: 353.1560. To a solution of **20-3** (1.233 g, 3.003 mmol) in CH_2Cl_2 (20 ml) was added DIBAH (8.07 ml, 0.93 M in hexane, 7.51 mmol) at −78°C, and the mixture was stirred for 75 min. MeOH (7 ml) was added dropwise at −78°C and then saturated aqueous potassium sodium tartrate (80 ml) was added at 20°C. The mixture was stirred for 2 h and extracted with EtOAc (3×150 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=5) provided **22** (1.035 g, 90%) as a colorless oil. **22**: ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.33–7.74 (10H, m), 5.37 (1H, q, *J*=6.9 Hz), 4.14 (2H, d, *J*=4.6 Hz), 3.67 (2H, t, *J*=6.3 Hz), 2.09 (2H, t, *J*=7.3 Hz), 1.68 (3H, d, *J*=6.9 Hz), 0.85–1.62 (4H, m), 1.04 (9H, s); IR (film) ν_{max} 3328, 3072, 3052, 2940, 2860, 1474, 1464, 1430, 1112, 740, 702, 688, 614 cm^{-1}; LR-EIMS *m*/*z* 67 (16.6%), 109 (bp), 139 (17.4%), 199 (98.0%), 325 (M−*t*-Bu, 5.09%); HR-EIMS calcd for $C_{20}H_{25}O_2Si$ [M−*t*-Bu]: 325.1624, found: 325.1622.

(2*R,3*R**)-2-[4-(*tert*-Butyldiphenylsilyloxy)butyl]-1-methoxybutane-2,3-diol (16b).** A mixture of **21** (1.124 g, 2.938 mmol), MeI (0.55 ml, 8.8 mmol), and *t*-BuOK (659.4 mg, 5.88 mmol) in THF (20 ml) was stirred at 20°C for 30 min. The reaction was quenched with saturated aqueous $NaHCO_3$ (50 ml). After extractive work up (AcOEt×3), the combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=5) provided (*E*)-2-[4-(*tert*-butyldiphenylsilyloxy)butyl]-1-methoxy-2-butene (**21-1**) (1.142 g, 98%) as a pale yellow oil. **21-1**: ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.31–7.74 (10H, m), 5.50 (1H, q, *J*=6.5 Hz), 3.79 (2H, s), 3.67 (2H, t, *J*=6.1 Hz), 3.26 (3H, s), 2.07 (2H, t, *J*=7.6 Hz), 1.62 (3H, d, *J*=6.5 Hz), 1.19–1.58 (4H, m), 1.04 (9H, s); IR (film) ν_{max} 2936, 2860, 2820, 1430, 1112, 824, 740, 702, 614 cm^{-1}; LR-EIMS *m*/*z* 109 (bp), 339 (23.6%, [M−*t*-Bu]), 396 (0.3%, [M]); HR-EIMS calcd for $C_{25}H_{36}O_2Si$ [M]: 396.2485, found: 396.2490. Next, a mixture of **21-1** (1.199 g, 3.024 mmol), NMO (0.80 g, 6.80 mmol), and OsO_4 (5 mg/ml in *t*-BuOH, 7.57 ml, 0.151 mmol) in 1,4-dioxane−H_2O (2.8:1, 47.5 ml) was stirred at 20°C for 1 h. Then, the mixture was treated with saturated aqueous $Na_2S_2O_3$ (80 ml) and stirred for 20 min. After extractive workup (EtOAc×3), the combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=2) provided diol **16b** (1.332 g, ~100%) as a pale yellow oil. **16b**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.63–7.69 (4H, m), 7.33–7.46 (6H, m), 3.84 (1H, dq, *J*=3.5, 6.4 Hz), 3.67 (2H, t, *J*=6.3 Hz), 3.46 (1H, d, *J*=9.4 Hz), 3.40 (1H, d, *J*=9.4 Hz), 3.37 (3H, s), 2.62 (1H, s), 1.25–1.65 (6H, m), 1.12 (3H, d, *J*=6.4 Hz), 1.05 (9H, s); IR (film) ν_{max} 3456, 2396, 2864, 1430, 1112, 740, 702 cm^{-1}; LR-EIMS *m*/*z* 199 (bp, [Ph_2SiOH]), 385 (22.1%, [M−CH_2OCH_3]); HR-EIMS calcd for $C_{23}H_{33}O_3Si$ [M−CH_2OCH_3]: 385.2199, found: 385.2195.

(2*R,3*S**)-2-[4-(*tert*-Butyldiphenylsilyloxy)butyl]-1-methoxybutane-2,3-diol (16c)** was prepared from **22** via (*Z*)-2-[4-(*tert*-butyldiphenylsilyloxy)butyl]-1-methoxy-2-butene (**22-1**) in 89% yield (**22→22-1**: 92%, **22-1→16c**: 97%) similarly as described for **16b**. **22-1**: a colorless oil; ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.31–7.75 (10H, m), 5.44 (1H, q, *J*=6.9 Hz), 3.91 (2H, s), 3.66 (2H, t, *J*=6.3 Hz), 3.28 (3H, s), 2.05 (2H, brt, *J*=7.1 Hz), 1.66 (3H, d, *J*=6.9 Hz), 1.20–1.61 (4H, m), 1.04 (9H, s); IR (film) ν_{max} 2932, 2896, 2860, 1430, 1112, 824, 740, 702, 614 cm^{-1}; LR-EIMS *m*/*z* 109 (bp), 339 (21.6%, [M−*t*-Bu]), 396 (0.4%, [M]); HR-EIMS calcd for $C_{25}H_{36}O_2Si$ [M]: 396.2485, found: 396.2494. **16c**: a colorless oil; ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.32–7.72 (10H, m), 3.60–3.72 (1H, m), 3.66 (2H, t, *J*=6.6 Hz), 3.56 (1H, d, *J*=9.6 Hz), 3.37 (3H, s), 3.33 (1H, d, *J*=9.6 Hz), 1.33–1.65 (6H, m), 1.18 (3H, d, *J*=6.6 Hz), 1.04 (9H, s); IR (film) ν_{max} 3456, 2936, 2864, 1430, 1112, 740, 702 cm^{-1}; LR-EIMS *m*/*z* 199 (bp, [Ph_2SiOH]), 385 (29.3%, [M−CH_2OCH_3]); HR-EIMS calcd for $C_{23}H_{33}O_3Si$ [M−CH_2OCH_3]: 385.2199, found: 385.2196.

(2*R,3*R**)-2-[4-(*tert*-Butyldiphenylsilyloxy)butyl]-1-benzyloxybutane-2,3-diol (16d).** A mixture of **21** (1.660 g, 4.337 mmol), BnBr (0.77 ml, 6.5 mmol), TBAI (1.6 g, 4.6 mmol), and NaH (60% in mineral oil, 312.3 mg, 7.81 mmol) in THF (50 ml) was stirred at 20°C for 1 h. The reaction was quenched with saturated aqueous $NaHCO_3$ (50 ml). After extractive work up (AcOEt×3), the combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=5) provided an inseparable mixture of (*E*)-1-benzyloxy-2-[4-(*tert*-butyldiphenylsilyloxy)butyl]-2-butene (**21-2**) and BnBr (2.867 g) as well as recovered **21** (215.8 mg, 13%). **21-2**: ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.22–7.70 (15H, m), 5.54 (1H, q, *J*=6.8 Hz), 4.43 (2H, s), 3.90 (2H, s), 3.66 (2H, t, *J*=6.2 Hz), 2.11 (2H, t, *J*=7.6 Hz), 1.62 (3H, d, *J*=6.8 Hz), 1.39–1.60 (4H, m), 1.04 (9H, s). The above mixture of **21-2** and BnBr, NMO (1.21 g, 10.33 mmol), and OsO_4 (5 mg/ml in *t*-BuOH, 11.7 ml, 0.23 mmol) was dissolved in 1,4-dioxane−water (3:1, 60 ml) and the mixture was stirred at 20°C for 3 h. Then, the mixture was treated with saturated aqueous $Na_2S_2O_3$ (50 ml) and stirred for 30 min. After extractive workup (EtOAc×3), the combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=5→2) provided diol **16d** (1.620 g, 70% from **21**) as a colorless oil. **16d**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.60–7.69 (4H, m), 7.27–7.46 (11H, m), 4.56 (1H, d, *J*=11.8 Hz), 4.49 (1H, d, *J*=11.8 Hz), 2.90 (1H, d, *J*=3.5 Hz), 2.63 (1H, s), 1.29–1.64 (6H, m), 1.10 (3H, d, *J*=6.4 Hz), 1.04 (9H, s); IR (film) ν_{max} 3456, 2936, 2860, 1430, 1112, 738, 700, 614 cm^{-1}; LR-EIMS *m*/*z* 91 (bp), 199 (29.5%), 461 (M−CH_3CHOH, 1.58%); HR-EIMS calcd for $C_{29}H_{37}O_3Si$ [M−CH_3CHOH]: 461.2512, found: 461.2487.

(2*R,3*S**)-2-[4-(*tert*-Butyldiphenylsilyloxy)butyl]-1-benzyloxybutane-2,3-diol (16e)** was prepared from **22** via (*Z*)-1-benzyloxy-2-[4-(*tert*-butyldiphenylsilyloxy)butyl]-2-butene (**22-2**) in 78% yield similarly as described for **16d**. **22-2**: a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.61–7.70 (6H, m), 7.20–7.45 (9H, m), 5.44 (1H, q, *J*=6.8 Hz), 4.58 (1H, d, *J*=9.0 Hz), 4.45 (1H, d, *J*=9.0 Hz), 4.00 (2H, s), 3.65 (2H, t, *J*=6.1 Hz), 2.09 (2H, t, *J*=6.6 Hz), 1.62 (3H, d, *J*=6.8 Hz), 1.40–1.59 (4H, m), 1.04 (9H, s). **16e**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.60–7.71 (6H, m), 7.27–7.47 (9H, m), 4.14 (1H, d, *J*=7.2 Hz), 4.09 (1H, d, *J*=7.2 Hz), 3.68 (1H, q, *J*=6.6 Hz), 3.65 (2H, t, *J*=6.4 Hz), 3.63 (1H, d, *J*=9.4 Hz), 3.43 (1H, d, *J*=9.4 Hz), 3.12 (1H, s), 1.30–1.60 (6H, m), 1.15 (3H, d, *J*=6.6 Hz), 1.04 (9H, s); IR (film) ν_{max} 3448, 2936, 2960, 1430, 1112, 740, 702, 612 cm^{-1}; LR-EIMS *m*/*z* 91 (bp), 199 (34.0%), 461 (M−CH_3CHOH, 2.69%); HR-EIMS calcd for $C_{29}H_{37}O_3Si$ [M−CH_3CHOH]: 461.2512, found: 461.2504.

