Supporting Information

Catalytic Asymmetric Epoxidation of α,β -Unsaturated Amides: Efficient Synthesis of β -Aryl α -Hydroxy Amides Using a One Pot Tandem Catalytic Asymmetric Epoxidation–Pd-Catalyzed Epoxide Opening Process

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Experimental Procedures and Characterization of the Products

General: Infrared (IR) spectra were recorded on a JASCO FT/IR 410 Fourier transform infrared spectrophotometer. NMR spectra were recorded on a JEOL JNM-LA500 spectrometer, operating at 500 MHz for ^1H NMR and 125.65 MHz for ^{13}C NMR. Chemical shifts in CDCl_3 were reported downfield from TMS (= 0 ppm) for ^1H NMR. For ^{13}C NMR, chemical shifts were reported downfield from TMS (= 0 ppm) or in the scale relative to CHCl_3 (77.00 ppm for ^{13}C NMR) as an internal reference. Optical rotations were measured on a JASCO P-1010 polarimeter. ESI mass spectra were measured on Waters micromass ZQ. EI mass spectra were measured on JEOL JMS-DX303 or JMS-BU20 Gcmate. The enantiomeric excess (ee) was determined by HPLC analysis. HPLC was performed on JASCO HPLC systems consisting of the following: pump, 880-PU or PU-980; detector, 875-UV or UV-970, measured at 254 nm; column, DAICEL CHIRALPAK AS, CHIRALPAK AS-H, DAICEL CHIRALCEL OD-H; mobile phase, hexane–2-propanol; flow rate, 0.5–1 mL/min. Reactions were carried out in dry solvents under an argon atmosphere, unless otherwise stated. $\text{Ln}(\text{O-}i\text{-Pr})_3$ was purchased from Kojundo Chemical Laboratory Co., LTD., 5-1-28, Chiyoda, Sakado-shi, Saitama 350-0214, Japan (fax: +(81)-492-84-1351). Other reagents were purified by the usual methods.

Synthesis of the α,β -Unsaturated Amides 2a–2o. All of the α,β -unsaturated amides were prepared from the corresponding acid chlorides and amines. For the compounds **2i**, see: *Bull. Chem. Soc. Jpn.* **1976**, 49, 493. For the compound **2k**, see: *J. Org. Chem.* **1991**, 56, 553. For the compound **2l**, see: *Tetrahedron* **2001**, 31, 8705. For the compound **2m**, see: *Synth. Commun.* **2001**, 31, 1201. For the compound **2o**, see: *Tetrahedron* **1989**, 45, 4415.

5-Phenyl-pent-2-enoic acid methylamide (2a): white yellow solid; IR (KBr) ν 3303, 2924, 1668, 1624, 1557, 1498, 1454, 1410, 1353, 1159 959, 697 cm^{-1} ; ^1H NMR (CDCl_3) δ 2.49 (ddt, J = 7.6, 7.0, 1.1 Hz, 2H), 2.76 (t, J = 7.6 Hz, 2H), 2.85 (d, J = 4.9 Hz, 1H), 5.53 (br-s, 1H), 5.76 (dt, J = 15.3, 1.1 Hz, 1H), 6.85 (dt, J = 15.3, 7.0 Hz, 1H), 7.16–7.29 (m, 5H); ^{13}C

NMR (CDCl₃) δ 26.2, 33.7, 34.6, 124.0, 126.1, 128.3 (x 2), 128.4 (x 2), 141.0, 143.2, 166.5; ESI-MS m/z 212 [M+Na⁺], 189 [M+H⁺]; Anal. Calcd for C₁₂H₁₅NO: C, 76.16; H, 7.99; N, 7.40. Found: C, 76.15; H, 8.06; N, 7.38.

5-Phenyl-pent-2-enoic acid benzylamide (2b): white-yellow solid; IR (KBr) ν 3224, 3061, 1661, 1615, 1557, 1452, 1424, 1337, 1266, 1221, 1040 cm⁻¹; ¹H NMR (CDCl₃) δ 2.49 (ddt, J = 1.5, 7.0, 7.8 Hz, 2H), 2.76 (t, J = 7.8 Hz, 2H), 4.52 (d, J = 5.8 Hz, 2H), 5.75 (br-t, 1H), 5.79 (dt, J = 15.3, 1.5 Hz, 1H), 6.91 (dt, J = 15.3, 7.0 Hz, 1H), 7.15–7.43 (m, 10H); ¹³C NMR (CDCl₃) δ 33.8, 34.6, 43.6, 123.9, 126.1, 127.5, 127.9 (x 2), 128.3 (x 2), 128.4 (x 2), 128.7 (x 2), 138.3, 141.0, 144.0, 165.7; ESI-MS m/z 288 [M+Na⁺]; Anal. Calcd for C₁₈H₁₉NO: C, 81.47; H, 7.22; N, 5.28. Found: C, 81.50; H, 7.40; N, 5.20.

