Chemoselective two-directional reaction of bi-functionalized substrates: formal ketal-selective Mukaiyama aldol type reaction
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1. General and Materials
All reactions were carried out under Ar atmosphere. Melting points were uncorrected. NMR spectra were recorded on a Bruker Avance III Nanobay 400 MHz spectrometer (400 MHz for 1H, 100 MHz for 13C) in CDCl3 or CD3CN. Chemical shifts (in ppm) were referenced to the solvent signal (CDCl3, 7.26 ppm for 1H NMR and 77.0 ppm for 13C NMR; CD3CN, 1.93 ppm for 1H NMR and 117.7 ppm for 13C NMR). Coupling constants (J) are given in Hz. Mass spectra were measured on a Micromass LCT mass spectrometer using electrospray ionization-time of flight (ESI-TOF) technique. Column chromatography was performed on neutral silica gel (Kanto Silica gel 60N, 63-210 μm). Zwitterion 31 and carbon acid 82 were prepared by the previously reported procedure from Tf2CH2,3 which was kindly supplied from Central Glass Co.
2. Preparation of \(\omega,\omega\)-Dialkoxy Carbonyl Compounds

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4,4-Dimethoxycyclohexan-1-one \(1a\) and 4,4-dimethoxy-3,4-dihydrornaphthalen-1(2\(H\))-one \(1b\) were prepared as follows.

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To a solution of 4-methoxyphenol (627 mg, 5.00 mmol) in MeOH (12 mL), iodobenzene diacetate (1.62 g, 5.03 mmol) was slowly added at 0 °C. After being stirred for 1 h at room temperature, the reaction mixture was quenched with a saturated NaHCO\(_3\) aqueous solution (30 mL) and extracted with Et\(_2\)O (30 mL x 3). The combined organic layer was dried over anhydrous MgSO\(_4\) and concentrated under reduced pressure. This residue was purified by column chromatography on silica gel (hexane/EtOAc = 5 : 1) to give 4,4-dimethoxyxycyclohexa-2,5-dien-1-one in 97% yield (750 mg, 4.87 mmol). Its structure was confirmed by comparison of \(^1\)H and \(^13\)C NMR data reported in the literature. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 3.36 (6H, s), 6.26 (2H, brd, \(J = 10.0 \text{ Hz}\)), 6.81 (2H, brd, \(J = 10.0 \text{ Hz}\)); \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 50.4, 92.5, 130.0, 143.3, 185.1\).

To a solution of Willkinson’s catalyst (141 mg, 0.152 mmol) in benzene (140 mL), a solution of 4,4-dimethoxyxycyclohexa-2,5-dien-1-one (463 mg, 3.00 mmol) in benzene (10 mL) was added. After being stirred for 6 h at room temperature under H\(_2\) atmosphere (1 atm), the reaction mixture was concentrated under reduced pressure. The resulting residue was directly purified by column chromatography on silica gel.
(hexane/EtOAc = 3 : 1) to give 4,4-dimethoxy cyclohexan-1-one 1a in 93% yield (441 mg, 2.79 mmol). Its structure was confirmed by comparison of $^1$H and $^{13}$C NMR data with the authentic sample.$^5$ $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 2.03 (4H, t, $J = 6.8$ Hz), 2.38 (4H, t, $J = 6.8$ Hz), 3.26 (6H, s); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 31.4, 37.2, 48.2, 98.5, 210.8.

4,4-Dimethoxy-3,4-dihydropyran-1(2H)-one (1b)

To a solution of 4-methoxy naphthalen-1-ol (1.67 g, 9.60 mmol) in MeOH (50 mL), iodo benzene diacetate (3.70 g, 11.5 mmol) was slowly added at 0 °C. After being stirred for 1 h at room temperature, the reaction mixture was quenched with a saturated NaHCO$_3$ aqueous solution (30 mL) and extracted with Et$_2$O (30 mL x 3). The combined organic layer was dried over anhydrous MgSO$_4$ and concentrated under reduced pressure. This residue was purified by column chromatography on silica gel (hexane/EtOAc = 3 : 1) to give 4,4-dimethoxynaphthalen-1(4H)-one in 93% yield (1.82 g, 8.92 mmol). Its structure was confirmed by comparison of $^1$H and $^{13}$C NMR data reported in the literature.$^4$ $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 3.19 (6H, s), 6.61 (1H, d, $J = 10.5$ Hz), 6.93 (1H, d, $J = 10.5$ Hz), 7.51 (1H, td, $J = 7.8, 1.4$ Hz), 7.67 (1H, td, $J = 7.8, 1.4$ Hz), 7.74 (1H, dd, $J = 7.8, 0.9$ Hz), 8.09 (1H, dd, $J = 7.8, 0.9$ Hz); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 51.3, 95.2, 126.4, 126.7, 129.4, 131.7, 132.7, 133.6, 139.7, 144.3, 184.0.

According to the synthetic procedure for 1a, 4,4-dimethoxy-3,4-dihydronaphthalen-1(2H)-one 1b was obtained in 98% yield (201 mg, 0.976 mmol) by hydrogenation reaction of 4,4-dimethoxynaphthalen-1(4H)-one (204 mg, 1.00 mmol) using Wilkinson’s catalyst (47.1 mg, 0.051 mmol) and H$_2$ (1 atm) in benzene (40 mL) for 6 h at room temperature after column chromatography on silica gel (hexane/EtOAc = 3 : 1). Colorless crystals (from hexane/EtOAc): Mp. 40.0-42.0 °C; IR (ATR) $\nu$ 2937, 1682, 1595, 1283, 1039, 761 cm$^{-1}$; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 2.37 (2H, t, $J = 6.6$ Hz), 2.82 (2H, t, $J = 6.6$ Hz), 3.19 (6H, s), 7.44 (1H, t, $J = 7.8$ Hz), 7.58 (1H, t, $J = 7.8$ Hz), 7.77 (1H, d, $J = 7.8$ Hz), 8.02 (1H, d, $J = 7.8$ Hz); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 31.1, 34.9, 48.9, 97.1, 126.5, 127.3, 128.8, 131.5, 132.7, 141.1, 197.7; MS (ESI-TOF) $m/z$ 229 [M+Na]$^+$; HRMS calcd for C$_{12}$H$_{14}$NaO$_3$ [M+Na]$^+$, 229.0841; found, 229.0833. Anal. Calcd for C$_8$H$_{14}$O$_3$: C, 64.67; H, 8.88. Found: C, 64.76; H, 9.00.

$\gamma,\gamma$-Dimethoxy carbonyl compounds 1c-1j were prepared by modification of reported procedure as follows.$^6$ $\gamma,\gamma$-Diethoxy derivative 1k was also prepared in a similar manner by using HC(OEt)$_3$ and EtOH as reagents for the first step.
5,5-Dimethoxyhexan-2-one (1c)

To a solution of N,4,4-trimethoxy-N-methylpentanamide (1.03 g, 4.98 mmol) in THF (20 mL), a 3.0 M solution of MeMgBr in Et₂O (3.3 mL, 9.9 mmol) was added over 15 min at 0 °C. After being stirred for 1 h at the same temperature, the reaction mixture was acidified by a saturated NH₄Cl aqueous solution (30 mL), then it was extracted with Et₂O (30 mL x 3). The combined organic layer was washed with brine (25 mL), dried over anhydrous MgSO₄, and evaporated. Thus obtained residue was purified by column chromatography on silica gel (hexane/EtOAc = 10 : 1) to give 5,5-dimethoxyhexan-2-one (1c) in 92% yield (737 mg, 4.60 mmol). Its structure was confirmed by comparison of ¹H and ¹³C NMR data reported in the literature. ¹H NMR (400 MHz, CDCl₃) δ 1.23 (3H, s), 1.90 (2H, brt, J = 7.4 Hz), 2.15 (3H, s), 2.49 (2H, brt, J = 7.4 Hz), 3.16 (6H, s); ¹³C NMR (100 MHz, CDCl₃) δ 21.0, 30.0, 30.1, 38.8, 48.2, 101.1, 208.1.

4,4-Dimethoxy-1,4-diphenylbutan-1-one (1d)

A solution of 4-oxo-4-phenylbutanoic acid (3.56 g, 20.0 mmol) and trimethy orthoformate (66 mL, 64 mmol) in MeOH (90 mL) was treated with sulfuric acid (10 drops) for 19.5 h at 65 °C. The reaction mixture diluted with Et₂O (150 mL) and carefully quenched with a saturated NaHCO₃ aqueous solution (150 mL). After separation of organic layer, it was washed with brine (150 mL), dried over anhydrous MgSO₄, and evaporated. Thus obtained methyl 4,4-dimethoxy-4-phenylbutanoate was used in next step without further purification.