***tert*-Butyldiphenylsilyl 5-hexen-1-yl ether (24).** A mixture of 5-hexenol (**23**) (1.1 ml, 9.16 mmol), imidazole (1.277 g, 18.76 mmol), and TBDPSCl (2.4 ml, 9.23 mmol) in DMF (0.5 ml) was stirred at 20°C for 40 min. The reaction mixture was purified directly by flash chromatography (silica gel, hexane/EtOAc=10) to provide **24** as a colorless oil (2.973 g, 94%). **24**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.63–7.70 (4H, m), 7.33–7.46 (6H, m), 5.79 (1H, tdd, *J*=6.6, 10.1, 17.1 Hz), 4.90–5.03 (2H, m), 3.66 (2H, t,

J=6.2 Hz), 2.04 (2H, brq, J=7.1 Hz), 1.40–1.63 (4H, m), 1.05 (9H, s); IR (film) ν_{max} 3072, 3051, 2999, 2931, 2986, 2858, 1472, 1463, 1428, 1389, 1112, 1007, 998, 910, 823, 741, 724, 701, 688, 622, 614 cm^{-1}; LR-EIMS m/z 199 (54.7%, $C_{12}H_{11}OSi$), 281 (bp, [M−t-Bu]); HR-EIMS calcd for $C_{18}H_{21}OSi$ [M−t-Bu]: 281.1362, found: 281.1313.

***tert*-Butyldiphenylsilyl 5-hydroxyhexyl ether (25).** A mixture of **24** (2.917 g, 8.616 mmol) and *m*-CPBA (75% w/w, 2.447 g, 10.635 mmol) in CH_2Cl_2 (30 ml) was stirred at 20°C for 3 h. The mixture was diluted with hexane (50 ml), washed with 1 M aqueous NaOH (2×20 ml), dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=10) provided *tert*-butyldiphenylsilyl 5,6-epoxyhexyl ether (**24-1**) as a colorless oil (2.866 g, 94%). **24-1**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.63–7.70 (4H, m), 7.33–7.46 (6H, m), 3.67 (2H, t, J=6.1 Hz), 2.85–2.93 (1H, m), 2.73 (1H, dd, J=4.0, 5.1 Hz), 2.44 (1H, dd, J=2.8, 5.1 Hz), 1.47–1.68 (6H, m), 1.05 (9H, s); IR (film) ν_{max} 3071, 3048, 3014, 2998, 2931, 2858, 1472, 1462, 1428, 1389, 1112, 1008, 998, 823, 741, 702, 688, 622, 614 cm^{-1}; LR-EIMS m/z 199 (bp, $C_{12}H_{11}OSi$), 297 (69.9%, [M−t-Bu]); HR-EIMS calcd for $C_{18}H_{21}O_2Si$ [M−t-Bu]: 297.1311, found: 297.1319. To a stirred solution of $LiEt_3BH$ (1.0 M in THF, 12.1 ml, 12.1 mmol) in THF (12 ml) was added **24-1** (2.858 g, 8.060 mmol) in THF (15 ml) dropwise at 0°C. After 1 h, the mixture was diluted with brine (20 ml) and extracted with ether (3×10 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=5) provided **25** as a colorless oil (2.813 g 98%). **25**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.63–7.70 (4H, m), 7.33–7.46 (6H, m), 3.70–3.84 (1H, m), 3.67 (2H, t, J=6.3 Hz), 1.64–1.32 (6H, m), 1.27 (1H, d, J=4.6 Hz, OH), 1.17 (3H, d, J=6.1 Hz), 1.05 (9H, s); IR (film) ν_{max} 3346, 3071, 3049, 2960, 2931, 2858, 1472, 1462, 1428, 1389, 1112, 823, 741, 701, 688, 622, 614 cm^{-1}; LR-EIMS m/z 199 (bp, $C_{12}H_{11}OSi$), 299 (33.1%, [M−t-Bu]); HR-EIMS calcd for $C_{18}H_{23}O_2Si$ [M−t-Bu]: 299.1467, found: 299.1457.

***tert*-Butyldiphenylsilyl 5-methyl-5-hexen-1-yl ether (26).** To oxalyl chloride (1.03 ml, 11.8 mmol) in CH_2Cl_2 (60 ml) was added DMSO (1.34 ml, 18.9 mmol) in CH_2Cl_2 (10 ml) dropwise at −78°C and the reaction mixture was stirred for 10 min. Then, **25** (2.807 mg, 7.873 mmol) in CH_2Cl_2 (15 ml) was added dropwise at −78°C. The mixture was stirred for 30 min. Et_3N (5.5 ml, 39.5 mmol) was added dropwise at −78°C and the mixture was warmed to 0°C and stirred for 1 h. Then, the mixture was treated with water (50 ml), diluted with hexane (100 ml), and washed with 1 M aqueous HCl (2×50 ml), saturated aqueous $NaHCO_3$ (50 ml), and brine (50 ml). The organic layer was dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=10⟶3) provided *tert*-butyldiphenylsilyl 5-oxohexyl ether (**25-1**) (2.113 g, 76%) as a colorless oil. **25-1**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.62–7.69 (4H, m), 7.33–7.46 (6H, m), 3.66 (2H, t, J=6.1 Hz), 2.40 (2H, t, J=7.2 Hz), 2.11 (3H, s), 1.49–1.73 (4H, m), 1.04 (9H, s); IR (film) ν_{max} 3071, 3049, 3014, 2999, 2954, 2931, 2894, 2858, 1718, 1472, 1463, 1428, 1410, 1389, 1361, 1189, 1162, 1112, 1029, 1008, 998, 823, 741, 702, 688, 622, 614 cm^{-1}; LR-EIMS m/z 199 (bp, $C_{12}H_{11}OSi$), 297 (79.2%, [M−t-Bu]); HR-EIMS calcd for $C_{18}H_{21}O_2Si$ [M−t-Bu]: 297.1311, found: 297.1315. To Cp_2TiCl_2 (1.062 g, 4.265 mmol) was added $AlMe_3$ (2.0 M in toluene, 4.23 ml, 8.46 mmol) dropwise at 20°C, and the mixture was stirred for 91 h. Then, **25-1** (998.7 mg, 2.820 mmol) in THF (8 ml) was added at 20°C. After 10 min, 2 M aqueous NaOH (ca. 1 ml) was added dropwise until the evolution of CH_4 ceased. Then, anhydrous $MgSO_4$ was added. The mixture was filtered through Celite and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=10) provided **26** (918.9 mg, 92%) as a pale yellow oil. **26**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.64–7.70 (4H, m), 7.33–7.46 (6H, m), 4.69 (1H, brs), 4.64 (1H, brs), 3.67 (2H, t, J=6.1 Hz), 1.99 (2H, brt, J=6.9 Hz), 1.70 (3H, s), 1.44–1.62 (4H, m), 1.05 (9H, s); IR (film) ν_{max} 3071, 3050, 3015, 2999, 2932, 2895, 2858, 1649, 1590, 1487, 1472, 1462, 1428, 1389, 1374, 1362, 1188, 1112, 1037, 1030, 1007, 998, 978, 887, 823, 766, 740, 723, 701, 688, 622, 614 cm^{-1}; LR-EIMS m/z 199 (45.0%, $C_{12}H_{11}OSi$), 295 (bp, [M−t-Bu]); HR-EIMS calcd for $C_{19}H_{23}OSi$ [M−t-Bu]: 295.1518, found: 295.1524.

6-(*tert*-Butyldiphenylsilyloxy)-2-methylhexane-1,2-diol (16f). To a mixture of **26** (914.0 mg, 2.592 mmol) and NMO (616.0 mg, 5.258 mmol) in 1,4-dioxane–H_2O (3:1, 24 ml) was added OsO_4 (0.02 M in *t*-BuOH, 6.6 ml, 0.13 mmol) at 20°C, and the mixture was stirred for 1.5 h. Then, the mixture was treated with saturated aqueous $Na_2S_2O_3$ (5 ml), stirred for 30 min, diluted with brine (15 ml), and extracted with EtOAc (3×15 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=1) provided **16f** (1.001 g, ~100%) as a colorless oil. **16f**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.64–7.70 (4H, m), 7.33–7.46 (6H, m), 3.68 (2H, t, J=6.3 Hz), 3.44 (1H, dd, J=5.9, 10.8 Hz), 3.39 (1H, dd, J=6.1, 10.8 Hz), 1.79 (1H, brt, J=6.0 Hz, OH), 1.71 (1H, s, OH), 1.53–1.63 (2H, m), 1.35–1.51 (4H, m), 1.15 (3H, s), 1.05 (9H, s); IR (film) ν_{max} 3386, 3071, 3049, 2932, 2858, 1472, 1463, 1428, 1389, 1362, 1112, 1060, 1008, 998, 823, 741, 701, 688, 622, 614 cm^{-1}; LR-EIMS m/z 199 (bp, $C_{12}H_{11}OSi$), 311 (33.9%, [M−$C_3H_7O_2$]), 371 (0.31%, [M−CH_3]), 387 (0.14%, [M+H]); HR-EIMS calcd for $C_{22}H_{31}O_3Si$ [M−CH_3]: 371.2042, found: 371.2027; calcd for $C_{23}H_{35}O_3Si$ [M+H]: 387.2355, found: 387.2324.

4-[4-(*tert*-Butyldiphenylsilyloxy)butyl]-2,2-dimethyl-4-methoxymethyl-1,3-dioxolane (27a). A mixture of **16a** (428.4 mg, 1.028 mmol), 2,2-dimethoxypropane (0.63 ml, 5.1 mmol), and PPTS (12.9 mg, 0.0513 mmol) in CH_2Cl_2 (15 ml) was stirred at 20°C for 1 h. The reaction was quenched with saturated aqueous $NaHCO_3$ (30 ml). After extractive work up (CH_2Cl_2×3), the combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=5) provided acetal **27a** (458.0 mg, 98%) as a

colorless oil. **27a**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.30–7.71 (10 H, m), 3.90 (1H, d, J=8.6 Hz), 3.71 (1H, d, J=8.6 Hz), 3.67 (2H, t, J=6.2 Hz), 3.36 (3H, s), 3.30 (2H, s), 1.40 (3H, s), 1.37 (3H, s), 1.16–1.68 (6H, m), 1.04 (9H, s); IR (film) ν_{max} 2988, 2936, 2896, 2864, 1430, 1214, 1114, 1056, 824, 702, 614 cm^{-1}; LR-EIMS *m/z* 309 (bp), 399 (36.2%, [M−*t*-Bu]), 411 (25.8%, [M−CH_2OCH_3]), 441 (21.7%, [M−CH_3]); HR-EIMS calcd for $C_{26}H_{37}O_4Si$ [M−CH_3]: 441.2461, found: 441.2464.