5-Phenyl-pent-2-enoic acid allylamide (2c): white solid; IR (KBr) ν 3295, 3061, 3027, 2921 1670, 1625, 1549, 1452, 1360, 1253, 990, 917 cm⁻¹; ¹H NMR (CDCl₃) δ 2.50 (ddt, J = 1.5, 7.0, 7.6 Hz, 2H), 2.76 (t, J = 7.6 Hz, 2H), 3.93 (ddd, J = 1.3, 1.5, 4.1 Hz, 2H), 5.13 (ddt, J = 1.5, 10.2, 1.3 Hz, 1H), 5.18 (ddt, J = 1.5, 17.1, 1.5 Hz, 1H), 5.80 (dt, J = 15.2, 1.5 Hz, 1H), 5.85 (ddt, J = 10.2, 17.1, 4.1 Hz, 1H), 6.89 (dt, J = 15.2, 7.0 Hz, 1H), 7.10–7.43 (m, 5H); ¹³C NMR (CDCl₃) δ 33.8, 34.6, 41.9, 116.5, 126.1, 128.4 (x 2), 128.4 (x 2), 134.2, 141.0, 143.8, 165.6; ESI-MS m/z 238 [M+Na⁺], 216 [M+H⁺]; Anal. Calcd for C₁₄H₁₇NO: C, 78.10; H, 7.96; N, 6.51. Found: C, 78.18; H, 7.98; N, 6.43.

5-Phenyl-pent-2-enoic acid cyclohexylamide (2d): white solid; IR (KBr) ν 3299, 3065, 3027, 2921, 2851, 1669 1626, 1545, 1445 1350, 1220, 978, 697 cm⁻¹; ¹H NMR (CDCl₃) δ 1.09–1.21 (m, 3H), 1.34–1.42 (m, 2H), 1.60–1.72 (m, 3H), 1.92–1.95 (m, 2H), 2.48 (ddt, J = 1.6, 7.0, 8.0 Hz, 2H), 2.75 (t, J = 8.0 Hz, 2H), 3.83 (m, 1H), 5.74 (dt, J = 15.3, 1.6 Hz, 1H), 6.85 (dt, J = 15.3, 7.0 Hz, 1H), 7.16–7.29 (m, 5H); ¹³C NMR (CDCl₃) δ 24.8 (x 2), 25.6 (x 2), 33.2 (x 2), 33.8, 34.6, 48.1, 124.5, 126.1, 128.3 (x 2), 128.4 (x 2), 141.1, 143.1, 164.9; ESI-MS m/z 280 [M+Na⁺], 258 [M+H⁺]; Anal. Calcd for C₁₂H₁₅NO: C, 79.33; H, 9.01; N, 5.44. Found: C, 79.03; H, 8.95 N, 5.31.

5-Phenyl-pent-2-enoic acid *tert*-butylamide (2e): white solid; IR (KBr) ν 3259, 3067, 2959, 1663, 1627, 1557, 1450, 1361, 1227, 975, 705 cm⁻¹; ¹H NMR (CDCl₃) δ 1.38 (s, 9H), 2.47 (ddd, J = 7.8, 6.7, 1.6 Hz, 2H), 2.75 (t, J = 7.8 Hz, 2H), 5.24 (s, 1H), 5.71 (dt, J = 15.3, 1.6 Hz, 1H), 6.82 (dt, J = 15.3, 6.7 Hz, 1H), 7.16–7.30 (m, 5H); ¹³C NMR (CDCl₃) δ 28.9 (x 3), 33.7, 34.7, 51.2, 125.2, 126.0, 128.3 (x 2), 128.4 (x 2), 141.1, 142.6, 165.2; ESI-MS m/z 254 [M+Na⁺], 232 [M+H⁺]; Anal. Calcd for C₁₂H₁₅NO: C, 77.88; H, 9.15; N, 6.05. Found: C, 77.69; H, 8.90; N, 5.89.