To a solution of this ester in THF (30 mL), N,O-dimethylhydroxylamine hydrochloride (2.92 g, 30.0 mmol) and i-PrMgCl (a 2.0 M solution in THF, 30 mL, 60 mmol) were added at 0 °C. After being stirred for 1 h at 0 °C, the reaction was quenched a saturated NH₄Cl aqueous solution (100 mL), then the mixture was extracted with Et₂O (100 mL x 3). The combined organic layer was washed with brine (70 mL), dried over anhydrous Na₂SO₄, and evaporated. Thus obtained residue was purified by column chromatography on silica gel (hexane/EtOAc = 1 : 1) to give N,4,4-trimethoxy-N-methyl-4-phenylbutanamide in 79% yield (4.23g, 15.8 mmol) from 4-oxo-4-phenylbutanoic acid. Colorless oil; IR (neat) ν 2951, 1666, 1448, 1136, 1078, 1039, 1000, 702 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 2.06-2.12 (2H, m), 2.21-2.27 (2H, m), 3.06 (3H, s), 3.16 (6H, s), 3.46 (3H, s), 7.27 (1H, tt, J = 7.3, 1.3 Hz), 7.31-7.37 (2H, m), 7.44-7.48 (2H, m); ¹³C NMR (100 MHz, CDCl₃) δ 26.7, 31.9, 32.2, 48.7, 61.0, 103.2, 127.0, 127.8, 128.0, 140.3, 173.9; MS (ESI-TOF) m/z 290 [M+Na]⁺; HRMS calcd for C₁₄H₂₁NNaO₄ [M+Na]⁺, 290.1368; found, 290.1368. Anal. Calcd for C₁₄H₂₁NO₄: C, 62.90; H, 7.92; N, 5.24. Found: C, 62.70; H, 7.99; N, 5.28.

To a solution of this Weinreb amide (801 mg, 3.00 mmol) in THF (12 mL), a 1.0 M solution of PhMgBr in THF (6.0 mL, 6.0 mmol) was added over 15 min at 0 °C. After being stirred for 3 h at the same temperature, the
reaction mixture was acidified by a saturated NH₄Cl aqueous solution (30 mL), then it was extracted with Et₂O (30 mL x 3). The combined organic layer was washed with brine (25 mL), dried over anhydrous MgSO₄, and evaporated. Thus resulting residue was purified by column chromatography on silica gel (hexane/EtOAc = 20 : 1) to give 4,4-dimethoxy-1,4-diphenylbutan-1-one 1d in 73% yield (623 mg, 2.19 mmol). Colorless crystals (from EtOAc/hexane); Mp. 54.5-56.0 °C; IR (ATR) ν 3057, 2941, 2830, 1677, 1490, 1283, 1131, 1072, 956, 704, 688, 615 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 2.32-2.40 (2H, m), 2.65-2.70 (2H, m), 3.19 (3H, s), 7.27-7.34 (1H, m), 7.35-7.41 (4H, m), 7.47-7.53 (3H, m), 7.76 (2H, d, J = 6.8 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 31.4, 33.2, 48.8, 103.2, 127.0, 127.89, 127.93, 128.2, 128.5, 132.9, 136.8, 140.3, 199.3; MS (ESI-TOF) m/z 307 [M+Na]⁺; HRMS calcd for C₁₈H₂₀NaO₃ [M+Na]⁺, 307.1310; found, 307.1308. Anal. Calcd for C₁₈H₂₀O₃: C, 76.03; H, 7.09. Found: C, 75.84; H, 7.12.

4,4-Dimethoxy-1-phenylpentan-1-one (1e)

According to the synthetic procedure for 1c, this compound was obtained in 84% yield (943 mg, 4.25 mmol) by the reaction of N,N′,4,4-trimethoxy-N-methylpentanamide⁶ (1.04 g, 5.07 mmol) with PhMgBr (a 1.1 M solution in THF, 9.1 mL, 10.0 mmol) in THF (20 mL) for 30 min at 0 °C followed by acidification using a saturated NH₂Cl aqueous solution (50 mL) after chromatographic purification using silica gel (hexane/EtOAc = 10 : 1). Its structure was confirmed by comparison of ¹H and ¹³C NMR data reported in the literature.⁸ ¹H NMR (400 MHz, CDCl₃) δ 1.32 (3H, s), 2.09 (2H, t, J = 7.7 Hz), 3.00-3.06 (2H, m), 3.20 (6H, s), 7.46 (2H, t, J = 7.6 Hz), 7.52-7.59 (1H, m), 7.98 (2H, d, J = 7.6 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 21.1, 30.5, 33.8, 48.3, 101.3, 128.0, 128.6, 133.0, 136.9, 199.5.

5,5-Dimethoxy-5-phenylpentan-2-one (1f)

According to procedure for 1d, this compound was obtained in 80% yield (442 mg, 1.99 mmol) by the reaction of N,N′,4,4-trimethoxy-N-methyl-4-phenylbutanamide (668 mg, 2.50 mmol) with MeMgBr (a 3.0 M solution in Et₂O, 1.67 mL, 5.01 mmol) in THF (10 mL) for 1.5 h at 0 °C followed by chromatographic purification using silica gel (hexane/EtOAc = 20 : 1). Colorless oil; IR (neat) ν 2940, 2900, 2825, 1715, 1684, 1593, 1354, 1211, 1127, 1042, 724, 688 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 1.99 (3H, s), 2.12 (1H, dd, J = 5.4, 3.2 Hz), 2.14 (1H, dd, J = 5.1, 1.4 Hz), 2.17 (1H, dd, J = 5.1, 1.4 Hz), 2.20 (1H, dd, J = 5.4, 3.2 Hz), 3.14 (6H, s), 7.29 (1H, dd, J = 7.3, 1.5 Hz), 7.30-7.40 (2H, m), 7.44 (2H, dt, J = 7.2, 1.5 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 29.9, 30.9, 38.2, 48.7, 103.0, 126.9, 127.9, 128.1, 140.2, 207.8; MS (ESI-TOF) m/z 245 [M+Na]⁺; HRMS calcd for C₁₃H₁₈NaO₃ [M+Na]⁺, 245.1154; found, 245.1153.
6,6-Dimethoxy-6-phenylhexan-3-one (1g)

According to procedure for 1d, this compound was obtained in 86% yield (1.02 g, 4.32 mmol) by the reaction of N,4,4-trimethoxy-N-methyl-4-phenylbutanamide (1.34 g, 5.00 mmol) with EtMgBr (a 0.97 M solution in Et₂O, 11.0 mL, 10.7 mmol) in THF (20 mL) for 1 h at 0 °C followed by chromatographic purification using silica gel (hexane/EtOAc = 10 : 1). Colorless oil; IR (neat) ν 2945, 2899, 2825, 1712, 1442, 1300, 1130, 1041, 765, 700 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 0.93 (3H, t, J = 7.3 Hz), 2.08-2.12 (2H, m), 2.17-2.22 (2H, m), 2.26 (2H, q, J = 7.3 Hz), 3.14 (6H, s), 7.27-7.29 (1H, m), 7.30-7.39 (2H, m), 7.44 (2H, d, J = 8.5 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 7.7, 30.9, 35.9, 36.8, 48.7, 103.1, 126.9, 127.8, 128.1, 140.3, 210.5; MS (ESI-TOF) m/z 259 [M+Na]⁺; HRMS calcd for C₁₄H₂₀NaO₃ [M+Na]⁺, 259.1310; found, 259.1314. Anal. Calcd for C₁₄H₂₀O₃: C, 71.16; H, 8.53. Found: C, 71.16; H, 8.50.

1,1-Dimethoxy-6-methyl-1-phenylheptan-4-one (1h)

According to procedure for 1d, this compound was obtained in 90% yield (1.19 g, 4.51 mmol) by the reaction of N,4,4-trimethoxy-N-methyl-4-phenylbutanamide (1.34 g, 5.00 mmol) with i-BuMgBr (a 1.0 M solution in Et₂O, 10.0 mL, 10.0 mmol) in THF (20 mL) for 2 h at room temperature followed by chromatographic purification using silica gel (hexane/EtOAc = 10 : 1). Colorless oil; IR (neat) ν 2951, 2870, 2830, 1712, 1445, 1365, 30.9, 35.9, 48.7, 103.1, 126.9, 127.8, 128.1, 140.3, 210.5; MS (ESI-TOF) m/z 287 [M+Na]⁺; HRMS calcd for C₁₆H₂₄NaO₃ [M+Na]⁺, 287.1623; found, 287.1619. Anal. Calcd for C₁₆H₂₄O₃: C, 72.56; H, 9.15. Found: C, 72.56; H, 9.16.

1-Cyclopropyl-4,4-dimethoxy-4-phenylbutan-1-one (1i)

According to procedure for 1d, this compound was obtained in 96% yield (1.19 g, 4.80 mmol) by the reaction of N,4,4-trimethoxy-N-methyl-4-phenylbutanamide (1.34 g, 5.00 mmol) with c-C₃H₅MgBr (a 0.7 M solution in Et₂O, 15.0 mL, 10.5 mmol) in THF (20 mL) for 4 h at 0 °C followed by chromatographic purification using silica gel (hexane/EtOAc = 5 : 1). Colorless oil; IR (neat) ν 2947, 2898, 2825, 1695, 1443, 1388, 1128,
1038, 898, 699 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 0.73-0.78 (2H, m), 0.87-0.91 (2H, m), 1.74 (1H, tt, J = 7.8, 4.6 Hz), 2.17-2.34 (4H, m), 3.15 (6H, s), 7.30 (1H, t, J = 7.1 Hz), 7.32-7.39 (2H, m), 7.46 (2H, d, J = 7.2 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 10.7, 20.4, 31.0, 38.0, 48.7, 103.1, 126.9, 127.8, 128.1, 140.3, 209.9; MS (ESI-TOF) m/z 271 [M+Na]⁺; HRMS calcd for C₁₅H₂₀NaO₃ [M+Na]⁺, 271.1310; found, 271.1307.