(4*R,5*R**)-2,2,5-Trimethyl-4-[4-(*tert*-butyldiphenylsilyloxy)butyl]-4-methoxymethyl-1,3-dioxolane (27b)** was prepared from **16b** in 89% yield similarly as described for **27a**. **27b**: a colorless oil; ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.31–7.73 (10H, m), 4.15 (1H, q, J=6.6 Hz), 3.67 (2H, t, J=6.3 Hz), 3.40 (1H, d, J=9.6 Hz), 3.28 (1H, d, J=9.6 Hz), 3.33 (3H, s), 1.41 (3H, s), 1.35 (3H, s), 1.15–1.63 (6H, m), 1.04 (9H, s); IR (film) ν_{max} 2936, 2864, 1114, 702 cm^{-1}; LR-EIMS *m/z* 213 (bp), 323 (31.5%), 355 (15.9%), 367 (8.8%), 413 (14.0%), 455 (9.8%, [M−CH_3]); HR-EIMS calcd for $C_{27}H_{39}O_4Si$ [M−CH_3]: 455.2617, found: 455.2604.

(4*R,5*S**)-2,2,5-Trimethyl-4-[4-(*tert*-butyldiphenylsilyloxy)butyl]-4-methoxymethyl-1,3-dioxolane (27c)** was prepared from **16c** in 81% yield similarly as described for **27a**. **27c**: a colorless oil; ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.31–7.76 (10H, m), 3.98 (1H, q, J=6.6 Hz), 3.67 (2H, d, J=6.1 Hz), 3.32 (1H, d, J=9.2 Hz), 3.31 (3H, s), 3.20 (1H, d, J=9.2 Hz), 1.46–1.82 (6H, m), 1.42 (3H, s), 1.33 (3H, s), 1.23 (2H, d, J=6.6 Hz), 1.04 (9H, s); IR (film) ν_{max} 2988, 2940, 2896, 2864, 1432, 1380, 1248, 1218, 1188, 1112, 1006, 702, 614 cm^{-1}; LR-EIMS *m/z* 213 (bp), 323 (79.5%), 355 (56.4%), 367 (43.9%), 413 (20.8%), 425 (15.0%), 455 (23.7%, [M−CH_3]); HR-EIMS calcd for $C_{27}H_{39}O_4Si$ [M−CH_3]: 455.2617, found: 455.2624.

(4*R,5*R**)-2,2,5-Trimethyl-4-[4-(*tert*-butyldiphenylsilyloxy)butyl]-4-benzyloxymethyl-1,3-dioxolane (27d)** was prepared from **16d** in 96% yield similarly as described for **27a**. **27d**: a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.59–7.70 (4H, m), 7.19–7.47 (11H, m), 4.55 (1H, d, J=12.2 Hz), 4.46 (1H, d, J=12.2 Hz), 4.19 (1H, q, J=6.6 Hz), 3.65 (2H, t, J=6.2 Hz), 3.49 (1H, d, J=9.7 Hz), 3.36 (1H, d, J=9.7 Hz), 1.18–1.64 (6H, m), 1.40 (3H, s), 1.35 (3H, s), 1.23 (3H, d, J=6.6 Hz), 1.04 (9H, s); IR (film) ν_{max} 3072, 2984, 2936, 2860, 1430, 1246, 1214, 1194, 1110, 702, 612 cm^{-1}; LR-EIMS *m/z* 91 (bp), 263 (87.7%), 531 (M−CH_3, 7.3%); HR-EIMS calcd for $C_{33}H_{43}O_4Si$ [M−CH_3]: 531.2931, found: 531.2961.

(4*R,5*S**)-2,2,5-Trimethyl-4-[4-(*tert*-butyldiphenylsilyloxy)butyl]-4-benzyloxymethyl-1,3-dioxolane (27e)** was prepared from **16e** in 96% yield similarly as described for **27a**. **27e**: a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.60–7.70 (6H, m), 7.21–7.46 (9H, s), 4.49 (2H, s), 3.97 (1H, q, J=6.4 Hz), 3.66 (2H, t, J=6.2 Hz), 3.40 (1H, d, J=9.3 Hz), 3.26 (1H, d, J=9.3 Hz), 1.42–1.80 (6H, m), 1.39 (3H, s), 1.33 (3H, s), 1.24 (3H, d, J=6.4 Hz), 1.04 (9H, s); IR (film) ν_{max} 2988, 2936, 2904, 2860, 1112, 700, 612 cm^{-1}; LR-EIMS *m/z* 91 (bp), 263 (68.5%), 531 (M−CH_3, 4.7%); HR-EIMS calcd for $C_{33}H_{43}O_4Si$ [M−CH_3]: 531.2931, found: 531.2923.

2,2,5-Trimethyl-5-[4-(*tert*-butyldiphenylsilyloxy)butyl]-1,3-dioxolane (27f) was prepared from **16f** in 96% yield similarly as described for **27a**. **27f**: a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.64–7.70 (4H, m), 7.33–7.46 (6H, m), 3.75 (1H, d, J=8.3 Hz), 3.68 (1H, d, J=8.3 Hz), 3.66 (1H, t, J=6.2 Hz), 1.34–1.63 (6H, m), 1.40 (3H, s), 1.36 (3H, s), 1.25 (3H, s), 1.04 (9H, s); IR (film) ν_{max} 3071, 3050, 2981, 2932, 2859, 1472, 1462, 1428, 1377, 1368, 1243, 1212, 1158, 1112, 1061, 1008, 998, 984, 862, 823, 808, 741, 702, 688, 614 cm^{-1}; LR-EIMS *m/z* 199 (73.8%, $C_{12}H_{11}OSi$), 311 (bp, [M−$C_6H_{11}O_2$]), 411 (6.9%, [M−CH_3]); HR-EIMS calcd for $C_{25}H_{35}O_3Si$ [M−CH_3]:411.2355, found: 411.2365.

2,2-Dimethyl-4-(4-hydroxybutyl)-4-methoxymethyl-1,3-dioxolane (28a). To a solution of **27a** (1.255 g, 2.75 mmol) in THF (20 ml) was added TBAF (6.04 ml, 1.0 M in THF, 6.04 mmol) at 0°C, and the mixture was stirred at 20°C for 1.5 h. Then, saturated $NaHCO_3$ (20 ml) and brine (20 ml) were added and the resulting mixture was extracted with ether (4×50 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=5→0.25) provided alcohol **28a** (588.0 mg, 98%) as a colorless oil. **28a**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 3.92 (1H, d, J=8.7 Hz), 3.73 (1H, d, J=8.7 Hz), 3.66 (2H, t, J=6.3 Hz), 3.37 (3H, s), 3.32 (2H, s), 1.40 (3H, s), 1.38 (3H, s), 1.19–1.74 (6H, m); IR (film) ν_{max} 3436, 2988, 2940, 2872, 1382, 1372, 1256, 1214, 1176, 1154, 1112, 1058 cm^{-1}; LR-EIMS *m/z* 115 (bp), 173 (41.2%, [M−CH_2OCH_3]), 203 (45.5%, [M−CH_3]); HR-EIMS calcd for $C_{10}H_{19}O_4$ [M−CH_3]: 203.1283, found: 203.1281.

(4*R,5*R**)-2,2,5-Trimethyl-4-(4-hydroxybutyl)-4-methoxymethyl-1,3-dioxolane (28b)** was prepared from **27b** in 92% yield similarly as described for **28a**. **28b**: a colorless oil; ^{1}H NMR (270 MHz, $CDCl_3$) δ 4.16 (1H, q, J=6.6 Hz), 3.60–3.72 (2H, m), 3.44 (1H, d, J=9.6 Hz), 3.28 (1H, d, J=9.6 Hz), 3.35 (3H, s), 1.16–1.66 (6H, m), 1.42 (3H, s), 1.36 (3H, s), 1.24 (3H, d, J=6.6 Hz); IR (film) ν_{max} 3440, 2988, 2940, 2872, 1380, 1372, 1248, 1216, 1190, 1112, 1032 cm^{-1}; LR-EIMS *m/z* 129 (bp), 157 (38.4%), 187 (26.1%), 217 (75.9%, [M−CH_3]); HR-EIMS calcd for $C_{11}H_{21}O_4$ [M−CH_3]: 217.1440, found: 217.1427.

(4*R,5*S**)-2,2,5-Trimethyl-4-(4-hydroxybutyl)-4-methoxymethyl-1,3-dioxolane (28c)** was prepared from **27c** in ~100% yield similarly as described for **28a**. **28c**: a colorless oil; ^{1}H NMR (270 MHz, $CDCl_3$) δ 3.98 (1H, q, J=6.6 Hz), 3.67 (2H, t, J=6.3 Hz), 3.34 (1H, d, J=9.6 Hz), 3.32 (3H, s), 3.22 (1H, d, J=9.6 Hz), 1.44–1.84 (6H, m), 1.42 (3H, s), 1.35 (3H, s), 1.24 (3H, d, J=6.6 Hz); IR (film) ν_{max} 3432, 2988, 2940, 1460, 1380, 1250, 1218, 1186, 1154, 1112, 1072, 1034, 1006, 860 cm^{-1}; LR-EIMS *m/z* 129 (bp), 157 (9.8%), 187 (24.8%), 217 (25.4%, [M−CH_3]); HR-EIMS calcd for $C_{11}H_{21}O_4$ [M−CH_3]: 217.1440, found: 217.1450.

(4*R,5*R**)-2,2,5-Trimethyl-4-(4-hydroxybutyl)-4-benzyloxymethyl-1,3-dioxolane (28d)** was prepared from **27d** in ~100% yield similarly as described for **28a**. **28d**: a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.27–7.40 (5H, m), 4.57 (1H, d, J=12.1 Hz), 4.47 (1H, d, J=12.1 Hz), 4.19 (1H,

q, J=6.4 Hz), 3.64 (2H, brm), 3.53 (1H, d, J=9.5 Hz), 3.36 (1H, d, J=9.5 Hz), 1.44–1.65 (6H, m), 1.42 (3H, s), 1.35 (3H, s), 1.25 (3H, d, J=6.4 Hz); IR (film) ν_{max} 3432, 2988, 2940, 2868, 1380, 1370, 1246, 1218, 1192, 1104, 1030 cm^{-1}; LR-EIMS m/z 91 (bp), 129 (54.9%), 293 (M−CH_3, 8.8%); HR-EIMS calcd for $C_{17}H_{25}O_4$ [M−CH_3]: 293.1753, found: 293.1764.