5-Phenyl-pent-2-enoic acid dimethylamide (2f): yellow oil; IR (neat) ν 3472, 3025, 2928, 1660, 1616, 1495, 1454, 1395, 1141, 749, 701 cm⁻¹; ¹H NMR (CDCl₃) δ 2.52 (ddt, J = 1.5, 7.0, 7.6 Hz, 2H), 2.77 (t, J = 7.6 Hz, 2H), 2.98 (s, 6H), 6.21 (dt, J = 15.0, 1.5 Hz, 1H), 6.88 (dt, J = 15.0, 7.0 Hz, 1H), 7.16–7.28 (m, 5H); ¹³C NMR (CDCl₃) δ 34.1, 34.6, 121.0, 125.9, 128.3 (x 2), 128.3 (x 2), 141.0, 144.6, 166.7; ESI-MS m/z 226 [M+Na⁺], 204 [M+H⁺]; HRMS (M⁺) Calcd for C₁₃H₁₇NO: 203.1310. Found 203.1300.

5-Phenyl-1-pyrrolidin-1-yl-pent-2-en-1-one (2g): yellow oil; IR (neat) ν 3476, 3025, 2927, 2875, 1652, 1455, 1415, 1341, 751, 701 cm^{-1} ; ^1H NMR (CDCl_3) δ 1.84–1.90 (m, 4H), 2.51 (ddt, J = 1.0, 7.1, 7.7 Hz, 2H), 2.76 (t, J = 7.7 Hz, 2H), 3.46 (m, 4H), 6.08 (dt, J = 15.4, 1.0, Hz, 1H), 6.94 (dt, J = 15.4, 7.1 Hz, 1H), 7.17–7.28 (m, 5H); ^{13}C NMR (CDCl_3) δ 24.1, 25.9, 33.9, 34.5, 45.5, 46.2, 122.2, 125.7, 128.1 (x 2), 128.2 (x 2), 140.9, 144.0, 164.5; ESI-MS m/z 252 $[\text{M}+\text{Na}^+]$, 230 $[\text{M}+\text{H}^+]$; HRMS (M^+) Calcd for $\text{C}_{15}\text{H}_{19}\text{NO}$: 229.1467. Found 229.1466.

7-Phenyl-hept-2-enoic acid methylamide (2h): white solid; IR (KBr) ν 3301, 3026, 2931, 2855, 1627, 1159, 977, 746, 701 cm^{-1} ; ^1H NMR (CDCl_3) δ 1.46–1.51 (m, 2H), 1.61–1.67 (m, 2H), 2.17–2.21 (m, 2H), 2.61 (t, J = 7.6 Hz, 2H), 2.86 (d, J = 4.0 Hz, 3H), 5.51 (br-s, 1H), 5.73 (d, J = 15.3 Hz, 1H), 6.81 (dt, J = 6.7, 15.3 Hz, 1H), 7.15–7.19 (m, 3H), 7.23–7.29 (m, 2H); ^{13}C NMR (CDCl_3) δ 26.2, 27.8, 30.9, 31.8, 35.6, 123.4, 125.7, 128.2 (x 2), 128.3 (x 2), 142.2, 144.4, 166.9; ESI-MS m/z 240 $[\text{M}+\text{Na}^+]$, 218 $[\text{M}+\text{H}^+]$; HRMS (M^+) Calcd for $\text{C}_{14}\text{H}_{19}\text{NO}$: 217.1467. Found 217.1468.

N-Benzyl-3-cyclohexyl-acrylamide (2j): white solid; IR (KBr) ν 3287, 3065, 3032, 2915, 2851, 1666, 1625, 1548, 1337, 1238, 985, 695 cm^{-1} ; ^1H NMR (CDCl_3) δ 1.07–1.30 (m, 6H), 1.63–1.73 (m, 4H), 2.09–2.14 (m, 1H), 4.48 (d, J = 3.3 Hz, 2H), 5.72 (d, J = 15.3 Hz, 1H), 6.82 (dd, J = 15.3, 6.7 Hz, 1H), 7.24–7.32 (m, 5H); ^{13}C NMR (CDCl_3) δ 25.7, 25.9, 31.9, 40.2, 43.6, 120.8, 127.5, 127.9, 128.7, 138.3, 150.3, 166.2; ESI-MS m/z 266 $[\text{M}+\text{Na}^+]$, 244 $[\text{M}+\text{H}^+]$; HRMS (M^+) Calcd for $\text{C}_{16}\text{H}_{21}\text{NO}$: 243.1623. Found 243.1618.