4,4-Dimethoxy-4-phenylbutanal (1j)

To a solution of N,4,4-trimethoxy-N-methyl-4-phenylbutanamide (534 mg, 2.00 mmol) in THF (8.0 mL), a 1.0 M solution of DIBAL-H in hexane (2.0 mL, 2.0 mmol) was slowly added at –78 °C. After being stirred for 1 h at the same temperature, the reaction mixture was quenched with a saturated aqueous solution of potassium sodium tartrate (30 mL). After extraction with EtOAc (30 mL x 3), the combined organic layer was washed with brine (20 mL), dried over anhydrous Na₂SO₄, and concentrated under reduced pressure. The following column chromatography on silica gel (hexane/EtOAc = 8 : 1) gave 4,4-dimethoxy-4-phenylbutanal 1j in 51% yield (214 mg, 1.03 mmol). Colorless oil; IR (neat) ν 2955, 2910, 2830, 2725, 1724, 1424, 1306, 1202, 1118, 1100, 1022, 962, 766, 702 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 2.14-2.25 (4H, m), 3.16 (6H, s), 7.30 (1H, tt, J = 7.2, 1.4 Hz), 7.33-7.39 (2H, m), 7.45 (2H, dd, J = 8.2, 1.4 Hz), 9.54 (1H, d, J = 1.3 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 29.5, 38.7, 48.8, 103.0, 126.9, 128.0, 128.2, 140.0, 201.4; MS (ESI-TOF) m/z 231 [M+Na]⁺; HRMS calcd for C₁₂H₁₆NaO₃ [M+Na]⁺, 231.0997; found, 231.1000.

6,6-Diethoxy-6-phenylhexan-3-one (1k)

A solution of 4-oxo-4-phenylbutanoic acid (890 mg, 5.00 mmol) and triethyl orthoformate (17 mL, 100 mmol) in EtOH (20 mL) was treated with sulfuric acid (4 drops) for 2 h at 80 °C. The reaction mixture diluted with Et₂O (40 mL) and quenched with a saturated NaHCO₃ aqueous solution (40 mL). After separation of organic layer, it was washed with brine (40 mL), dried over anhydrous MgSO₄, and evaporated. Ethyl 4,4-diethoxy-4-phenylbutanoate thus obtained was used in next step without further purification.

To a solution of ethyl 4,4-diethoxy-4-phenylbutanoate in THF (20 mL), N,O-dimethylhydroxylamine hydrochloride (548 mg, 5.61 mmol) and i-PrMgCl (a 2.0 M solution, 5.6 mL, 11 mmol) were slowly added at –10 °C. After being stirred for 5 h at the same temperature, the reaction was quenched with a saturated NH₄Cl aqueous solution (20 mL), then the mixture was extracted with Et₂O (20 mL x 3). The combined organic layer was washed with brine (20 mL), dried over anhydrous Na₂SO₄, and evaporated. Thus obtained residue was purified by column chromatography on silica gel (hexane/EtOAc = 2 : 1) to give 4,4-diethoxy-N-methoxy-N-methyl-4-phenylbutanamide in 56% yield (819 mg, 2.78 mmol) from
4-oxo-4-phenylbutanoic acid. Colorless oil; IR (neat) ν 3010, 2970, 2919, 1664, 1447, 1384, 1299, 1063, 1041, 1018, 702 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 1.20 (6H, t, J = 7.0 Hz), 2.05-2.12 (2H, m), 2.23-2.29 (2H, m), 3.06 (3H, s), 3.31-3.48 (4H, m), 3.45 (3H, s), 7.26 (1H, tt, J = 7.8, 1.4 Hz), 7.31-7.36 (2H, m), 7.49-7.53 (2H, m); ¹³C NMR (100 MHz, CDCl₃) δ 15.2, 26.9, 32.2, 32.8, 56.4, 61.0, 102.7, 126.9, 127.6, 127.9, 141.2, 174.1; MS (ESI-TOF) m/z 318 [M+Na]⁺; HRMS calcd for C₁₆H₂₅NO₄ [M+H]⁺, 318.1681; found, 318.1684. Anal. Calcd for C₁₆H₂₅NO₄: C, 65.06; H, 8.53; N, 4.74. Found: C, 65.06; H, 8.53; N, 4.74.

According to the synthetic procedure for 1d, 6,6-diethoxy-6-phenylpentan-3-one 1k was obtained in 91% yield (481 mg, 1.82 mmol) by the reaction of this Weinreb amide (590 mg, 2.00 mmol) with EtMgBr (a 0.97 M solution in Et₂O, 4.2 mL, 4.0 mmol) in THF (8.0 mL) for 2 h at 0 °C followed by chromatographic purification using silica gel (hexane/EtOAc = 3 : 1). Colorless oil; IR (neat) ν 2975, 1718, 1444, 1118, 1053, 1018, 702 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 0.93 (3H, t, J = 7.2 Hz), 1.19 (6H, t, J = 6.8 Hz), 2.04-2.12 (2H, m), 2.19-2.25 (2H, m), 2.25 (2H, q, J = 7.2 Hz), 3.28-3.44 (4H, m), 7.27 (1H, tt, J = 7.3, 1.4 Hz), 7.31-7.35 (2H, m), 7.46-7.50 (2H, m); ¹³C NMR (100 MHz, CDCl₃) δ 7.7, 15.2, 31.9, 35.8, 37.0, 56.4, 102.6, 126.8, 127.6, 128.0, 141.2, 210.6; MS (ESI-TOF) m/z 287 [M+Na]⁺; HRMS calcd for C₁₆H₂₄NaO₃ [M+Na]⁺, 287.1623; found, 287.1625. Anal. Calcd for C₁₆H₂₄O₃: C, 72.69; H, 9.15. Found: C, 72.46; H, 9.22.

6,6-Dimethoxy-6-phenylhexan-2-one (1m)

A solution of 5-oxo-5-phenylpentanoic acid (3.84 g, 20.0 mmol) and trimethy orthoformate (70 mL, 68 mmol) in MeOH (90 mL) was treated with sulfuric acid (10 drops) for 4 h at 65 °C. The reaction mixture diluted with Et₂O (150 mL) and quenched with a saturated NaHCO₃ aqueous solution (150 mL). After separation of organic layer, it was washed with brine (150 mL), dried over anhydrous MgSO₄, and evaporated. Methyl 5,5-dimethoxy-5-phenylpentanoate thus obtained was used in next step without further purification.

A mixture of this ester and N,O-dimethylhydroxylamine hydrochloride (2.92 g, 30.0 mmol) was dissolved in THF (70 mL). To this solution, was added i-PrMgCl (a 2.0 M solution, 30 mL, 60 mmol) at 0 °C. After being stirred for 1 h at the same temperature, the reaction was quenched with a saturated NH₄Cl aqueous solution (100 mL), then the mixture was extracted with Et₂O (100 mL x 3). The combined organic layer was washed with brine (70 mL), dried over anhydrous Na₂SO₄, and evaporated. Thus obtained residue was purified by column chromatography on silica gel (hexane/EtOAc = 2 : 1) to give N₅₅-trimethoxy-N-methyl-5-phenylpentanamide in 79% yield (4.23 g, 15.8 mmol) from 5-oxo-5-phenylpentanoic acid. Colorless oil; IR (neat) ν 2944, 2903, 2831, 1661, 1449, 1308, 1133, 1042, 954, 772, 704 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 1.29-1.38 (2H, m), 1.90-1.96 (2H, m), 2.25 (2H, t, J = 7.2 Hz), 3.11 (3H, s), 3.17 (6H, s), 3.58 (3H, s), 7.24-7.28 (1H, m), 7.31-7.38 (2H, m), 7.46 (2H, dt, J = 8.6, 1.4 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 18.5, 31.4, 32.1, 36.8, 48.6,
61.1, 103.4, 126.9, 127.6, 127.9, 140.8, 174.2; MS (ESI-TOF) m/z 304 [M+Na]; HRMS calcd for C₁₄H₂₃NO₄Na [M+Na]⁺, 304.1526; found, 304.1525.

According to procedure for 1d, 6,6-dimethoxy-6-phenylhexan-2-one 1m was obtained in 90% yield (1.07 g, 4.53 mmol) by the reaction of N,N,5,5-trimethoxy-N-methyl-5-phenylpentanamide (1.41 g, 5.02 mmol) with MeMgBr (a 3.0 M solution in Et₂O, 3.4 mL, 10 mmol) in THF (20 mL) for 1.5 h at 0 °C followed by chromatographic purification using silica gel (hexane/EtOAc = 10 : 1). Colorless oil; IR (neat) ν 2950, 2900, 2825, 1715, 1445, 1305, 1130, 1045, 770, 705 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 1.21-1.31 (2H, m), 1.82-1.90 (2H, m), 2.02 (3H, s), 2.23 (2H, t, J = 7.3 Hz), 3.15 (6H, s), 7.27 (1H, t, J = 7.0 Hz), 7.34 (2H, t, J = 7.0 Hz), 7.45 (2H, dt, J = 7.0 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 17.7, 29.8, 36.5, 43.2, 48.6, 103.3, 126.9, 127.7, 128.0, 140.7, 208.6; MS (ESI-TOF) m/z 259 [M+Na]; HRMS calcd for C₁₄H₂₇NaO₃ [M+Na]⁺, 259.1310; found, 259.1320.