(4*R,5*S**)-2,2,5-Trimethyl-4-(4-hydroxybutyl)-4-benzyloxymethyl-1,3-dioxolane (28e)** was prepared from **27e** in 92% yield similarly as described for **28a**. **28e**: a colorless oil; ^{1}H NMR (270 MHz, $CDCl_3$) δ 7.24–7.38 (5H, m), 4.45–4.46 (2H, m), 3.98 (1H, q, J=6.4 Hz), 3.64 (2H, m), 3.42 (1H, d, J=9.2 Hz), 3.28 (1H, d, J=9.2 Hz), 1.39 (3H, s), 1.34 (3H, s), 1.26 (3H, d, J=6.4 Hz), 1.18–1.88 (6H, m); IR (film) ν_{max} 3440, 2988, 2940, 2868, 1456, 1380, 1248, 1216, 1190, 1102, 1030, 1008, 736, 698 cm^{-1}; LR-EIMS m/z 91 (bp), 129 (81.6%), 293 (M−CH_3, 15.1%); HR-EIMS calcd for $C_{17}H_{25}O_4$ [M−CH_3]: 293.1753, found: 293.1722.

2,2,5-Trimethyl-5-(4-hydroxybutyl)-1,3-dioxolane (28f). A mixture of **27f** (1.040 g, 2.438 mmol) and TBAF (1.0 M in THF, 2.9 ml, 2.9 mmol) was stirred at 20°C for 50 min and then concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/ether=2→ether, then silica gel, hexane/EtOAc=1) provided **28f** (457.0 mg, ~100%) as a colorless oil. **28f**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 3.78 (1H, d, J=8.3 Hz), 3.70 (1H, d, J=8.3 Hz), 3.66 (1H, dt, J=5.5, 6.2 Hz), 1.34–1.68 (6H, m), 1.40 (3H, brs), 1.38 (3H, brs), 1.28 (3H, s), 1.27 (1H, t, J=5.5 Hz, OH); IR (film) ν_{max} 3426, 2983, 2938, 2867, 1459, 1377, 1250, 1212, 1161, 1117, 1060, 984, 941, 912, 860, 807 cm^{-1}; LR-EIMS m/z 95 (bp), 115 (87.9%, $C_6H_{11}O_2$), 173 (68.7%, [M−CH_3]); HR-EIMS calcd for $C_9H_{17}O_3$ [M−CH_3]: 173.1178, found: 173.1192.

4-(2,2-Dimethyl-4-methoxymethyl-1,3-dioxolan-4-yl)-butanal (29a). To a mixture of the alcohol **28a** (588.0 mg, 2.69 mmol), NMO (0.49 g, 4.04 mmol), molecular sieves 4 Å (0.6 g), and acetonitrile (1.5 ml) in CH_2Cl_2 (15 ml) was added TPAP (0.05 g, 0.13 mmol) at 20°C. The reaction mixture was stirred for 1.5 h and then purified directly by flash chromatography (silica gel, ether) to give ketone **29a** (496.9 mg, 85%) as a colorless oil. **29a**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 9.77 (1H, t, J=1.6 Hz), 3.93 (1H, d, J=8.7 Hz), 3.73 (1H, d, J=8.7 Hz), 3.36 (3H, s), 3.32 (2H, s), 2.48 (2H, dt, J=1.6, 7.0 Hz), 1.52–1.83 (4H, m), 1.40 (3H, s), 1.38 (3H, s); IR (film) ν_{max} 2988, 2936, 2884, 2828, 1730, 1382, 1372, 1254, 1214, 1114, 1058 cm^{-1}; LR-EIMS m/z 171 (bp), 201 (48.9%, [M−CH_3]); HR-EIMS calcd for $C_{10}H_{17}O_4$ [M−CH_3]: 201.1127, found: 201.1120.

(4′*R,5′*R**)-4-(2′,2′,5′-Trimethyl-4′-methoxymethyl-1′,3′-dioxolan-4′-yl)butanal (29b).** To oxalyl chloride (0.48 ml, 5.5 mmol) in CH_2Cl_2 (30 ml) was added DMSO (0.49 ml, 6.9 mmol) in CH_2Cl_2 (2 ml) dropwise at −78°C and the reaction mixture was stirred for 10 min. Then, **28b** (642.0 mg, 2.763 mmol) in CH_2Cl_2 (12 ml) was added dropwise at −78°C. The mixture was warmed to −45°C and stirred for 30 min. Et_3N (254 μl, 1.82 mmol) was added dropwise at −45°C and the mixture was warmed to 0°C and stirred for 20 min. Saturated aqueous NH_4Cl (70 ml) was added and the mixture was extracted with EtOAc (3×150 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the resultant residue by flash chromatography (silica gel, hexane/EtOAc=3) provided **29b** (570.3 mg, 90%) as a brownish yellow oil. **29b**: ^{1}H NMR (270 MHz, $CDCl_3$) δ 9.78 (1H, brs), 4.15 (1H, q, J=6.3 Hz), 3.45 (1H, d, J=9.6 Hz), 3.29 (1H, d, J=9.6 Hz), 3.35 (3H, s), 2.47 (2H, brt, J=6.8 Hz), 1.12–1.95 (4H, m), 1.43 (3H, s), 1.36 (3H, s), 1.23 (3H, d, J=6.3 Hz); IR (film) ν_{max} 2988, 2940, 2888, 1730, 1114 cm^{-1}; LR-EIMS m/z 127 (94.9%), 185 (94.9%, [M−C_2H_5O]), 215 (bp, [M−CH_3]); HR-EIMS calcd for $C_{11}H_{19}O_4$ [M−CH_3]: 215.1283, found: 215.1277.

(4′*R,5′*S**)-4-(2′,2′,5′-Trimethyl-4′-methoxymethyl-1′,3′-dioxolan-4′-yl)butanal (29c)** was prepared from **28c** in 85% yield similarly as described for **29b**. **29c**: a colorless oil; ^{1}H NMR (270 MHz, $CDCl_3$) δ 9.78 (1H, brs), 3.98 (1H, q, J=6.6 Hz), 3.34 (1H, d, J=9.3 Hz), 3.32 (3H, s), 3.22 (1H, d, J=9.3 Hz), 2.48 (2H, t, J=6.6 Hz), 1.45–1.86 (4H, m), 1.41 (3H, s), 1.34 (3H, s), 1.24 (3H, d, J=6.6 Hz); IR (film) ν_{max} 2988, 2940, 2888, 1730, 1380, 1248, 1218, 1186, 1170, 1110, 1006 cm^{-1}; LR-EIMS m/z 127 (99.7%), 185 (bp, [M−C_2H_5O]), 215 (47.1%, [M−CH_3]); HR-EIMS calcd for $C_{11}H_{19}O_4$ [M−CH_3]: 215.1283, found: 215.1287.

(4′*R,5′*R**)-4-(2′,2′,5′-Trimethyl-4′-benzyloxymethyl-1′,3′-dioxolan-4′-yl)butanal (29d)** was prepared from **28d** in 80% yield similarly as described for **29a**. **29d**: a brownish yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 9.74 (1H, t, J=1.8 Hz), 7.27–7.39 (5H, m), 4.57 (1H, d, J=12.0 Hz), 4.48 (1H, d, J=12.0 Hz), 4.18 (1H, q, J=6.4 Hz), 3.55 (1H, d, J=9.5 Hz), 3.36 (1H, d, J=9.5 Hz), 2.44 (2H, dt, J=1.8, 7.0 Hz), 1.46–1.88 (4H, m), 1.43 (3H, s), 1.35 (3H, s), 1.24 (3H, d, J=6.4 Hz); IR (film) ν_{max} 2988, 2940, 2868, 1728, 1248, 1216, 1102 cm^{-1}; LR-EIMS m/z 91 (bp), 127 (62.7%), 185 (60.6%), 291 (M′−CH_3, 18.0%); HR-EIMS calcd for $C_{17}H_{23}O_4$ [M−CH_3]: 291.1596, found: 291.1594.

(4′*R,5′*S**)-4-(2′,2′,5′-Trimethyl-4′-benzyloxymethyl-1′,3′-dioxolan-4′-yl)butanal (29e)** was prepared from **28e** in 81% yield similarly as described for **29a**. **29e**: a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 9.74 (1H, t, J=1.8 Hz), 7.27–7.38 (5H, m), 4.49 (2H, s), 3.97 (1H, q, J=6.6 Hz), 3.43 (1H, d, J=9.4 Hz), 3.28 (1H, d, J=9.4 Hz), 2.45 (2H, dt, J=1.8, 7.2 Hz), 1.67–1.88 (4H, m), 1.38 (3H, s), 1.34 (3H, s), 1.26 (3H, d, J=6.6 Hz); IR (film) ν_{max} 2988, 1728, 1218, 1102 cm^{-1}; LR-EIMS m/z 91 (bp), 127 (63.2%), 185 (56.8%), 291 (M−CH_3, 10.6%), 306 (M, 0.07%); HR-EIMS calcd for $C_{17}H_{23}O_4$ [M−CH_3]: 291.1596, found: 291.1571.

4-(2,2,5-Trimethyl-1,3-dioxolan-5-yl)butanal (29f) was prepared from **28f** in 81% yield similarly as described for **29a**. **29f**: a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 9.78 (1H, t, J=1.6 Hz), 3.79 (1H, d, J=8.3 Hz), 3.72 (1H, d, J=8.3 Hz), 2.48 (1H, dt, J=1.6, 7.2 Hz), 1.48–1.81 (3H, s), 1.40 (3H, s), 1.38 (3H, s), 1.29 (3H, s); IR (film) ν_{max} 2983, 2936, 2871, 2822, 2722, 1726, 1459, 1378, 1370, 1249, 1212, 1163, 1118, 1060, 984, 905, 858, 808 cm^{-1}; LR-EIMS m/z 115 (59.5%, $C_6H_{11}O_2$), 171 (bp, [M−CH_3]); HR-EIMS calcd for $C_9H_{15}O_3$ [M−CH_3]: 171.1021, found: 171.1050.