3-(4-Fluoro-phenyl)-N-methyl-acrylamide (2n): white solid; IR (KBr) ν 3262, 3077, 1660, 1613, 1567, 1509, 1342, 1224, 1160, 985, 831, 509 cm^{-1} ; ^1H NMR (CDCl_3) δ 2.92 (d, J = 4.6 Hz, 3H), 5.65 (br-s, 1H), 6.28 (d, J = 15.5 Hz, 1H), 7.00–7.04 (m, 2H), 7.43–7.46 (m, 2H), 7.56 (d, J = 15.5 Hz, 1H); ^{13}C NMR (CDCl_3) δ 26.4, 115.7 (d, J = 21.7 Hz) (x 2), 120.4, 129.4 (d, J = 8.2 Hz) (x 2), 131.0, 139.4, 163.43 (d, J = 250 Hz) (x 2), 166.72; ESI-MS m/z 202 $[\text{M}+\text{Na}^+]$, 180 $[\text{M}+\text{H}^+]$; HRMS (M^+) Calcd for $\text{C}_{10}\text{H}_{10}\text{FNO}$: 179.0746. Found 179.0745

Synthesis of the α , β -Epoxy Amides 3a–o Using the Sm–(S)-BINOL– $\text{Ph}_3\text{As}=\text{O}$ Complex and Enantiomeric Analysis of 3a–o. The α , β -epoxy amides **3a–o** were prepared according to the general procedure of catalytic asymmetric epoxidation of α , β -unsaturated amides. For the known compound **3j**, see: *J. Org. Chem.* **1985**, 50, 5696. For the known compound **3k**, see: *J. Chem. Soc. Perkin Trans 1* **1988**, 2663. For the known compound **3l**, see: *J. Am. Chem. Soc.* **2001**, 123, 9474. For the known compound **3m**, see: *Tetrahedron Lett.* **1998**, 39, 1017. The absolute configurations of **3k** and **3l** were determined by comparing the measured optical rotations with the reported ones. The absolute configurations of **3a**, **3b**, **3f** and **3j** were determined by comparing the measured optical rotations with the authentic samples, which were prepared by the method shown in the Scheme SI–1.

General Procedure for the Catalytic Asymmetric Epoxidation of β -Alkyl Substituted α,β -Unsaturated Amides Using the Sm-BINOL-Ph₃As=O Complex **4.** To a mixture of (*S*)-BINOL (14.3 mg, 0.05 mmol), triphenylarsine oxide (16.1 mg, 0.05 mmol) and MS 4A [500 mg (1000 mg/mmol of starting material); MS 4A was not dried.] in dry THF (5 mL) was added a solution of Sm(O-*i*-Pr)₃ (0.5 mL, 0.05 mmol, 0.1 M solution in THF) at room temperature. After being stirred for 45 min at the same temperature, TBHP (0.12 mL, 0.6 mmol, 5 M solution in decane) was added. After being stirred for 10 min, amide **2a** (94.6 mg, 0.5 mmol) was added directly and the mixture was stirred at room temperature. After complete consumption of the starting material (8 h), the reaction mixture was diluted with ethyl acetate (20 mL) and quenched with 2% aqueous citric acid (5 mL). The water layer was extracted with ethyl acetate (10 mL), the combined organic layers were washed with brine (10 mL) and dried over sodium sulphate. After concentration in *vacuo*, the residue was purified by flash chromatography (SiO₂, hexane/ethyl acetate = 4/1 to 3/1) to give epoxy amide **3a** (101.9 mg, 99%) as a white yellow solid. IR (KBr) ν 3294, 3124, 1656, 1580, 1450, 1267, 902, 742, 695 cm⁻¹; ¹H NMR (CDCl₃) δ 1.80–1.81 (m, 1H), 1.99–2.06 (m, 4H), 2.73–2.83 (m, 2H), 2.79 (d, *J* = 5.0 Hz, 3H), 2.96 (ddd, *J* = 6.6, 4.3, 2.1 Hz, 1H), 3.23 (d, *J* = 2.1 Hz, 1H), 6.09 (br-s, 1H), 7.19–7.23 (m, 3H), 7.27–7.33 (m, 2H); ¹³C NMR (CDCl₃) δ 25.7, 32.0, 33.7, 55.7, 59.2, 126.5, 128.6 (x 2), 128.8 (x 2), 140.7, 169.2; ESI-MS *m/z* 228 [M+Na⁺]; HRMS (M⁺) Calcd for C₁₂H₁₅NO₂: 205.1103. Found 205.1111. The enantiomeric excess of **3a** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 0.6 mL/min, *t*_R 26.0 min ((2*S*,3*R*)-isomer) and 35.5 min ((2*R*,3*S*)-isomer), detection at 254 nm]; [α]_D²⁷ +12.2 [c 1.50 CHCl₃(>99% ee)].