3. Two-directional Reaction of ω,ω-Dialkoxy Carbonyl Compounds with Ketene Silyl Acetals

**Ethyl 2-((tert-butyldimethylsilyl)oxy)-1,4-dimethoxycyclohexyl)acetate (2a)**

![2a](image_url)

To a solution of 4,4-dimethoxycyclohexan-1-one 1a (79.1 mg, 0.501 mmol) and zwitterion 3 (2.6 mg, 4.9 μmol) in Et₂O (1.5 mL), a solution of tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (114 mg, 0.565 mmol) in Et₂O (0.5 mL) was slowly added at 0 °C. After being stirred for 10 min at the temperature, Et₃N (0.3 mL) was added to this mixture to quench the reaction. After concentration of the resulting mixture under reduced pressure, the obtained residue was purified by column chromatography on silica gel (hexane/EtOAc = 15 : 1) to give 2a in 94% yield (170 mg, 0.470 mmol, dr = 2.9 : 1). Separation of these diastereomers was achieved by recycling preparative HPLC technique (hexane/EtOAc = 10 : 1) to give less-2a (23% yield, 42.3 mg, 0.117 mmol) and more-2a (67% yield, 121 mg, 0.335 mmol), respectively.

For less-2a  Colorless oil; IR (neat) ν 2950, 2819, 1731, 1251, 1110, 1074, 838, 711 cm⁻¹; ¹H NMR (400 MHz, CD₃CN) δ 0.11 (6H, s), 0.90 (9H, s), 1.21 (3H, t, J = 7.1 Hz), 1.58-1.68 (6H, m), 1.73-1.80 (2H, m), 2.45 (2H, s), 3.15 (3H, s), 3.19 (3H, s), 4.05 (2H, q, J = 7.1 Hz); ¹³C NMR (100 MHz, CD₃CN) δ −3.9, 13.3, 17.6, 25.0, 30.3, 31.6, 41.1, 47.6, 48.1, 59.6, 73.5, 98.9, 170.1; MS (ESI-TOF) m/z 383 [M+Na]; HRMS calcd for C₁₈H₃₆NaO₆Si [M+Na]⁺, 383.2230; found, 383.2218.

For more-2a  Colorless oil; IR (neat) ν 2949, 1732, 1251, 1098, 1073, 1014, 833, 772 cm⁻¹; ¹H NMR (400 MHz, CD₃CN) δ 0.11 (6H, s), 0.88 (9H, s), 1.29 (2H, t, J = 7.1 Hz), 1.49 (2H, td, J = 13.1, 3.5 Hz), 1.63 (2H, td, J = 13.1, 3.1 Hz), 1.67-1.82 (4H, m), 2.42 (2H, s), 3.15 (3H, s), 3.16 (3H, s), 4.05 (2H, q, J = 7.1 Hz); ¹³C NMR (100 MHz, CD₃CN) δ −3.8, 13.2, 17.5, 24.9, 30.4, 31.3, 41.4, 47.1, 48.1, 59.5, 73.1, 98.4, 170.1; MS (ESI-TOF) m/z 383 [M+Na]; HRMS calcd for C₁₈H₃₆NaO₆Si [M+Na]⁺, 383.2230; found, 383.2227.
Ethyl 2-(1-methoxy-4-oxocyclohexyl)acetate (9a)

\[
\begin{align*}
\text{MeO} & \quad \text{EtO} \quad \text{O} \\
\end{align*}
\]

**Acid hydrolysis:** To a solution of methyl silyl acetal 2a (185 mg, 0.512 mmol) in a mixed solvent of acetone (1.0 mL) and H\(_2\)O (1.0 mL), was added AcOH (1.0 mL) at 0 °C. After being stirred at the same temperature for 1 h, the reaction mixture was quenched with a saturated NaHCO\(_3\) aqueous solution (30 mL) and extracted with EtOAc (30 mL x 3). The combined organic layer was washed with brine (30 mL), dried over anhydrous MgSO\(_4\), and evaporated. The resulting residue was purified by column chromatography on silica gel (hexane/EtOAc = 5 : 1) to give the corresponding ketone 9a in 88% yield (96.2 mg, 0.449 mmol). Colorless oil; IR (neat) \(\nu\) 2980, 1727, 1718, 1256, 1153, 1064, 1029 cm\(^{-1}\); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 1.27 (3H, t, \(J = 7.1\) Hz), 1.85 (2H, td, \(J = 13.8, 4.7\) Hz), 2.18-2.32 (4H, m), 2.53-2.64 (4H, m), 3.35 (3H, s), 4.15 (2H, q, \(J = 7.1\) Hz); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 14.2, 33.5, 36.6, 41.6, 49.6, 60.6, 73.3, 170.2, 221.1; MS (ESI-TOF) \(m/z\) 215 [M+Na]\(^+\); HRMS calcd for C\(_{11}\)H\(_{18}\)NaO\(_4\) [M+Na]\(^+\), 215.1283; found, 215.1278.

**Fluoride ion-induced reaction:** To a solution of methyl silyl acetal 2a (172 mg, 0.476 mmol) in THF (1.0 mL), a 1.0 M solution of tetrabutylammonium fluoride (TBAF, 1.5 mL, 1.5 mmol) was added at –78 °C. After being stirred for 8 h at 0 °C, the reaction mixture was poured into water (10 mL). After extraction with Et\(_2\)O (30 mL x 3), the combined organic layer was washed with brine (30 mL), dried over anhydrous MgSO\(_4\), and evaporated. The resulting residue was purified by column chromatography on silica gel (hexane/EtOAc = 5 : 1) to give the corresponding ketone 9a in 75% yield (76.1 mg, 0.355 mmol).

Ethyl 6-((tert-butyldimethylsilyl)oxy)-3,6-dimethoxy-3-methylheptanoate (2c)

\[
\begin{align*}
\text{TBSO} & \quad \text{OMe} \\
\end{align*}
\]

According to the synthetic procedure for 2a, this compound was obtained in 87% yield (157 mg, 0.433 mmol) as a mixture of inseparable diastereomers in a ratio of 1 : 1.0 by the reaction of 5,5-dimethoxyhexan-2-one 1c (80.3 mg, 0.500 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (121 mg, 0.598 mmol) in the presence of zwitterion 3 (2.6 mg, 4.9 \(\mu\)mol) in Et\(_2\)O (2.0 mL) for 20 min at 0 °C and the following column chromatography on silica gel (hexane/EtOAc = 15 : 1). Colorless oil; IR (neat) \(\nu\) 2950, 1735, 1460, 1375, 1250, 1090, 1000, 835, 780 cm\(^{-1}\); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 0.11 (3H, s), 0.13 (3H, s), 0.89 (9H, s), 1.25 (3H, t, \(J = 7.1\) Hz), 1.27 (3H, s), 1.34 (3H, s), 1.58-1.69 (4H, m), 2.44 (1H, d, \(J = 13.5\) Hz), 2.51 (1H, dd, \(J = 13.5, 2.6\) Hz), 3.206 (3H, s), 3.214 (3H, s), 4.08-4.18 (2H, m); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) –2.9, –2.7, 14.2, 18.2, 23.0, 23.2, 25.87 and 25.93, 32.2, 34.0, 43.14 and 43.22, 48.57, 49.18 and 49.24, 60.3, 75.5, 100.6 and 100.7, 170.86 and 170.87; MS (ESI-TOF) \(m/z\) 385 [M+Na]\(^+\); HRMS calcd for C\(_{18}\)H\(_{38}\)NaO\(_5\)Si [M+Na]\(^+\), 385.2386; found, 385.2389. Anal. Calcd for C\(_{18}\)H\(_{38}\)O\(_5\)Si: C, 59.63; H, 10.56. Found: C, 59.87; H, 10.68.
Ethyl 3-methoxy-6-oxo-3,6-diphenylhexanoate (9d) and ethyl 3-((tert-butylimethylsilyl)oxy)-6-oxo-3,6-diphenylhexanoate (10d)

To a solution of 4,4-dimethoxy-1,4-diphenylbutan-1-one (1d) (142 mg, 0.500 mmol) and zwitterion 3 (2.6 mg, 5.0 μmol) in 1,2-dimethoxyethane (DME, 19.5 mL), a solution of tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane (5a) (162 mg, 0.800 mmol) in DME (0.5 mL) was added at 0 °C. After being stirred for 15 min at the same temperature, the reaction was quenched by treatment with Et3N (0.3 mL), then it was concentrated under reduced pressure. The resulting residue was dissolved in a mixed solvent of acetone, H2O, and AcOH (1 : 1 : 1 v/v, 3.0 mL). This mixture was stirred for 1 h at room temperature. After usual extractive workup, the obtained residue was purified by column chromatography on silica gel (hexane/EtOAc = 5 : 1) to give ethyl 3-methoxy-6-oxo-3,6-diphenylhexanoate 9d (138 mg, 0.406 mmol, 81% yield) and ethyl 3-((tert-butylimethylsilyl)oxy)-6-oxo-3,6-diphenylhexanoate 10d (7.1 mg, 0.016 mmol, 3% yield), respectively.