1-Methoxymethyl-6,8-dioxabicyclo[3.2.1]octane (4a). A mixture of **29a** (496.9 mg, 2.30 mmol) and $TsOH \cdot H_2O$ (8.7 mg, 0.046 mmol) in CH_2Cl_2 (15 ml) was stirred at 20°C for 1.5 h. The reaction was quenched with saturated aqueous $NaHCO_3$ (40 ml). After extractive work up (CH_2Cl_2×3), the combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, ether) provided **4a** (291.7 mg, 80%) as a colorless oil. **4a**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.56 (1H, s), 3.94 (1H, d, J=6.8 Hz), 3.57 (1H, dd, J=1.5, 6.8 Hz), 3.49 (1H, d, J=10.1 Hz), 3.44 (1H, d, J=10.1 Hz), 3.40 (3H, s), 1.50–1.98 (6H, m); IR (film) ν_{max} 2948, 2886, 2816, 1477, 1458, 1440, 1365, 1344, 1329, 1310, 1190, 1141, 1111, 1093, 1050, 1013, 997, 981, 955, 939, 903, 888, 861, 834, 800 cm^{-1}; LR-EIMS m/z 84 (bp), 140 (26.7%, [M−H_2O]), 158 (5.4%, [M]); HR-EIMS calcd for $C_8H_{14}O_3$ [M]: 158.0943, found: 158.0946.

(1*R,5*R**,7*R**)-1-Methoxymethyl-7-methyl-6,8-dioxabicyclo-[3.2.1]octane (4b)** was prepared from **29b** in 79% yield similarly as described for **4a**. **4b**: a colorless oil; ^{1}H NMR (270 MHz, $CDCl_3$) δ 5.53 (1H, brs), 3.90 (1H, q, J=6.6 Hz), 3.39 (3H, s), 3.38 (1H, d, J=10.2 Hz), 3.32 (1H, d, J=10.2 Hz), 1.08–2.12 (6H, m), 1.34 (3H, d, J=6.6 Hz); IR (film) ν_{max} 2940, 2880, 1468, 1196, 1186, 1110, 1088, 936 cm^{-1}; LR-EIMS m/z 71 (bp), 128 (75.4%, [M−C_2H_4O]), 172 (3.2%, [M]); HR-EIMS calcd for $C_9H_{16}O_3$ [M]: 172.1099, found: 172.1089.

(1*R,5*R**,7*S**)-1-Methoxymethyl-7-methyl-6,8-dioxabicyclo-[3.2.1]octane (4c)** was prepared from **29c** in 78% yield similarly as described for **4a**. **4c**: a colorless oil; ^{1}H NMR (270 MHz, $CDCl_3$) δ 5.53 (1H, brs), 4.21 (1H, q, J=6.3 Hz), 3.43 (1H, d, J=9.2 Hz), 3.38 (3H, s), 3.38 (1H, d, J=9.2 Hz), 1.51–1.97 (6H, m), 1.11 (3H, d, J=6.3 Hz); IR (film) ν_{max} 2952, 2816, 1192, 1114, 1096, 1062, 944 cm^{-1}; LR-EIMS m/z 71 (bp), 144 (83.8%, [M−C_2H_4]), 172 (2.5%, [M]); HR-EIMS calcd for $C_9H_{16}O_3$ [M]: 172.1099, found: 172.1100.

(1*R,5*R**,7*R**)-1-Benzyloxymethyl-7-methyl-6,8-dioxabicyclo-[3.2.1]octane (4d)** was prepared from **29d** in 78% yield similarly as described for **4a**. **4d**: a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.23–7.39 (5H, m), 5.53 (1H, brs), 4.57 (2H, s), 3.92 (1H, dq, J=1.3, 6.4 Hz), 3.44 (1H, d, J=10.3 Hz), 3.40 (1H, d, J=10.3 Hz), 1.50–2.11 (6H, m), 1.32 (3H, d, J=6.4 Hz); IR (film) ν_{max} 3032, 2940, 2872, 1456, 1364, 1118, 1102, 1074, 1028, 936, 736, 698 cm^{-1}; LR-EIMS m/z 91 (bp), 92 (13.4%), 107 (12.1%), 248 (M, 0.97%); HR-EIMS calcd for $C_{15}H_{20}O_3$ [M]: 248.1376, found: 248.1416.

(1*R,5*R**,7*S**)-1-Benzyloxymethyl-7-methyl-6,8-dioxabicyclo-[3.2.1]octane (4e)** was prepared from **29e** in 78% yield similarly as described for **4a**. **4e**: a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.23–7.40 (5H, m), 5.53 (1H, brs), 4.60 (1H, d, J=12.1 Hz), 4.50 (1H, d, J=12.1 Hz), 4.21 (1H, q, J=6.4 Hz), 3.51 (1H, d, J=9.4 Hz), 3.45 (1H, d, J=9.4 Hz), 1.52–2.06 (6H, m), 1.09 (3H, d, J=6.4 Hz); IR (film) ν_{max} 3064, 3032, 2948, 2872, 1456, 1366, 1338, 1322, 1200, 1120, 1094, 1062, 1050, 1030, 984, 952, 944, 902, 860, 736, 698 cm^{-1}; LR-EIMS m/z 91 (bp), 92 (12.3%), 107 (11.3%), 248 (M, 6.2%); HR-EIMS calcd for $C_{17}H_{23}O_4$ [M−CH_3]: 248.1376, found: 248.1420.

1-Methyl-6,8-dioxabicyclo[3.2.1]octane (4f) was prepared from **29f** in 66% yield similarly as described for **4a**. **4f**: a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.53 (1H, brs), 3.95 (1H, d, J=6.8 Hz), 3.38 (1H, dd, J=1.8, 6.8 Hz), 1.78–1.98 (1H, m), 1.50–1.77 (5H, m), 1.34 (3H, s); IR (film) ν_{max} 2945, 2879, 2846, 1459, 1380, 1342, 1306, 1268, 1204, 1124, 1098, 1051, 1005, 984, 955, 938, 928, 891, 863, 856, 834, 796 cm^{-1}; LR-EIMS m/z 72 (bp), 128 (74.3%, [M]); HR-EIMS calcd for $C_7H_{12}O_2$ [M]: 128.0837, found: 128.0848.

General method of reductive cleavage of 6,8-dioxabicyclo[3.2.1]octanes with DIBAH

To a solution of **4** (20–50 mg) in CH_2Cl_2 (2 ml, the concentration of **4** was in the range of 0.05–0.1 M) was added DIBAH (1.0 M in hexane, 8 equiv.) dropwise at 0°C. Then, the reaction mixture was stirred at 20°C for 2–3 days, quenched with MeOH (2 ml), treated with saturated aqueous potassium sodium tartrate (10 ml), stirred for 1 h, and extracted with CH_2Cl_2 (5×20 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc system) provided the corresponding oxane **31**.

General method of Lewis acid-catalyzed reductive cleavage of 6,8-dioxabicyclo[3.2.1]octanes with Et_3SiH

To a solution of **4** (20–50 mg) and Et_3SiH (8 equiv.) in CH_2Cl_2 (2 ml, the concentration of **4** was in the range of 0.05–0.1 M) was added Lewis acid (2.4–4 equiv.) dropwise at −78°C. Then, the reaction mixture was stirred under the conditions indicated in Table 1. When $TiCl_4$, $SnCl_4$, $Sn(OTf)_2$, or $BF_3 \cdot OEt_2$ was used as a Lewis acid, the reaction was quenched with brine (10 ml). When an aluminum Lewis acid was used, the reaction mixture was quenched with MeOH (2 ml), treated with saturated aqueous potassium sodium tartrate (10 ml), and stirred for 1 h. After extractive work up (CH_2Cl_2×5), the combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc system) provided the corresponding **30** and **31**. Sometimes the crude residue contained a small amount of silylated products. In such a case, purification was performed after desilylation of the residue with TBAF.

3-Hydroxy-3-methoxymethyloxepane (30a):[18] a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.80 (1H, brtd, J=5.5, 12.2 Hz, H1b), 3.70 (1H, brddd, J=5.3, 8.3, 12.2 Hz, H1a), 3.66 (1H, d, J=12.6 Hz, H6b), 3.52 (1H, brd, J=12.6 Hz, H6a), 3.39 (3H, s, OMe), 3.35 (1H, d, J=9.2 Hz, H7b), 3.25 (1H, d, J=9.2 Hz, H7a), 1.47–1.84 (6H, m, H2, H3, H4); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm) δ 77.7 (CH_2, C7), 74.4 (C, C5), 74.3 (CH_2, C6), 71.9 (CH_2, C1), 59.4 (CH_3, OMe), 37.8 (CH_2, C4), 30.7 (CH_2, C3 or C2), 20.6 (CH_2, C2 or C3); IR (film) ν_{max} 3440, 2929, 2863, 1470, 1461, 1450, 1264, 1198, 1150, 1111, 1091, 1007,

979 cm^{-1}; LR-EIMS *m/z* 115 (bp, [M−CH_2OCH_3]), 128 (67.9%, [M−CH_3OH]), 142 (6.0%, [M−H_2O]), 160 (19.3%, [M]); HR-EIMS calcd for $C_8H_{16}O_3$ [M]: 160.1099, found: 160.1109.

(2*R,3*R**)-3-Hydroxy-3-methoxymethyl-2-methyloxepane (30b):**[18] a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.93 (1H, td, *J*=5.1, 12.1 Hz, H1b), 3.61 (1H, ddd, *J*=5.5, 6.6, 12.1 Hz, H1a), 3.56 (1H, q, *J*=6.7 Hz, H6), 3.45 (1H, d, *J*=9.2 Hz, H8b), 3.38 (3H, s, H9), 3.33 (1H, d, *J*=9.2 Hz, H8a), 2.52 (1H, s, OH), 1.52–1.87 (6H, m, H2, H3, H4), 1.17 (3H, d, *J*=6.7 Hz, H7); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm) δ 80.8 (CH, C6), 75.9 (C, C5), 75.4 (CH_2, C8), 70.9 (CH_2, C1), 59.3 (CH_3, C9), 38.6 (CH_2, C4), 31.0 (CH_2, C3 or C2), 20.4 (CH_2, C2 or C3), 16.2 (CH_3, C7); IR (film) ν_{max} 3465, 2930, 2867, 2818, 1461, 1453, 1376, 1321, 1277, 1198, 1107, 1064, 1036, 1003, 970, 947 cm^{-1}; LR-EIMS *m/z* 85 (bp), 98 (62%), 128 (62.7%, [M−C_2H_6O]), 129 (63.7%, [M−C_2H_5O]), 142 (26.3%, [M−CH_4O]), 174 (21.4%, [M]); HR-EIMS calcd for $C_9H_{18}O_3$ [M]: 174.1256, found: 174.1253.