(2*R*,3*S*)-3-Phenethyl-oxirane-2-carboxylic acid benzylamide (3b**):** white solid; IR (KBr) ν 3262, 3054, 1654, 1566, 1495, 1454, 1423, 1223, 900, 719, 697 cm⁻¹; ¹H NMR (CDCl₃) δ 1.83–1.89 (m, 1H), 1.98–2.05 (m, 1H), 2.73–2.83 (m, 2H), 2.99 (ddd, *J* = 6.5, 4.6, 2.1 Hz, 1H), 3.30 (d, *J* = 2.1 Hz, 1H), 4.38 (dd, *J* = 14.7, 5.8 Hz, 1H), 4.42 (dd, *J* = 14.7, 5.8 Hz, 1H), 6.39 (br-s, 1H), 7.05–7.37 (m, 10H); ¹³C NMR (CDCl₃) δ 31.8, 33.4, 42.8, 55.4, 59.0, 126.2, 127.6, 127.7 (x 2), 128.3 (x 2), 128.6 (x 2), 128.7 (x 2), 137.6, 140.4, 168.2; ESI-MS *m/z* 304 [M+Na⁺]; HRMS (M⁺) Calcd for C₁₈H₁₉NO₂: 281.1416. Found 281.1421. The enantiomeric excess of **3b** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 0.8 mL/min, *t*_R 28.4 min ((2*S*,3*R*)-isomer) and 50.5 min ((2*R*,3*S*)-isomer), detection at 254 nm]; [α]_D²⁵ –20.1 [c 0.97 CHCl₃(>99% ee)].

(2*R*,3*S*)-3-Phenethyl-oxirane-2-carboxylic acid allylamide (3c**):** colorless oil; IR (KBr) ν 3298, 3027, 2925, 1666, 1538, 1454, 1261, 905, 700 cm⁻¹; ¹H NMR (CDCl₃) δ 1.83–1.90 (m, 1H), 1.98–2.06 (m, 1H), 2.73–2.83 (m, 2H), 2.97–3.01 (m, 1H), 3.27 (d, *J* = 2.0 Hz, 1H), 3.78–3.91 (m, 2H), 5.11–5.18 (m, 2H), 5.78 (ddd, *J* = 17.0, 10.0, 5.5 Hz,

1H), 6.21 (br-s, 1H), 7.17–7.23 (m, 3H), 7.30 (d, $J = 7.5$ Hz, 2H); ^{13}C NMR (CDCl_3) δ 31.8, 33.3, 41.0, 55.4, 59.0, 116.6, 126.2, 128.2 (x 2), 128.5 (x 2), 133.5, 140.4, 168.1; ESI-MS m/z 254 $[\text{M}+\text{Na}^+]$; HRMS (M^+) Calcd for $\text{C}_{14}\text{H}_{17}\text{NO}_2$: 231.1259. Found 231.1262. The enantiomeric excess of **3c** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 0.8 mL/min, t_R 16.2 min (minor isomer) and 26.4 min (major isomer), detection at 254 nm]; $[\alpha]_D^{26} -4.05$ [c 4.2 CHCl_3 (98% ee)].

(2R,3S)-3-Phenethyl-oxirane-2-carboxylic acid cyclohexylamide (3d): white solid; IR (KBr) ν 3295, 3063, 3027, 2930, 2850, 1653, 1540, 1497, 1450, 1314, 1123, 1105, 899, 739, 695 cm^{-1} ; ^1H NMR (CDCl_3) δ 1.07–1.19 (m, 3H), 1.31–1.38 (m, 2H), 1.58–1.72 (m, 2H), 1.79–1.91 (m, 2H), 1.98–2.04 (m, 1H), 2.73–2.83 (m, 2H), 2.94 (ddd, $J = 6.5, 4.6, 2.2$ Hz, 1H), 3.23 (d, $J = 2.2$ Hz, 1H), 3.69–3.76 (m, 1H), 5.95 (d, $J = 7.0$ Hz, 1H), 7.18–7.31 (m, 5H); ^{13}C NMR (CDCl_3) δ 24.7 (x 2), 25.4, 31.8, 32.9, 33.0, 33.4, 47.6, 55.5, 59.1, 126.2, 128.3 (x 2), 128.5 (x 2), 140.5, 167.4; ESI-MS m/z 296 $[\text{M}+\text{Na}^+]$; HRMS (M^+) Calcd for $\text{C}_{17}\text{H}_{23}\text{NO}_2$: 273.1729. Found 273.1723. The enantiomeric excess of **3d** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 0.5 mL/min, t_R 24.1 min (minor isomer) and 48.2 min (major isomer), detection at 254 nm]; $[\alpha]_D^{28} +0.77$ [c 0.78 CHCl_3 (>99% ee)].