For 9d  IR (neat) ν 3052, 2900, 2872, 1724, 1682, 1442, 1318, 1284, 1200, 1180, 1082, 1065, 742, 698 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 1.04 (3H, t, J = 7.1 Hz), 2.40 (1H, ddd, J = 14.8, 10.8, 4.4 Hz), 2.58 (1H, ddd, J = 14.8, 11.2, 5.2 Hz), 2.86 (1H, ddd, J = 17.2, 11.2, 4.4 Hz), 2.92 (1H, d, J = 13.7 Hz), 2.97 (1H, d, J = 13.7 Hz), 3.21 (3H, s), 4.07 (2H, q, J = 7.1 Hz), 7.24-7.30 (1H, m), 7.33-7.38 (2H, m), 7.39-7.45 (4H, m), 7.50-7.56 (1H, m), 7.86-7.92 (2H, m); ¹³C NMR (100 MHz, CDCl₃) δ 13.9, 30.5, 32.7, 42.9, 50.1, 60.3, 79.5, 126.3, 127.3, 128.0, 128.2, 133.0, 136.9, 142.2, 169.8, 199.7; MS (ESI-TOF) m/z 363 [M+Na]⁺; HRMS calcd for C₂₁H₂₄NaO₄ [M+Na]⁺, 363.1572; found, 363.1567. Anal. Calcd for C₂₁H₂₄O₄: C, 74.09; H, 7.11. Found: C, 74.14; H, 7.12.

For 10d  IR (neat) ν 3152, 2952, 2944, 2852, 1730, 1682, 1598, 1442, 1362, 1258, 1078, 838, 700 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 0.05 (3H, s), 0.16 (3H, s), 0.97 (9H, s), 1.02 (3H, t, J = 7.1 Hz), 2.43 (1H, ddd, J = 14.5, 11.4, 4.3 Hz), 2.58 (1H, ddd, J = 14.5, 9.9, 4.6 Hz), 2.75 (1H, ddd, J = 17.8, 11.4, 4.6 Hz), 2.94 (1H, d, J = 14.5 Hz), 3.02 (1H, d, J = 14.5 Hz), 3.05 (1H, ddd, J = 17.8, 9.9, 4.3 Hz), 3.92 (2H, q, J = 7.1 Hz), 7.19-7.27 (1H, m), 7.30-7.36 (2H, m), 7.37-7.43 (2H, m), 7.45-7.48 (2H, m), 7.49-7.53 (1H, m), 7.80-7.86 (2H, m); ¹³C NMR (100 MHz, CDCl₃) δ –2.3, –2.2, 13.9, 18.7, 26.1, 33.5, 35.8, 48.1, 60.1, 77.9, 125.6, 126.8, 127.9, 128.0, 1285.5, 132.9, 136.9, 144.7, 169.5, 199.7; MS (ESI-TOF) m/z 463 [M+Na]⁺; HRMS calcd for C₂₆H₃₆NaO₄Si [M+Na]⁺, 463.2281; found, 463.2274.

Ethyl 3-methoxy-3-methyl-6-oxo-6-phenylhexanoate (9e) and ethyl 3-((tert-butylimethylsilyl)oxy)-6-oxo-3-phenylheptanoate (10e)

- S11 -
According to the synthetic procedure for 9c, the reaction of 6,6-dimethoxy-6-phenylhexan-3-one 1e (112 mg, 0.503 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (152 mg, 0.750 mmol) in the presence of zwitterion 3 (2.6 mg, 4.9 μmol) in Et₂O (2.0 mL) for 15 min at 0 °C followed by acid hydrolysis using AcOH-acetone-H₂O (1:1:1 v/v, 3.0 mL) gave a crude mixture. Column chromatography of this mixture on silica gel (hexane/EtOAc = 20 : 1) gave ethyl 3-methoxy-3-methyl-6-oxo-6-phenylhexanoate 9e (97.2 mg, 0.349 mmol, 69% yield) and ethyl 3-((tert-butylidimethylsilyl)oxy)-6-oxo-3-phenylheptanoate 10e (12.6 mg, 33.3 μmol, 6.6% yield), respectively.

For 9e  
IR (neat) ν 2990, 2945, 2830, 1730, 1682, 1595, 1445, 1295, 1213, 1073, 743, 691 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 1.25 (3H, t, J = 7.2 Hz), 1.34 (3H, s), 2.01-2.10 (2H, m), 2.52 (1H, d, J = 13.5 Hz), 2.59 (1H, d, J = 13.5 Hz), 3.04-3.10 (2H, m), 3.22 (3H, s), 4.14 (2H, q, J = 7.2 Hz), 7.42-7.50 (2H, m), 7.53-7.58 (1H, m), 7.99 (2H, dd, J = 7.2, 2.4 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 14.2, 23.0, 31.5, 32.7, 43.3, 49.4, 60.5, 75.2, 128.1, 128.6, 133.0, 137.0, 170.7, 200.0; MS (ESI-TOF) m/z 301 [M+Na]⁺; HRMS calcd for C₁₆H₂₂NaO₄ [M+Na]⁺, 301.1416; found, 301.1414.  Anal. Calcd for C₁₆H₂₂O₄: C, 69.04; H, 7.97. Found: C, 68.86; H, 8.01.

For 10e  
Colorless oil; IR (neat) ν 2952, 2935, 2855, 1735, 1255, 1181, 1080, 838, 775, 700 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 1.28 (3H, t, J = 7.1 Hz), 1.31 (3H, s) and 1.33 (3H, s), 1.41-1.63 (2H, m), 1.96-2.07 (1H, m), 2.07-2.18 (1H, m), 2.86-2.89 (2H, m), 3.08 (3H, s) and 3.15 (3H, s), 3.13 (3H, d, J = 14.5 Hz), 3.79 (2H, d, J = 7.2 Hz); ¹³C NMR (100 MHz, CDCl₃) δ −2.3, −2.2, 13.9, 18.7, 26.1, 30.1, 35.4, 38.6, 48.3, 60.1, 77.7, 125.6, 126.8, 127.9, 144.6, 169.6, 208.4; MS (ESI-TOF) m/z 401 [M+Na]⁺; HRMS calcd for C₂₁H₃₄O₄Si [M+Na]⁺, 401.2111; found, 401.2124.

Ethyl 6-((tert-butylidimethylsilyl)oxy)-3,6-dimethoxy-3-phenylheptanoate (2f)

According to the synthetic procedure for 2a, this compound was obtained in 86% yield (185 mg, 0.435 mmol) as an inseparable mixture of diastereomers in a ratio of 1 : 1.1 by the reaction of 5,5-dimethoxy-5-phenylpentan-2-one 1f (112 mg, 0.505 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (121 mg, 0.598 mmol) in the presence of zwitterion 3 (2.6 mg, 4.9 μmol) in Et₂O (2.0 mL) for 30 min at 0 °C and the following column chromatography on silica gel (hexane/EtOAc = 15 : 1). Colorless oil; IR (neat) ν 2952, 2935, 2855, 1735, 1255, 1181, 1080, 838, 775, 700 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 0.05 (3H, s) and 0.07 (3H, s), 0.06 (3H, s) and 0.08 (3H, s), 0.86 (9H, s), 1.08 (3H, t, J = 7.1 Hz), 1.31 (3H, s) and 1.33 (3H, s), 1.41-1.63 (2H, m), 1.96-2.07 (1H, m), 2.07-2.18 (1H, m), 2.86-2.89 (2H, m), 3.08 (3H, s) and 3.15 (3H, s), 3.13 (3H, s) and 3.17 (3H, s), 3.93-4.04 (2H, m), 7.22-7.29 (1H, m), 7.31-7.39 (4H, m); ¹³C NMR (100 MHz, CDCl₃) δ −2.9, −2.74 and −2.69, 14.0, 18.2, 25.7 and 26.2, 25.9, 31.3 and 31.7, 33.6 and 33.9, 42.0 and 42.1, 48.4 and 48.6, 50.09 and 50.11, 60.2, 79.8, 100.59 and 100.63, 126.35 and 126.41, 127.15 and 127.21, 128.09 and 128.12, 142.7 and 142.8, 170.1; MS (ESI-TOF) m/z 447 [M+Na]⁺; HRMS calcd for C₂₃H₄₆NaO₅Si [M+Na]⁺, 447.2543; found, 447.2548.
Ethyl 3-methoxy-6-oxo-3-phenylheptanoate (9f)

According to the synthetic procedure for 9c, this compound was obtained in 83% yield (116 mg, 0.417 mmol) by the reaction of 5,5-dimethoxy-5-phenylpentan-2-one 1f (112 mg, 0.505 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (111 mg, 0.550 mmol) in the presence of zwitterion 3 (2.6 mg, 5.0 μmol) in Et₂O (2.0 mL) for 30 min at 0 °C followed by acid hydrolysis using AcOH-acetone-H₂O (1:1:1 v/v, 3.0 mL). Isolation of this compound was achieved by column chromatography on silica gel (hexane/EtOAc = 15 : 1). Colorless oil; IR (neat) ν 2980, 2945, 2901, 1738, 1722, 1184, 1070, 771, 703 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 1.05 (3H, t, J = 7.2 Hz), 2.08 (3H, s), 3.23 (1H, m), 2.30-2.45 (3H, m), 2.83 (1H, d, J = 13.6 Hz), 2.89 (1H, d, J = 13.6 Hz), 3.15 (3H, s), 3.96 (2H, q, J = 7.2 Hz), 7.24-7.29 (1H, m), 7.32-7.38 (4H, m); ¹³C NMR (100 MHz, CDCl₃) δ 14.0, 30.0, 30.2, 37.8, 42.5, 50.1, 60.3, 79.3, 126.3, 127.4, 128.2, 142.1, 169.8, 208.3; MS (ESI-TOF) m/z 301 [M+Na]⁺; HRMS calcd for C₁₆H₂₂NaO₄ [M + Na]⁺, 301.1416; found, 301.1410. Anal. Calcd for C₁₆H₂₂O₄: C, 69.04; H, 7.97. Found: C, 69.01; H, 8.02.