(2*S,3*R**)-3-Hydroxy-3-methoxymethyl-2-methyloxepane (30c):**[18] a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.77–3.81 (2H, m, H1), 3.55 (1H, q, *J*=6.4 Hz, H6), 3.34 (3H, s, OMe), 3.27 (1H, d, *J*=8.9 Hz, H8b), 3.22 (1H, d, *J*=8.9 Hz, H8a), 2.77 (1H, brs, OH), 1.75–1.86 (3H, m, H2b, H4), 1.57–1.72 (3H, m, H2a, H3), 1.14 (3H, d, *J*=6.4 Hz, H7); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm) δ 77.9 (CH_2, C8), 76.4 (CH, C6), 74.8 (C, C5), 69.0 (CH_2, C1), 59.4 (CH_3, C9), 39.7 (CH_2, C4), 29.5 (CH_2, C2), 19.9 (CH_2, C3), 15.9 (CH_3, C7); IR (film) ν_{max} 3473, 2980, 2931, 2867, 1451, 1368, 1304, 1195, 1155, 1117, 1083, 1056, 1036, 995, 965, 930 cm^{-1}; LR-EIMS *m/z* 85 (bp), 98 (73.3%), 128 (55.4%, [M−C_2H_6O]), 129 (45.9%, [M−C_2H_5O]), 142 (26.3%, [M−CH_4O]), 174 (15.9%, [M]); HR-EIMS calcd for $C_9H_{18}O_3$ [M]: 174.1256, found: 174.1256.

(2*R,3*R**)-3-Benzyloxymethyl-3-hydroxy-2-methyloxepane (30d):**[18] a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$, 45°C) δ 7.24–7.37 (5H, m, Bn), 4.58 (1H, d, *J*=12.0 Hz, Bn), 4.52 (1H, d, *J*=12.0 Hz, Bn), 3.90 (1H, brtd, *J*=5.5, 12.1 Hz, H1b), 3.60 (1H, brtd, *J*=6.7, 12.1 Hz, H1a), 3.57 (1H, d, *J*=9.3 Hz, H8b), 3.56 (1H, q, *J*=6.8 Hz, H6), 3.43 (1H, d, *J*=9.3 Hz, H8a), 2.55 (1H, s, 5-OH), 1.93–2.11 (1H, m, H4b), 1.62–1.79 (4H, m, H2, H3b, H4b), 1.48–1.62 (1H, m, H3a), 1.17 (3H, d, *J*=6.8 Hz, H7); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm, 45°C) δ 138.2 (C, Bn), 128.4 (CH×2, Bn), 127.7 (CH, Bn), 127.6 (CH×2, Bn), 80.9 (CH, C6), 76.1 (C, C5), 73.7 (CH_2, Bn), 73.1 (CH_2, C8), 70.8 (CH_2, C1), 38.8 (CH_2, C4), 30.9 (CH_2, C2), 20.4 (CH_2, C3), 16.3 (CH_3, C7); IR (film) ν_{max} 3484, 3064, 3032, 2936, 2864, 1500, 1456, 1376, 1320, 1278, 1098, 972, 944, 912, 842, 736, 698 cm^{-1}; LR-EIMS *m/z* 91 (bp), 250 (10.4%, [M]); HR-EIMS calcd for $C_{15}H_{22}O_3$ [M]: 250.1569, found: 250.1568.

(2*S,3*R**)-3-Benzyloxymethyl-3-hydroxy-2-methyloxepane (30e):**[18] a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25–7.38 (5H, m, Bn), 4.54 (1H, d, *J*=11.9 Hz, Bn), 4.47 (1H, d, *J*=11.9 Hz, Bn), 3.66–3.81 (2H, m, H1), 3.59 (1H, q, *J*=6.4 Hz, H6), 3.35 (1H, d, *J*=8.9 Hz, H8), 3.31 (1H, d, *J*=8.9 Hz, H8), 2.79 (1H, s, 5-OH), 1.75–1.90 (3H, m, H2b, H4), 1.55–1.74 (3H, m, H2a, H3), 1.12 (3H, d, *J*=6.4 Hz, H7); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm) δ 138.1 (c, Bn), 128.3 (CH_2×(2, Bn), 127.6 (CH_2×3, Bn), 76.4 (CH, C6), 75.2 (CH_2, C8), 74.9 (C, C5), 73.5 (CH_2, Bn), 68.9 (CH_2, C1), 39.8 (CH_2, C4), 29.5 (CH_2, C2), 19.9 (CH_2, C3), 15.9 (CH_3, C7); IR (film) ν_{max} 3471, 3088, 3063, 3030, 2978, 2932, 2862, 1497, 1484, 1453, 1372, 1302, 1276, 1256, 1204, 1156, 1101, 1084, 1054, 1039, 1029, 993, 971, 945, 930, 904, 832, 737, 698 cm^{-1}; LR-EIMS *m/z* 91 (bp), 250 (5.1%, [M]); HR-EIMS calcd for $C_{15}H_{22}O_3$ [M]: 250.1569, found: 250.1564.

2-Hydroxymethyl-2-methoxymethyloxane (31a):[18] a colorless oil; ^{1}H NMR (300 MHz, C_6D_6, C_6HD_5 as 7.15 ppm) δ 3.61–3.73 (2H, m, H6), 3.42 (2H, t, *J*=5.4 Hz, H1), 3.34 (1H, d, *J*=9.2 Hz, H7b), 3.26 (1H, d, *J*=9.2 Hz, H7a), 3.03 (3H, s, OCH_3), 2.03 (1H, brt, *J*=6.3 Hz, 6-OH), 1.43–1.50 (1H, m, H4b), 1.12–1.43 (5H, m, H2, H3, H4a); ^{13}C NMR (75 MHz, C_6D_6, $C_5{}^{13}CD_6$ as 128.0 ppm) δ 74.8 (CH_2, C7), 74.4 (C, C_5), 65.0 (CH_2, C6), 62.0 (CH_2, C1), 59.2 (CH_3, OCH_3), 27.6 (CH_2, C4), 25.9 (CH_2, C2), 19.1 (CH_2, C3); IR (film) ν_{max} 3453, 2933, 2870, 2812, 1476, 1457, 1374, 1355, 1289, 1264, 1247, 1198, 1180, 1162, 1146, 1115, 1086, 1047, 973, 858 cm^{-1}; LR-EIMS *m/z* 97 (69.8%, [M−$C_2H_7O_2$]), 115 (bp, [M−C_2H_5O]), 129 (71.8%, [M−CH_3O]); HR-EIMS calcd for $C_6H_{11}O_2$ [M−C_2H_5O]: 115.0795, found: 115.0759; calcd for $C_7H_{13}O_2$ [M−CH_3O]: 129.0948, found: 129.0915; LR-CIMS *m/z* 161 [M+H]; HR-CIMS calcd for $C_8H_{17}O_3$ [M+H]: 161.1147, found: 161.1178.

(1′*R,2*R**)-2-(1′-Hydroxyethyl)-2-methoxymethyloxane (31b):**[18] a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.93 (1H, brq, *J*=6.6 Hz, H6), 3.75–3.82 (1H, m, H1b), 3.75 (1H, d, *J*=10.3 Hz, H8b), 3.64–3.72 (1H, m, H1a), 3.38 (3H, s, OMe), 3.33 (1H, d, *J*=10.3 Hz, H8a), 2.75 (1H, brs, OH), 1.65–1.83 (2H, m, H2b, H4b), 1.48–1.62 (3H, m, H2a, H3), 1.37–1.45 (1H, m, H4a), 1.12 (3H, d, *J*=6.6 Hz, H7); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm) δ 76.1 (C, C5), 71.2 (CH_2, C8), 69.9 (CH, C6), 62.2 (CH_2, C1), 59.5 (CH_3, OCH_3), 25.7 (CH_2, C3), 24.4 (CH_2, C4), 18.9 (CH_2, C2), 16.0 (CH_3, C7); IR (film) ν_{max} 3483, 2938, 2871, 2812, 1481, 1458, 1402, 1365, 1276, 1201, 1185, 1165, 1111, 1052, 1028, 1001, 974, 911, 894 cm^{-1}; LR-EIMS *m/z* 55 (bp), 129 (78.6%, [M−C_2H_5O]), 157 (1.5%, [M−OH]), 175 (0.6%, [M+H]); HR-EIMS calcd for $C_9H_{19}O_3$ [M+H]: 175.1334, found: 175.1330.

(1′*S,2*R**)-2-(1′-Hydroxyethyl)-2-methoxymethyloxane (31c):**[18] a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.97 (1H, brdq, *J*=5.3, 6.6 Hz, H6), 3.78 (1H, brtd, *J*=5.0, 11.9 Hz, H1b), 3.71 (1H, brddd, *J*=4.9, 6.8, 11.9 Hz, H1a), 3.59 (1H, d, *J*=9.9 Hz, H8b), 3.48 (1H, d, *J*=9.9 Hz, H8a), 3.37 (3H, s, OMe), 2.91 (1H, brd, *J*=5.3 Hz, OH), 1.50–1.70 (5H, m, H2, H3, H4b), 1.42–1.50 (1H, m, H4a), 1.18 (3H, d, *J*=6.6 Hz, H7); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm) δ 75.7 (C, C5), 73.2 (CH_2, C8), 70.2 (CH, C6), 61.9 (CH_2, C1), 59.4 (CH_3, OCH_3), 26.7 (CH_2, C4), 25.4 (CH_2, C2), 18.8 (CH_2, C3), 17.3 (CH_3, C7); IR (film) ν_{max} 3474, 2937, 2872, 2812, 1460, 1397, 1367, 1351, 1286, 1265, 1200, 1175, 1165, 1113, 1084, 1046, 1024, 1007, 974, 908, 890 cm^{-1};

LR-EIMS *m/z* 129 (bp, [M−C_2H_5O]), 175 (1.2%, [M+H]); HR-EIMS calcd for $C_9H_{19}O_3$ [M+H]: 175.1334, found: 175.1340.

(1′*R,2*R**)-2-Benzyloxymethyl-2-(1′-hydroxyethyl)oxane (31d):**[18] a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27–7.39 (5H, m, Bn), 4.61 (1H, d, *J*=12.3 Hz, Bn), 4.49 (1H, d, *J*=12.3 Hz, Bn), 3.97 (1H, dq, *J*=3.7, 6.4 Hz, H6), 3.73–3.80 (1H, m, H1b), 3.76 (1H, d, *J*=10.3 Hz, H8b), 3.59–3.67 (1H, m, H1a), 3.37 (1H, d, *J*=10.3 Hz, H8a), 2.76 (1H, d, *J*=3.7 Hz, 6-OH), 1.73–1.82 (1H, m, H4b), 1.63–1.73 (1H, m, H3b), 1.38–1.57 (4H, m, H2, H3a, H4a), 1.07 (3H, d, *J*=6.4 Hz, H7); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm) δ 137.8 (C, Bn), 128.4 (CH×2, Bn), 127.8 (CH×3, Bn), 76.2 (C, C5), 73.5 (CH_2, Bn), 70.0 (CH, C6), 68.0 (CH_2, C8), 62.2 (CH_2, C1), 25.6 (CH_2, C2), 24.4 (CH_2, C4), 18.9 (CH_2, C3), 15.9 (CH_3, C7); IR (film) ν_{max} 3512, 3088, 3064, 3032, 2940, 2864, 1456, 1404, 1366, 1274, 1208, 1094, 1052, 1028, 912, 894, 736, 698 cm^{-1}; LR-EIMS *m/z* 91 (bp), 250 (2.1%, [M]); HR-EIMS calcd for $C_{15}H_{22}O_3$ [M]: 250.1569, found: 250.1565.