(2R,3S)-3-Phenethyl-oxirane-2-carboxylic acid *tert*-butylamide (3e): colorless oil; IR (neat) ν 3312, 3063, 3026, 2968, 1667, 1537, 1496, 1479, 1455, 1364, 1223, 896, 750, 700 cm^{-1} ; ^1H NMR (CDCl_3) δ 1.33 (s, 9H), 1.81–1.89 (m, 1H), 1.99–2.06 (m, 1H), 2.73–2.84 (m, 2H), 2.93 (ddd, $J = 6.5, 4.6, 2.2$ Hz, 1H), 3.14 (d, $J = 2.2$ Hz, 1H), 5.88 (s, 1H), 7.19–7.31 (m, 5H); ^{13}C NMR (CDCl_3) δ 28.6 (x 2), 31.9, 33.4, 50.9, 55.8, 59.1, 126.2, 128.3 (x 2), 128.6 (x 2), 140.6, 167.5; ESI-MS m/z 270 $[\text{M}+\text{Na}^+]$; HRMS (M^+) Calcd for $\text{C}_{15}\text{H}_{21}\text{NO}_2$: 247.1572. Found 247.1576. The enantiomeric excess of **3e** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 0.5 mL/min, t_R 9.5 min (minor isomer) and 13.7 min (major isomer), detection at 254 nm]; $[\alpha]_D^{25} +6.8$ [c 0.78 CHCl_3 (99% ee)].

(2R,3S)-3-Phenethyl-oxirane-2-carboxylic acid dimethylamide (3f): colorless oil; IR (neat) ν 3480, 3025, 2930, 1652, 1496, 1455, 1398, 1264, 1154, 752, 701 cm^{-1} ; ^1H NMR (CDCl_3) δ 1.98 (ddd, $J = 7.9, 7.0, 5.8$ Hz, 2H), 2.76 (dt, $J = 14.0, 7.9$ Hz, 1H), 2.86 (dt, $J = 14.0, 7.0$ Hz, 1H), 2.94 (s, 3H), 2.97 (s, 3H), 3.19 (dt, $J = 2.1, 5.8$ Hz, 1H), 3.32 (d, $J = 2.1$ Hz, 1H), 7.18–7.30 (m, 5H); ^{13}C NMR (CDCl_3) δ 31.9, 33.3, 35.7, 36.2, 53.8, 57.5, 126.2, 128.4 (x 2), 128.5 (x 2), 140.8, 167.2; ESI-MS m/z 242 $[\text{M}+\text{Na}^+]$; HRMS (M^+) Calcd for $\text{C}_{13}\text{H}_{17}\text{NO}_2$: 219.1259. Found 219.1257. The enantiomeric excess of **3f** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 0.5 mL/min, t_R 42.8 min ((2*S*,3*R*)-isomer) and 51.8 min ((2*R*,3*S*)-isomer), detection at 254 nm]; $[\alpha]_D^{26} -25.8$ [c 0.97 CHCl_3 (99% ee)].

(2R,3S)-(3-Phenethyl-oxiranyl)-pyrrolidin-1-yl-methanone (3g): colorless oil; IR (neat)

ν 3481, 2972, 2875, 1650, 1455, 1415, 1341, 910, 751, 701 cm^{-1} ; ^1H NMR (CDCl_3) δ 1.78–2.05 (m, 6H), 2.75 (ddd, $J = 14.1, 8.3, 7.9$ Hz, 1H), 2.87 (ddd, $J = 14.1, 8.2, 5.8$ Hz, 1H), 3.16–3.21 (m, 1H), 3.18 (d, $J = 2.1$ Hz, 1H), 3.23 (dt, $J = 2.1, 5.7$ Hz, 1H), 3.43–3.52 (m, 3H), 7.18–7.30 (m, 5H); ^{13}C NMR (CDCl_3) δ 23.8, 26.1, 32.0, 33.2, 45.6, 46.2, 54.1, 57.4, 126.1, 128.4 (x 2), 128.5 (x 2), 140.8, 165.8; ESI-MS m/z 268 $[\text{M}+\text{Na}^+]$; HRMS (M^+) Calcd for $\text{C}_{15}\text{H}_{19}\text{NO}_2$: 245.1416. Found 245.1415. The enantiomeric excess of **3g** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/1, flow rate 0.5 mL/min, t_R 30.9 min (minor isomer) and 43.5 min (major isomer), detection at 254 nm]; $[\alpha]_D^{26} -32.1$ [c 0.77 CHCl_3 (>99% ee)].