Ethyl 3-methoxy-6-oxo-3-phenyloctanoate (9g)

According to the synthetic procedure for 9c, this compound was obtained in 92% yield (135 mg, 0.462 mmol) by the reaction of 6,6-dimethoxy-6-phenylhexan-3-one 1g (118 mg, 0.500 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (121 mg, 0.598 mmol) in the presence of zwitterion 3 (2.6 mg, 5.0 μmol) in Et₂O (2.0 mL) for 30 min at 0 °C followed by acid hydrolysis using AcOH-acetone-H₂O (1:1:1 v/v, 3.0 mL). Isolation of this compound was achieved by column chromatography on silica gel (hexane/EtOAc = 15 : 1). Colorless oil; IR (neat) ν 2972, 2935, 2898, 1722, 1716, 1178, 1068, 763, 700 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 0.99 (3H, t, J = 7.3 Hz), 1.05 (3H, t, J = 7.1 Hz), 2.23-2.42 (6H, m), 2.83 (1H, d, J = 13.7 Hz), 2.89 (1H, d, J = 13.7 Hz), 3.16 (3H, s), 3.96 (2H, q, J = 7.1 Hz), 7.25-7.28 (1H, m), 7.32-7.37 (4H, m); ¹³C NMR (100 MHz, CDCl₃) δ 14.0, 30.0, 30.2, 37.8, 42.5, 50.1, 60.3, 79.4, 126.3, 127.4, 128.2, 142.1, 169.8, 211.0; MS (ESI-TOF) m/z 315 [M+Na]⁺; HRMS calcd for C₁₇H₂₄NaO₄ [M+Na]⁺, 315.1572; found, 315.1576.

Ethyl 3-methoxy-8-methyl-6-oxo-3-phenylnonanoate (9h)
According to the synthetic procedure for 9c, this compound was obtained in 91% yield (153 mg, 0.477 mmol) by the reaction of 1,1-dimethoxy-6-methyl-1-phenylheptan-4-one 1h (139 mg, 0.527 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (125 mg, 0.619 mmol) in the presence of zwitterion 3 (2.6 mg, 5.0 μmol) in Et₂O (2.0 mL) for 30 min at 0 °C followed by acid hydrolysis using AcOH-acetone-H₂O (1:1 v/v, 3.0 mL). Isolation of this compound was achieved by column chromatography on silica gel (hexane/EtOAc = 15 : 1). Colorless oil; IR (neat) ν 2951, 2870, 2825, 1721, 1712, 1442, 1364, 1180, 1068, 763, 699 cm⁻¹; 1H NMR (400 MHz, CDCl₃) δ 0.85 (3H, d, J = 6.4 Hz), 0.86 (3H, d, J = 6.8 Hz), 1.03 (3H, t, J = 7.2 Hz), 2.00-2.14 (1H, m), 2.15-2.43 (6H, m), 2.82 (1H, d, J = 13.7 Hz), 2.88 (1H, d, J = 13.7 Hz), 3.14 (3H, s), 3.95 (2H, q, J = 7.2 Hz), 7.22-7.27 (1H, m), 7.30-7.37 (4H, m); 13C NMR (100 MHz, CDCl₃) δ 14.0, 22.6, 24.7, 25.7, 29.9, 37.3, 42.6, 50.1, 51.9, 60.3, 79.4, 126.3, 127.3, 128.2, 142.2, 142.2, 169.8, 210.3; MS (ESI-TOF) m/z 343 [M+Na]+; HRMS calcd for C₁₉H₂₈O₄ [M+Na]+, 343.1885; found, 343.1891. Anal. Calcd for C₁₉H₂₈O₄: C, 71.22; H, 8.81. Found: C, 70.98; H, 8.86.

Ethyl 6-cyclopropyl-3-methoxy-6-oxo-3-phenylhexanoate (9i) and ethyl 3-((tert-butyl dimethylsilyl)oxy)-3-cyclopropyl-6-oxo-6-phenylhexanoate (10i)

According to the synthetic procedure for 9c, the reaction of 1-cyclopropyl-4,4-dimethoxy-4-phenylbutan-1-one 1i (124 mg, 0.500 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (121 mg, 0.598 mmol) in the presence of zwitterion 3 (2.6 mg, 5.0 μmol) in Et₂O (2.0 mL) for 30 min at 0 °C followed by acid hydrolysis using AcOH-acetone-H₂O (1:1 v/v, 3.0 mL) gave a crude mixture. Column chromatography of this mixture on silica gel (hexane/EtOAc = 15 : 1) gave ethyl 6-cyclopropyl-3-methoxy-6-oxo-3-phenylhexanoate 9i (73% yield, 111 mg, 0.365 mmol) and ethyl 3-((tert-butyl dimethylsilyl)oxy)-3-cyclopropyl-6-oxo-6-phenylhexanoate 10i (18% yield, 36.1 mg, 89.1 μmol), respectively.

For 9i Colorless oil; IR (neat) ν 2976, 2930, 2825, 1728, 1695, 1443, 1388, 1182, 1085, 900, 760, 700 cm⁻¹; 1H NMR (400 MHz, CDCl₃) δ 0.78-0.87 (2H, m), 0.90-1.01 (2H, m), 1.05 (3H, t, J = 7.1 Hz), 1.86 (1H, tt, J = 7.08, 1.6 Hz), 2.20-2.31 (1H, m), 2.37-2.60 (3H, m), 2.85 (1H, d, J = 13.7 Hz), 2.91 (1H, d, J = 13.7 Hz), 3.17 (3H, s), 3.96 (2H, q, J = 7.1 Hz), 7.24-7.29 (1H, m), 7.32 (4H, m); 13C NMR (100 MHz, CDCl₃) δ 10.7, 14.0, 20.5, 30.2, 37.5, 42.6, 50.1, 60.3, 79.4, 126.3, 127.3, 128.2, 142.2, 169.8, 210.3; MS (ESI-TOF) m/z 327 [M+Na]+; HRMS calcd for C₁₉H₂₈O₄ [M+Na]+, 327.1572; found, 327.1572.

For 10i Colorless oil; IR (neat) ν 2976, 2930, 2825, 1731, 1684, 1207, 1062, 838, 771 cm⁻¹; 1H NMR (400 MHz, CDCl₃) δ 0.12 (6H, s) 0.32-0.46 (3H, m), 0.50-0.58 (1H, m), 0.86 (9H, s), 1.08-1.15 (1H, m), 1.26 (3H, t, J = 7.1 Hz), 2.02 (1H, ddd, J = 14.0, 11.0, 4.6 Hz), 2.22 (1H, ddd, J = 14.0, 11.0, 5.2 Hz), 2.59 (1H, d, J = 14.8 Hz), 2.61 (1H, d, J = 14.8 Hz), 3.11 (1H, ddd, J = 16.8, 11.0, 4.6 Hz), 3.26 (1H, ddd, J = 16.8, 11.0, 5.2 Hz), 4.13 (2H, q, J = 7.1 Hz), 7.42-7.50 (2H, m), 7.56 (1H, t, J = 7.4 Hz), 7.97 (2H, d, J = 7.1 Hz); 13C NMR (100 MHz, CDCl₃) δ -2.1, -2.0, 0.4, 2.0, 14.2, 18.6, 19.6, 25.9, 33.5, 34.3, 47.0, 60.4, 74.7, 128.0, 128.6,
132.9, 137.1, 170.6, 200.2; MS (ESI-TOF) m/z 427 [M+Na]^+; HRMS calcd for C_{23}H_{36}O_4Si [M+Na]^+, 427.2281; found, 427.2285.