(1′*S,2*R**)-2-Benzyloxymethyl-2-(1′-hydroxyethyl)oxane (31e):**[18] a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26–7.38 (5H, m, Bn), 4.59 (1H, d, *J*=12.1 Hz, Bn), 4.51 (1H, d, *J*=12.1 Hz, Bn), 3.94 (1H, dq, *J*=5.7, 6.4 Hz, H6), 3.73–3.80 (1H, m, H1b), 3.63–3.70 (1H. m, H1a), 3.66 (1H, d, *J*=9.7 Hz, H8b), 3.56 (1H, d, *J*=9.7 Hz, H8a), 2.89 (1H, d, *J*=5.7 Hz, 6-OH), 1.42–1.68 (6H, m, H2, H3, H4), 1.16 (3H, d, *J*=6.4 Hz, H7); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm) δ 137.9 (C, Bn), 128.4 (CH×2, Bn), 127.71 (CH, Bn), 127.68 (CH×2, Bn), 75.8 (C, C5), 73.7 (CH_2, Bn), 70.7 (CH, C6), 70.0 (CH_2, C8), 62.0 (CH_2, C1), 26.7 (CH_2, C4), 25.4 (CH_2, C3 or C2), 18.8 (CH_2, C2 or C3), 17.2 (CH_3, C7); IR (film) ν_{max} 3475, 3088, 3063, 3030, 2937, 2867, 1497, 1472, 1454, 1399, 1367, 1286, 1265, 1206, 1099, 1083, 1047, 1028, 1015, 909, 891, 737, 698 cm^{-1}; LR-EIMS *m/z* 91 (bp), 205 (30.9%, [M−C_2H_5O]), 250 (0.2%, [M]); HR-EIMS calcd for $C_{15}H_{22}O_3$ [M]: 250.1569, found: 250.1564.

2-Methoxymethyl-2-methyloxane (31f):[18] a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 3.69 (1H, brt, *J*=5.1 Hz), 3.50 (1H, brd, *J*=11.2 Hz), 3.37 (1H, brd, *J*=11.2 Hz), 2.32 (1H, brs, OH), 1.57–1.73 (3H, m), 1.45–1.56 (2H, m), 1.25–1.42 (1H, m), 1.18 (3H, s); ^{13}C NMR (75 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm) δ 73.4 (C), 69.4 (CH_2), 61.7 (CH_2), 30.9 (CH_2), 25.8 (CH_2), 19.3 (CH_3), 19.0 (CH_2); IR (film) ν_{max} 3433, 2936, 2866, 1475, 1456, 1441, 1402, 1372, 1350, 1288, 1225, 1207, 1191, 1168, 1130, 1088, 1046, 987, 963, 899, 856, 839, 812, 724, 711, 691 cm^{-1}; LR-EIMS *m/z* 99 (bp, [M−CH_2OH]), 115 (5.9%, [M−CH_3]), 131 (2.1%, [M+H]); HR-EIMS calcd for $C_6H_{11}O_2$ [M−CH_3]: 115.0759, found: 115.0764; calcd for $C_6H_{11}O$ [M−CH_2OH]: 99.0810, found: 99.0803.

$TiCl_4$-catalyzed allylation of 4d

To a mixture of **4d** (39.2 mg, 0.158 mmol) and allyltrimethylsilane (0.20 ml, 1.26 mmol) in CH_2Cl_2 (3.2 ml) was added $TiCl_4$ (0.069 ml, 0.63 mmol) at −78°C. The reaction mixture was stirred at −78°C for 2 h, quenched with H_2O (15 ml), stirred at 20°C for an additional 2 h, diluted with brine (15 ml), and extracted with CH_2Cl_2 (5×20 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/ether=10→5→ether) provided a mixture of **4d**, **32**, and **33** (32.0 mg, **4d**: ~8%, **32**: ~48%, **33**: ~12%. The ratio was determined by ^{1}H NMR as a colorless oil and an inseparable mixture of **34** and **35** (10.2 mg, **34**: ~15%, **35**: ~15%. The ratio was determined by ^{1}H NMR as a colorless oil. Ethers **32** and **33** were separated by HPLC (YMC-Pack SIL-06, 250×10 mm, hexane/EtOAc=20). Diols **34** and **35** were converted to the corresponding monobenzoate **36** and dibenzoate **37**, respectively, for separation and characterization.

(2*R,3*R**,7*S**)-3-Benzyloxymethyl-3-hydroxy-2-methyl-7-(2′-propenyl)oxepane (32):**[18] a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$, 45°C) δ 7.24–7.26 (5H, m, Bn), 5.82 (1H, tdd, *J*=7.0, 10.3, 17.0 Hz, H2), 5.00–5.09 (2H, m, H1), 4.60 (1H, d, *J*=11.9 Hz, Bn), 4.52 (1H, d, *J*=11.9 Hz, Bn), 3.79 (1H, q, *J*=6.8 Hz, H9), 3.70 (1H, brtdd, *J*=5.9, 7.7, 10.4 Hz, H4), 3.64 (1H, brd, *J*=9.3 Hz, H11b), 3.55 (1H, d, *J*=9.3 Hz, H11a), 2.68 (1H, s, 8-OH), 2.25–2.35 (1H, m, H3b), 2.02–2.17 (2H, m, H3a, H7b), 1.78–1.87 (1H, m, H5b), 1.56–1.72 (1H, m, H6b), 1.42–1.54 (1H, m, H5a), 1.24–1.40 (2H, m, H6a, H7a), 1.19 (3H, d, *J*=6.8 Hz, H10); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm, 45°C) δ 138.3 (C, Bn), 135.6 (CH, C2), 128.4 (CH×2, Bn), 127.6 (CH×3, Bn), 116.6 (CH_2, C1), 76.2 (CH, C4), 75.2 (C, C8), 73.6 (CH_2, Bn), 71.8 (CH, C9), 71.0 (CH_2, C11), 40.0 (CH_2, C7), 39.7 (CH_2, C3), 34.3 (CH_2, C5), 20.5 (CH_2, C6), 16.3 (CH_3, C10); IR (film) ν_{max} 3473, 3072, 3031, 2975, 2929, 2857, 1641, 1497, 1454, 1414, 1377, 1367, 1332, 1262, 1235, 1217, 1100, 1076, 1067, 1029, 1014, 997, 963, 948, 933, 913, 826, 736, 697 cm^{-1}; LR-EIMS *m/z* 91 (bp), 249 (4%, [M−C_3H_5]), 290 (2.4%, [M]); HR-EIMS calcd for $C_{18}H_{26}O_3$ [M]: 290.1882, found: 290.1886.

(1′*R,2*R**,6*S**)-2-Benzyloxymethyl-2-(1′-hydroxyethyl)-6-(2″-propenyl)oxane (33):**[18] a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27–7.38 (5H, m, Bn), 5.78 (1H, ddd, *J*=6.6, 7.3, 10.3 Hz, H2), 4.96–5.06 (2H, m, H1), 4.53 (1H, d, *J*=12.0 Hz, Bn), 4.50 (1H, d, *J*=12.0 Hz, Bn), 4.25 (1H, brqd, *J*=6.6, 10.3 Hz, H9), 3.70 (1H, d, *J*=8.8 Hz, H11b), 3.42–3.50 (1H, m, H4), 3.25 (1H, dd, *J*=1.2, 8.8 Hz, H11a), 3.22 (1H, d, *J*=10.3 Hz, 9-OH), 2.40–2.48 (1H, m, H7b), 2.01–2.19 (2H, m, H3), 1.64–1.72 (2H, m, H6), 1.54–1.64 (1H, m, H5b), 1.22–1.33 (1H, m, H7a), 1.20 (3H, d, *J*=6.6 Hz, H10), 1.12–1.22 (1H, m, H5a); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm) δ 137.3 (C, Bn), 135.0 (CH, C2), 128.5 (CH×2, Bn), 127.9 (CH, Bn), 127.8 (CH×2, Bn), 116.5 (CH_2, C1), 76.7 (CH_2, C11), 74.4 (C, C7), 73.9 (CH_2, Bn), 70.2 (CH, C4), 66.2 (CH, C9), 41.3 (CH_2, C3), 30.9 (CH_2, C5), 29.2 (CH_2, C7), 18.3 (CH_2, C6), 17.3 (CH_3, C10); IR (film) ν_{max} 3516, 3071, 3031, 2961, 2931, 2858, 1738, 1732, 1642, 1497, 1454, 1442, 1429, 1415, 1370, 1290, 1260, 1205, 1103, 1078, 1043, 1029, 906, 867, 802, 737, 699, 661 cm^{-1}; LR-EIMS *m/z* 91 (bp), 245 (43.8%, [M−C_2H_5O]); HR-EIMS calcd for $C_{16}H_{21}O_2$ [M]: 245.1541, found: 245.1548.