(2R,3S)-3-(4-Phenyl-butyl)-oxirane-2-carboxylic acid methylamide (3h): white solid; IR (neat) ν 3277, 3107, 3026, 2936, 2853, 1662, 1567, 1451, 1412, 1268, 1162, 893, 749, 697 cm^{-1} ; ^1H NMR (CDCl_3) δ 1.48–1.74 (m, 6H), 2.62 (t, $J = 7.3$ Hz, 2H), 2.79 (d, $J = 5.2$ Hz, 3H), 2.92 (dt, $J = 6.0, 2.1$ Hz, 1H), 3.22 (d, $J = 2.1$ Hz, 1H), 6.11 (br-s, 1H), 7.15–7.18 (m, 3H), 7.23–7.29 (m, 2H); ^{13}C NMR (CDCl_3) δ 25.2, 25.4, 31.0, 31.6, 35.7, 55.4, 59.6, 125.8, 128.3 (x 2), 128.4 (x 2), 142.1, 169.2; ESI-MS m/z 256 $[\text{M}+\text{Na}^+]$; HRMS (M^+) Calcd for $\text{C}_{14}\text{H}_{19}\text{NO}_2$: 233.1416. Found 233.1415. The enantiomeric excess of **3h** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 1.0 mL/min, t_R 13.5 min (minor isomer) and 24.7 min (major isomer), detection at 254 nm]; $[\alpha]_D^{25} +21.8$ [c 1.29 CHCl_3 (>99% ee)].

(2R,3S)-3-Propyl-oxirane-2-carboxylic acid benzylamide (3i): white solid; IR (KBr) ν 3223, 3065, 2954, 1654, 1560, 1451, 1257, 1030, 907, 696 cm^{-1} ; ^1H NMR (CDCl_3) δ 0.97 (t, $J = 7.1$ Hz, 3H), 1.47–1.66 (m, 4H), 2.95 (m, 1H), 3.27 (d, $J = 2.1$ Hz, 1H), 4.42 (d, $J = 6.1$ Hz, 2H), 5.80 (s, 1H), 7.26–7.35 (m, 5H); ^{13}C NMR (CDCl_3) δ 13.7, 19.0, 33.7, 42.8, 55.4, 59.6, 127.6, 127.7 (x 2), 128.8 (x 2), 137.6, 168.5; ESI-MS m/z 242 $[\text{M}+\text{Na}^+]$; HRMS (M^+) Calcd for $\text{C}_{13}\text{H}_{17}\text{NO}_2$: 219.1259. Found 219.1264. The enantiomeric excess of **3i** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 0.5 mL/min, t_R 26.3 min (minor isomer) and 41.5 min (major isomer), detection at 254 nm]; $[\alpha]_D^{22} -1.78$ [c 0.56 CHCl_3 (94% ee)].

(2R,3S)-3-Cyclohexyl-oxirane-2-carboxylic acid benzylamide (3j): The enantiomeric excess of **3j** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 0.5 mL/min, t_R 27.6 min ((2R,3S)-isomer) and 68.0 min ((2S,3R)-isomer), detection at 254 nm]; $[\alpha]_D^{27} -4.14$ [c 0.29 CHCl_3 (>99% ee)].

General Procedure for the Catalytic Asymmetric Epoxidation of β -Aryl Substituted α,β -Unsaturated Amides Using the Sm–BINOL– $\text{Ph}_3\text{As}=\text{O}$ Complex 4. To a stirred mixture of MS 4A [250 mg (1000 mg/mmol of starting material); MS 4A was dried for 3 h at 180 $^\circ\text{C}$ under reduced pressure.] was added (*S*)-BINOL (7.2 mg, 0.025 mmol) and triphenylarsine oxide (8.1 mg, 0.025 mmol) as a THF solution (2.5 mL), and then $\text{Sm}(\text{O}-i\text{-Pr})_3$ (0.25 mL,

0.025 mmol, 0.1 M solution in THF) was added to the reaction mixture at room temperature. After being stirred for 45 min at the same temperature, TBHP (0.077 mL, 0.6 mmol, 3.9 M solution in toluene) was added. After being stirred for 10 min, **2k** (40.3 mg, 0.25 mmol) was added directly and the mixture was stirred at room temperature. After complete consumption of the starting material (18 h), the reaction mixture was diluted with ethyl acetate (10 mL) and quenched with 2% citric acid (2.5 mL). The water layer was extracted with ethyl acetate (10 mL), the combined organic layers were washed with brine (5 mL) and dried over sodium sulphate. After concentration in *vacuo*, the residue was purified by flash chromatography (SiO₂, hexane/ethyl acetate = 4/1 to 3/1) to give epoxy amide **3k** (42.3 mg, 95%) as a white yellow solid. The enantiomeric excess of **3k** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 1.0 mL/min, *t_R* 17.4 min ((2*S*,3*R*)-isomer) and 31.1 min ((2*R*,3*S*)-isomer), detection at 254 nm]; [α]_D²⁶ -50.8 [c 0.76 CHCl₃(>99% ee)].