**Ethyl 3-methoxy-6-oxo-3-phenylhexanoate (9j)**

![Structural formula of 9j](image)

According to the synthetic procedure for 9c, the reaction of 4,4-dimethoxy-4-phenylbutanal 1j (104 mg, 0.500 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (121 mg, 0.598 mmol) in the presence of zwitterion 3 (2.6 mg, 5.0 μmol) in Et₂O (2.0 mL) for 30 min at 0 °C followed by acid hydrolysis using AcOH-acetone-H₂O (1:1:1 v/v, 3.0 mL) gave a mixture of ethyl 3-methoxy-6-oxo-3-phenylhexanoate 9j and 4-oxo-4-phenylbutanal in a ratio of 6.6 : 1 after column chromatography on silica gel (hexane/EtOAc = 10 : 1). Separation of these compounds was achieved by recycling preparative HPLC technique (hexane/EtOAc = 3 : 1) and 9j was isolated in 71% yield (93.9 mg, 0.356 mmol). Colorless oil; IR (neat) ν 2998, 2957, 2841, 1722, 1442, 1324, 1182, 699 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 1.09 (3H, t, J = 7.2 Hz), 2.21-2.30 (1H, m), 2.31-2.42 (2H, m), 2.42-2.53 (1H, m), 2.88 (1H, d, J = 13.8 Hz), 2.92 (1H, d, J = 13.8 Hz), 3.16 (3H, s), 4.01 (2H, q, J = 7.2 Hz), 7.24-7.31 (1H, m), 7.33-7.38 (4H, m), 9.69 (1H, t, J = 1.4 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 14.0, 29.3, 38.5, 42.0, 50.3, 60.4, 79.4, 126.3, 127.5, 128.3, 141.8, 169.8, 201.7; MS (ESI-TOF) m/z 287 [M+Na]^+; HRMS calcd for C_{15}H_{20}NaO₄ [M+Na]^+, 287.1259; found, 287.1260.

**Ethyl 6-((tert-butyldimethylsilyl)oxy)-3,6-diethoxy-3-phenyloctanoate (2k)**

![Structural formula of 2k](image)

According to the synthetic procedure for 2a, this compound was obtained in 93% yield (217 mg, 0.465 mmol) as an inseparable mixture of diastereomers in a ratio of 1 : 1.0 by the reaction of 6,6-diethoxy-6-phenylhexan-3-one 1k (132 mg, 0.500 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (182 mg, 0.901 mmol) in the presence of zwitterion 3 (2.6 mg, 5.0 μmol) in Et₂O (2.0 mL) for 30 min at 0 °C after column chromatography on silica gel (hexane/EtOAc = 10 : 1). Colorless oil; IR (neat) ν 2973, 2926, 2874, 1737, 1249, 1075, 837, 775 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 0.04 (3H, s), 0.05 (1.5H, s) and 0.06 (1.5H, s), 0.80 (1.5H, t, J = 7.4 Hz) and 0.82 (1.5H, t, J = 7.5 Hz), 0.84 (9H, s), 1.03-1.12 (6H, m), 1.17 (3H, t, J = 7.0 Hz), 1.45-1.49 (1H, m), 1.51-1.65 (3H, m), 1.96-2.14 (2H, m), 2.88 (1H, d, J = 14.0 Hz), 2.92 (1H, d, J = 14.0 Hz), 3.19-3.25 (0.5H, m) and 3.30-3.39 (3.5H, m), 3.95-4.01 (2H, m), 7.22-7.26 (1H, m), 7.31-7.39 (4H, m); ¹³C NMR (100 MHz, CDCl₃) δ −2.70 and −2.51, −2.65 and −2.53, 8.4 and 8.5, 14.0, 15.38, 15.48 and 15.50, 18.3, 26.0, 30.4 and 30.8, 30.9 and 31.3, 31.4 and 31.6, 42.4 and 42.5, 55.7 and 55.9, 57.2, 60.2, 79.4 and 79.5, 102.68 and 102.70, 126.29 and 126.30, 127.0, 127.98 and 128.00, 143.5 and 143.6, 170.1 and 170.2; MS (ESI-TOF) m/z 489 [M+Na]^+; HRMS calcd for
C$_{26}$H$_{46}$O$_5$Si [M+Na]$^+$, 489.3012; found, 489.3013.

**Ethyl 3-ethoxy-6-oxo-3-phenyloctanoate (9k)**

![9k](image)

According to the synthetic procedure for 9c, this compound was obtained in 92% yield (72.4 mg, 0.236 mmol) by the reaction of 6,6-diethoxy-6-phenylhexan-3-one 1k (120 mg, 0.257 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (121 mg, 0.598 mmol) in the presence of zwitterion 3 (2.6 mg, 4.9 mmol) in Et$_2$O (2.0 mL) for 30 min at 0 °C followed by acid hydrolysis using AcOH-acetone-H$_2$O (1:1:v/v, 3.0 mL) for 1.5 h at room temperature. Isolation of this compound was achieved by column chromatography on silica gel (hexane/EtOAc = 15 : 1). Colorless oil; IR (neat) ν 2990, 2935, 2898, 1724, 1715, 1444, 1368, 1198, 1070, 764, 699 cm$^{-1}$; $^1$H NMR (400 MHz, CDCl$_3$) δ 1.00 (3H, t, $J$ = 7.2 Hz), 1.05 (3H, t, $J$ = 7.2 Hz), 1.17 (3H, t, $J$ = 7.0 Hz), 2.19-2.28 (2H, m), 2.28-2.45 (4H, m), 2.92 (1H, d, $J$ = 13.6 Hz), 2.95 (1H, d, $J$ = 13.6 Hz), 3.26 (2H, q, $J$ = 7.0 Hz), 3.96 (2H, q, $J$ = 7.2 Hz), 7.25 (1H, tt, $J$ = 6.9, 1.6 Hz), 7.31-7.39 (4H, m); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 7.81, 14.0, 15.4, 30.7, 36.0, 36.5, 43.0, 57.4, 60.3, 79.0, 126.2, 127.2, 128.1, 142.8, 169.9, 211.1; MS (ESI-TOF) m/z 329 [M+Na]$^+$; HRMS calcd for C$_{18}$H$_{26}$NaO$_4$ [M+Na]$^+$, 329.1729; found, 329.1738.

**Ethyl 3-methoxy-2,2-dimethyl-6-oxo-3-phenylheptanoate (9f’)**

To a solution of 5,5-dimethoxy-5-phenylpentan-2-one 1f (112 mg, 0.504 mmol) and carbon acid 8 (10.0 mg, 9.98 μmol) in Et$_2$O (0.5 mL), a solution of tert-butyl((1-ethoxy-2-methylprop-1-en-1-yl)oxy)dimethylsilane 5b (173 mg, 0.752 mmol) in Et$_2$O (0.5 mL) was added at 0 °C. After being stirred for 1 h at 0 °C, additional 8 (10.0 mg, 9.98 μmol) was added to the reaction mixture, then the reaction mixture was further stirred for 2 h. After that, the resulting mixture was treated with Et$_3$N (0.3 mL) to quench the reaction and concentrated under reduced pressure. After acid hydrolysis of thus obtained residue by using AcOH-acetone-H$_2$O (1:1:v/v, 3.0 mL) for 1 h at room temperature followed by usual extractive workup, the resulting residue was purified by column chromatography on silica gel (hexane/EtOAc = 15 : 1) to give ethyl 3-methoxy-2,2-dimethyl-6-oxo-3-phenylheptanoate 9f’ in 85% yield (131 mg, 0.428 mmol). Colorless oil; IR (neat) ν 3040, 2990, 2853, 1722, 1709, 1443, 1358, 1260, 1140, 762, 709 cm$^{-1}$; $^1$H NMR (400 MHz, CDCl$_3$) δ 1.10 (3H, s), 1.15 (3H, s), 1.16 (3H, t, $J$ = 7.1 Hz), 2.08 (3H, s), 2.32-2.43 (1H, m), 2.47-2.72 (3H, m), 3.21 (3H, s), 4.03 (2H, q, $J$ = 7.1 Hz), 7.21-7.33 (5H, m); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 14.0, 22.5, 22.8, 24.6, 30.2, 39.4, 51.3, 51.8, 60.5, 84.1, 127.0, 127.3, 128.1, 140.5, 176.2, 208.0; MS (ESI-TOF) m/z 329 [M+Na]$^+$; HRMS calcd for C$_{18}$H$_{26}$O$_4$ [M+Na]$^+$, 329.1729; found, 329.1735.
Ethyl 3-methoxy-7-oxo-3-phenyloctanoate (9m) and ethyl 3-((tert-butyldimethylsilyl)oxy)-3-methyl-7-oxo-7-phenylheptanoate (10m)

According to the synthetic procedure for 9c, the reaction of 6,6-dimethoxy-6-phenylhexan-2-one 1m (118 mg, 0.499 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (162 mg, 0.800 mmol) in DME (20 mL) was conducted in the presence of zwitterion 3 (2.6 mg, 4.9 μmol) for 30 min at 0 °C. The sequential acid hydrolysis using AcOH-acetone-H₂O (1:1:1 v/v, 3.0 mL) gave ethyl 3-methoxy-7-oxo-3-phenyloctanoate 9m (89.6 mg, 0.306 mmol, 61% yield) and ethyl 3-((tert-butyldimethylsilyl)oxy)-3-methyl-7-oxo-7-phenylheptanoate 10m (28.9 mg, 73.6 μmol, 15% yield) after column chromatography on silica gel (hexane/EtOAc = 10 : 1) followed by additional recycling preparative HPLC (hexane/EtOAc = 2 : 1). At the same time, 1-phenylhexane-1,5-dione was also isolated in 10% yield (9.3 mg, 49 μmol).