(2*R,3*R**,7*S**)-3-Benzoyloxymethyl-3-hydroxy-2-methyl-7-(2′-propenyl)oxepane (36) and (1′*R**,2*R**,6*S**)-2-(1′-Benzoyloxyethyl)-2-benzoyloxymethyl-6-(2″-propenyl)-oxane (37).** To a solution of **34** and **35** (10.2 mg, 0.0509 mmol) in CH_2Cl_2 (1.5 ml) was added BzCl (0.0355 ml, 0.306 mmol), pyridine (0.0330 ml, 0.408 mmol), and DMAP (a catalytic amount) at 0°C. The reaction mixture was stirred at 20°C for 12 h, quenched with saturated aqueous $NaHCO_3$ (10 ml) and brine (10 ml), and extracted with CH_2Cl_2 (4×20 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=9→5→EtOAc) provided **36** (3.8 mg, 25%) as a colorless oil and **37** (6.6 mg, 32%) as a colorless oil. **36**:[18] ^{1}H NMR (400 MHz, C_6D_6, C_6HD_5 as 7.15 ppm) δ 8.09–8.14 (2H, m, Bz), 7.00–7.14 (3H, m, Bz), 5.86 (1H, dddd, *J*=6.4, 7.5, 9.5, 17.8 Hz, H2), 4.99–5.06 (2H, m, H1), 4.42 (2H, s, H11), 3.46 (1H, q, *J*=6.8 Hz, H9), 3.22–3.31 (1H, m, H4), 2.17–2.26 (1H, m, H3b), 2.13 (1H, s, 11-OH), 1.96–2.05 (1H, m, H3a), 1.77–1.85 (1H, m, H7b), 1.15–1.62 (5H, m, H5, H6, H7a), 1.21 (3H, d, *J*=6.8 Hz, H10); ^{13}C NMR (100 MHz, C_6D_6, $^{13}CC_5D_6$ as 128.0 ppm) δ 162.7 (C, Bz), 136.1 (CH, C2), 133.0 (CH, Bz), 130.7 (C, Bz), 130.0 (CH×2, Bz), 128.6 (CH×2, Bz), 116.3 (CH_2, C1), 82.1 (CH, C4), 81.0 (CH, C9), 76.3 (C, C8), 69.4 (CH_2, C11), 41.7 (CH_2, C3), 38.8 (CH_2, C7), 36.8 (CH_2, C5), 19.8 (CH_2, C6), 16.0 (CH_3, C10); IR (film) ν_{max} 3491, 3072, 2976, 2931, 2863, 1722, 1641, 1603, 1584, 1451, 1370, 1315, 1276, 1177, 1099, 1071, 1027, 914, 711 cm^{-1}; LR-EIMS *m*/*z* 105 (bp), 263 (4.5%, [M−C_3H_5]), 304 (0.3%, [M]); HR-EIMS calcd for $C_{18}H_{24}O_4$ [M]: 304.1674, found: 304.1652. **37**:[18] ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06–8.11 (2H, m, Bz), 7.97–8.02 (2H, m, Bz), 7.51–7.60 (2H, m, Bz), 7.41–7.47 (2H, m, Bz), 7.35–7.40 (2H, m, Bz), 5.89 (1H, q, *J*=6.6 Hz, H9), 5.86 (1H, tdd, *J*=7.1, 10.1, 17.6 Hz, H2), 5.00–5.10 (2H, m, H1), 4.55 (1H, d, *J*=11.5 Hz, Bn), 4.49 (1H, d, *J*=11.5 Hz, Bn), 3.62–3.71 (1H, m, H4), 2.12–2.30 (2H, m, H3), 1.56–1.86 (5H, m, H5b, H6, H7), 1.45 (3H, d, *J*=6.6 Hz, H10), 1.18–1.34 (1H, m, H5a); ^{13}C NMR (100 MHz, $CDCl_3$, $^{13}CDCl_3$ as 77.0 ppm) δ 166.6 (C, Bz), 165.8 (C, Bz), 134.8 (CH, C2), 133.1 (CH, Bz), 132.9 (CH, Bz), 130.4 (C, Bz), 129.9 (C, Bz), 129.69 (CH×2, Bz), 129.66 (CH×2, Bz), 128.40 (CH×2, Bz), 128.36 (CH×2, Bz), 116.8 (CH_2, C1), 75.0 (C, C8), 70.9 (CH, C4), 67.8 (CH, C9), 67.3 (CH_2, C11), 41.2 (CH_2, C3), 30.2 (CH_2, C5), 26.3 (CH_2, C7), 18.5 (CH_2, C6), 13.7 (CH_3, C10); IR (film) ν_{max} 3072, 2937, 2872, 2856, 1720, 1603, 1585, 1451, 1373, 1314, 1281, 1266, 1219, 1205, 1176, 1158, 1108, 1098, 1070, 1054, 1027, 1002, 915, 711, 687, 667 cm^{-1}; LR-EIMS *m*/*z* 105 (86.8%, C6H5CO), 259 (bp, [M−CH_3CHOBz]), 273 (2.0%, [M−CH_2OBz]), 367 (2.8%, [M−C_3H_5]); HR-EIMS calcd for $C_{16}H_{19}O_3$ [M−CH_3CHOBz]: 259.1334, found: 259.1328; calcd for $C_{17}H_{21}O_3$ [M−CH_2OBz]: 273.1491, found: 273.1482; calcd for $C_{22}H_{23}O_5$ [M−C_3H_5]: 367.1545, found: 367.1516.

$TiCl_4$-catalyzed allylation of 4e

To a mixture of **4e** (21.1 mg, 0.0850 mmol) and allyltrimethylsilane (0.108 ml, 0.680 mmol) in CH_2Cl_2 (1.7 ml) was added $TiCl_4$ (0.0373 ml, 0.340 mmol) at −78°C. The reaction mixture was stirred at −78°C for 1.5 h, quenched with H_2O (10 ml), stirred at 20°C for an additional 2 h, diluted with brine (10 ml), and extracted with CH_2Cl_2 (5×20 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/ether=10→5→ether) provided **38** (16.7 mg, 98%).

(2*S,3*R**,7*R**)-3-Hydroxy-3-hydroxymethyl-2-methyl-7-(2′-propenyl)oxepane (38):**[18] a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.84 (1H, tdd, *J*=7.0, 10.1, 17.1 Hz, H2), 5.02–5.14 (2H, m, H1), 3.77 (1H, tdd, *J*=5.3, 8.3, 11.4 Hz, H4), 3.72 (1H, q, *J*=6.4 Hz, H9), 3.51 (1H, brdd, *J*=4.4, 10.6 Hz, H11b), 3.43 (1H, brdd, *J*=5.0, 10.6 Hz, H11a), 3.10 (1H, s, 8-OH), 2.25–2.38 (1H, m, H3b), 2.10–2.22 (1H, m, H3a), 1.23–1.96 (6H, m, H5, H6, H7), 1.14 (3H, d, *J*=6.4 Hz, H10). Diol **38** was converted to the corresponding monobenzoate **39** for characterization.

(2*S,3*R**,7*R**)-3-Benzoyloxymethyl-3-hydroxy-2-methyl-7-(2′-propenyl)oxepane (39).** A mixture of **38** (7.0 mg, 0.035 mmol), BzCl (0.0243 ml, 0.209 mmol), pyridine (0.0226 ml, 0.279 mmol), and DMAP (a catalytic amount) in CH_2Cl_2 (1.5 ml) was stirred at 20°C for 1 day, quenched with saturated aqueous $NaHCO_3$ and brine. After extractive workup (CH_2Cl_2×4), the combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography (silica gel, hexane/EtOAc=5) provided **39** (5.3 mg, 50%) as a colorless oil.

39:[18] ^{1}H NMR (400 MHz, acetone-d_6, $CHD_2C(O)CD_3$ as 2.04 ppm) δ 8.02–8.06 (2H, m, Bz), 7.61–7.66 (1H, m, Bz), 7.49–7.55 (2H, m, Bz), 5.87 (1H, tdd, *J*=7.0, 10.3, 17.2 Hz, H2), 5.06 (1H, tdd, *J*=1.5, 2.3, 17.2 Hz, H1b), 4.98 (1H, tdd, *J*=1.1, 2.3, 10.3 Hz, H1a), 4.12 (1H, d, *J*=11.0 Hz, H11b), 4.11 (1H, d, *J*=11.0 Hz, H11a), 3.95 (1H, q, *J*=6.6 Hz, H9), 3.76 (1H, tdd, *J*=5.1, 8.1, 11.2 Hz, H4), 3.72 (1H, s, 8-OH), 2.32 (1H, brtddd, *J*=1.5, 6.8, 8.1, 14.1 Hz, H3b), 2.15 (1H, brtddd, *J*=1.3, 5.1, 7.2, 14.1 Hz, H3a), 1.81–1.90 (2H, m, H5b, H7b), 1.68–1.81 (2H, m, H6b, H7a), 1.57–1.66 (1H, m, H6a), 1.40–1.52 (1H, m, H5a), 1.14 (3H, d, *J*=6.6 Hz, H10); ^{13}C NMR (100 MHz, acetone-d_6, $^{13}CD_3C(O)CD_3$ as 29.8 ppm) δ 166.5 (C, Bz), 137.1 (CH, C2), 134.0 (CH, Bz), 131.1 (C, Bz), 130.2 (CH×2, Bz), 129.4 (CH×2, Bz), 116.4 (CH_2, C1), 76.7 (CH, C4), 74.7 (C, C8), 70.2 (CH_2, C11), 70.1 (CH, C9), 40.5 (CH_2, C3), 39.9 (CH_2, C7), 35.1 (CH_2, C5), 20.5 (CH_2, C6), 16.3 (CH_3, C10); IR (film) ν_{max} 3519, 3073, 2978, 2930, 2859, 1722, 1642, 1602, 1452, 1367, 1315, 1273, 1198, 1177, 1159, 1111, 1083, 1070, 1026, 980, 944, 915, 712, 688, 629 cm^{-1}; LR-EIMS *m*/*z* 105 (bp), 263 (17.9%, [M−C_3H_5]), 304 (0.2%, [M]); HR-EIMS calcd for $C_{18}H_{24}O_4$ [M]: 304.1674, found: 304.1680.

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14. In order to accelerate the cleavage reaction, an excess amount of $TiCl_4$ was required. In fact, when 1.2 equiv. of $TiCl_4$ were used in the case of **4b** or **4d**, the amount of recovered starting **4b** or **4d** increased (**4b**: 3%, **4d**: 70%), while the selectivity of oxepane in each case remained unchanged.

15. At present, we can only speculate on the origins of these selectivities. Obstruction of the coordination of $TiCl_4$ to O8 by bulkiness of C7-methyl group may increase the selectivity in **4b** and **4c** rather than in **4a**. The steric repulsion of C7-methyl group to methylene at C3 may improve the cleaving ability of C5–O8 bond in **4b** and **4d** rather than in **4c** and **4e**, respectively. Detailed mechanistic study is currently under way.

16. The chelation ability of aluminum reagents is well documented. For recent examples, see: (a) Ooi, T.; Kagoshima, N.; Ichikawa, H.; Maruoka, K. *J. Am. Chem. Soc.* **1999**, *121*, 3328–3333. (b) Evans, D. A.; Allison, B. D.; Yang, M. G. *Tetrahedron Lett.* **1999**, *40*, 4457–4460. (c) Evans, D. A.; Halstead, D. P.; Allison, B. D. *Tetrahedron Lett.* **1999**, *40*, 4461–4462. (d) Heller, D. P.; Goldberg, D. R.; Wulff, W. D. *J. Am. Chem. Soc.* **1997**, *119*, 10 551–10 552.

17. Bulkiness around the reaction center of the silyl reagent may play a role in the oxepane selection. Detailed mechanistic study is currently under way.

18. Position numberings of cyclic ethers (**30**, **31**, **32**, **33**, **36**, **37**, **38**, and **39**) in NMR data are specified in Figs. 1–3.