For 9m Colorless oil; IR (neat) ν 2989, 2960, 2853, 1727, 1718, 1368, 1182, 700 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 1.09 (3H, t, J = 7.1 Hz) 1.37-1.48 (1H, m), 1.48-1.60 (1H, m), 1.91-2.07 (2H, m), 2.08 (3H, s), 2.39 (2H, t, J = 7.3 Hz), 2.85 (1H, d, J = 13.8 Hz), 2.92 (1H, d, J = 13.8 Hz), 4.00 (2H, q, J = 7.1 Hz), 7.21-7.29 (1H, m), 7.30-7.39 (4H, m); ¹³C NMR (100 MHz, CDCl₃) δ 14.0, 17.8, 29.8, 36.4, 41.4, 43.7, 50.2, 60.3, 79.9, 126.3, 127.3, 128.2, 142.6, 170.1, 208.7; MS (ESI-TOF) m/z 315 [M+Na]+; HRMS calcd for C₁₇H₂₄NaO₄ [M+Na]+, 315.1572; found, 315.1573.

For 10m Colorless oil; IR (neat) ν 2961, 2937, 2854, 1731, 1687, 1254, 1040, 837 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 0.075 (3H, s) 0.083 (3H, s), 0.84 (9H, s), 1.24 (3H, t, J = 7.2 Hz), 1.38 (3H, s), 1.64-1.71 (2H, m), 1.76-1.88 (2H, m), 2.50 (2H, s), 2.97 (2H, t, J = 7.4 Hz), 4.09 (2H, q, J = 7.2 Hz), 7.42-7.49 (2H, m), 7.55 (1H, tt, J = 7.4, 1.4 Hz), 7.96 (2H, dt, J = 8.5, 1.4 Hz); ¹³C NMR (100 MHz, CDCl₃) δ −2.1, −2.0, 14.2, 18.1, 19.2, 25.8, 27.9, 39.0, 42.3, 46.8, 60.2, 74.6, 128.1, 128.6, 132.9, 137.0, 171.1, 200.1; MS (ESI-TOF) m/z 415 [M+Na]+; HRMS calcd for C₂₂H₃₆NaO₄ [M+Na]+, 415.2281; found, 415.2279.

4. Carbonyl-selective Mukaiyama Aldol Reaction
Ethyl 2-(1-((tert-butyldimethylsilyl)oxy)-4,4-dimethoxy-1,2,3,4-tetrahydronaphthalen-1-yl)acetate (7b)

This compound was obtained in 78% yield (160 mg, 0.391 mmol) by the reaction of 4,4-dimethoxy-3,4-dihydronaphthalen-1(2H)-one 1b (103 mg, 0.500 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (122 mg, 0.603 mmol) in Et₂O (2.0 mL) for 10 min at 0 °C and the following column chromatography on silica gel (hexane/EtOAc = 5 : 1). Colorless oil; IR (neat) ν 2950, 2819, 1732, 1180, 1056, 998, 833, 778, 762 cm⁻¹;
A study using a mixture of benzaldehyde and its dimethyl acetal

To a solution of benzaldehyde (54.1 mg, 0.510 mmol), (dimethoxymethyl)benzene (78.1 mg, 0.513 mmol), and zwitterion 3 (2.6 mg, 4.9 μmol) in CH₂Cl₂ (1.5 mL), a solution of tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (121 mg, 0.598 mmol) in CH₂Cl₂ (0.5 mL) was added at –78 °C. After being stirred for 30 min at the same temperature, the reaction was quenched by addition of Et₃N (0.3 mL). After usual extractive workup, the reaction mixture was purified by column chromatography on silica gel to give ethyl 3-((tert-butyldimethylsilyl)oxy)-3-phenylpropanoate in 97% yield (153 mg, 0.496 mmol). The ratio of ethyl 3-((tert-butyldimethylsilyl)oxy)-3-phenylpropanoate and ethyl 3-methoxy-3-phenylpropanoate (chemoselectivity = >97 : 3) was determined by ¹H NMR analysis of crude mixture. Colorless oil; IR ( neat) ν 2958, 2940, 2852, 1738, 1256, 1087, 836, 777 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ –0.18 (3H, s), 0.02 (3H, s), 0.84 (9H, s), 1.25 (3H, t, J = 7.1 Hz), 2.54 (1H, dd, J = 14.7, 4.0 Hz), 2.72 (1H, dd, J = 14.7, 9.3 Hz), 4.01-4.20 (2H, m), 5.14 (1H, dd, J = 9.3, 4.0 Hz), 7.22-7.27 (1H, m), 7.29-7.36 (4H, m); ¹³C NMR (100 MHz, CDCl₃) δ –5.3 and –4.7, 14.2, 43.6, 56.9, 60.6, 80.1, 126.6, 128.0, 128.6, 140.6, 171.0; MS (ESI-TOF) m/z 331 [M+Na⁺]; HRMS calcd for C₁₇H₂₈NaO₃Si [M+Na⁺], 331.1705; found, 331.1707. Anal. Calcd for C₁₇H₂₈O₃Si: C, 66.19; H, 9.15. Found: C, 65.93; H, 9.36.

Authentic sample of ethyl 3-methoxy-3-phenylpropanoate was prepared as follows.

According to the above synthetic procedure, ethyl 3-methoxy-3-phenylpropanoate was obtained in 39% yield (40.7 mg, 0.195 mmol) by the reaction of (dimethoxymethyl)benzene (76.1 mg, 0.500 mmol) with tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (121 mg, 0.598 mmol) in the presence of zwitterion 3 (2.6 mg, 5.0 μmol) for 1 h at 0 °C and the following column chromatography on silica gel (hexane/EtOAc = 20 : 1). Its structure was confirmed by comparison of ¹H and ¹³C NMR data reported in the literature.¹¹ ¹H NMR (400 MHz, CDCl₃) δ 1.24 (3H, t, J = 7.1 Hz), 2.57 (1H, dd, J = 15.3, 4.7 Hz), 2.80 (1H, dd, J = 15.3, 9.2 Hz), 3.22 (3H, s), 4.11-4.19 (2H, m), 4.64 (1H, dd, J = 9.2, 4.7 Hz), 7.28-7.39 (5H, m); ¹³C NMR (100 MHz, CDCl₃) δ 14.2, 43.6, 56.9, 60.6, 80.1, 126.6, 128.0, 128.6, 140.6, 171.0.
5. A Crossover Study Using a Mixture of 5,5-Dimethoxy-5-phenylpentan-2-one (1f) and
6,6-Diethoxy-6-phenylhexan-3-one (1k)

To a solution of 5,5-dimethoxy-5-phenylpentan-2-one 1f (55.6 mg, 0.250 mmol),
6,6-diethoxy-6-phenylhexan-3-one 1k (66.1 mg, 0.250 mmol), and zwitterion 3 (2.6 mg, 5.0 μmol) in Et₂O (1.5 mL),
a solution of tert-butyl((1-ethoxyvinyl)oxy)dimethylsilane 5a (121 mg, 0.598 mmol) in Et₂O (0.5 mL)
was added at 0 °C. After being stirred for 15 min at the same temperature, the reaction was quenched with Et₃N (0.3 mL)
and the resulting mixture was quickly concentrated under reduced pressure. Chromatographic purification
of the resulting residue gave ethyl 6-((tert-butyldimethylsilyl)oxy)-3,6-dimethoxy-3-phenylheptanoate 2f (82% yield, 87.5 mg, 0.206 mmol) and
ethyl 6-((tert-butyldimethylsilyl)oxy)-3,6-diethoxy-3-phenyloctanoate 2k (81% yield, 94.8 mg, 0.203 mmol),
respectively. In this study, any evidences of scrambling the alkoxy groups were not observed.
6. $^1$H and $^{13}$C NMR Spectra of All Compounds
HMQC of less-2a

HMBC of less-2a
HSQC of more-2a

HMBC of more-2a
HMOC of 2c

HMBC of 2c
Me
EtO₂C
OMe

9f

Current Data Parameters
NAME: TD-544
EXTRD: 1
F2 - Acquisition Parameters
Data: 20140920
TEMP: 19.19
FIDFORM: 5 mm PABRO RR
PERSIST: 299.30
TD: 65.54
SOLVENT: CDCl₃
NS: 217
DS: 405788 1.00 Hz
VFO: 5.2500000000 nHz
AQ: 1.9631999999 sec
RG: 201.44
DW: 20.0000000000 sec
dE: 5.50 usec
TE: 290.6 µsec
T1: 1.0000000000 sec
T2: 1

---- CHANNEL F1 -----
WD: 3
F1: 10.00 usec
FWM: 78.300000000
FWM: 100.6256293 MHz

---- CHANNEL F2 -----
WD: 18
PW: 90.00 usec
PLW: 16.00000000000
PLL: 0.197500000
PFL: 0.14000000000
SPFL: 400.1140000 MHz

F2 - Processing parameters
FL: 37.748
SF: 100.6256293 MHz
FWM: 1
LH: 0
SH: 1.00 Hz
FH: 1.40
HMOC spectrum of 7b

HMBC spectrum of 7b
7. References