(2*R*,3*S*)-3-Phenyl-oxirane-2-carboxylic acid benzylamide (3l): The enantiomeric excess of **3l** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 1.0 mL/min, *t_R* 25.0 min ((2*S*,3*R*)-isomer) and 62.2 min ((2*R*,3*S*)-isomer), detection at 254 nm]; [α]_D²⁵ -86.1 [c 0.62 CHCl₃(>99% ee)].

(2*R*,3*S*)-3-Phenyl-oxirane-2-carboxylic acid dimethylamide (3m): The enantiomeric excess of **3i** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/1, flow rate 0.5 mL/min, *t_R* 23.3 min (minor isomer) and 28.5 min (major isomer), detection at 254 nm]; [α]_D²⁶ -109.4 [c 1.09 CHCl₃(>99% ee)].

(2*R*,3*S*)-3-(4-Fluoro-phenyl)-oxirane-2-carboxylic acid methylamide (3n): white solid; IR (KBr) ν 3300, 3121, 1652, 1578, 1509, 1413, 1219, 1155, 887, 841, 554, 528 cm⁻¹; ¹H NMR (CDCl₃) δ 2.87 (d, *J* = 5.2 Hz, 3H), 3.50 (d, *J* = 2.1 Hz, 1H), 3.86 (d, *J* = 2.1 Hz, 1H), 6.25 (br-s, 1H), 7.04–7.07 (m, 2H), 7.23–7.27 (m, 2H); ¹³C NMR (CDCl₃) δ 25.6, 58.5, 58.9, 115.7 (d, *J* = 21.6 Hz) (x 2), 127.5 (d, *J* = 9.3 Hz) (x 2), 130.72 (d, *J* = 3.1 Hz), 163.1 (d, *J* = 248 Hz), 167.8; ESI-MS *m/z* 218 [M+Na⁺]; HRMS (M⁺) Calcd for C₁₀H₁₀FNO₂: 195.0696. Found 195.0704. The enantiomeric excess of **3n** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 1.0 mL/min, *t_R* 20.5 min (minor isomer) and 40.0 min (major isomer), detection at 254 nm]; [α]_D²⁶ +39.7 [c 0.64 CHCl₃(99% ee)].

(2*R*,3*S*)-3-*p*-Tolyl-oxirane-2-carboxylic acid methylamide (3o): white solid; ¹H NMR (CDCl₃) δ 2.34 (s, 3H), 2.85 (d, *J* = 5.0 Hz, 3H), 3.52 (d, *J* = 2.0 Hz, 1H), 3.83 (d, *J* = 2.0 Hz, 1H), 6.34 (s, 1H), 7.12–7.16 (m, 4H); ¹³C NMR (CDCl₃) δ 21.2, 25.5, 58.9, 59.1, 125.7 (x 2), 129.2 (x 2), 131.8, 138.9, 168.2; ESI-MS *m/z* 214 [M+Na⁺]; HRMS (M⁺) Calcd for C₁₁H₁₃NO₂: 191.0946. Found 191.0940. The enantiomeric excess of **3o** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 1.0 mL/min, *t_R* 18.7 min (minor isomer) and 37.9 min (major isomer), detection at 254 nm]; [α]_D²⁷ -53.4 [c 1.31 CHCl₃(>99% ee)].

Synthesis of the β -Aryl α -Hydroxy Amides **6k–o.** The α , β -epoxy amides **3a–o** were prepared according to the general procedure of one pot tandem catalytic asymmetric epoxidation–Pd-catalyzed epoxide opening process. For the known compound **6k**, see: *Tetrahedron Lett.* **1984**, 25, 329. For the known compound **6l**, see: *J. Chem. Soc. Perkin Trans 1* **1999**, 1295. For the known compound **6m**, see: *J. Orgmet. Chem.* **1989**, 370, 81. The absolute configuration of **6l** was determined by comparing the measured optical rotations with the reported ones. The absolute configurations of **6k** and **6m** were determined by comparing the measured optical rotation with the authentic samples, which were prepared by the method shown in the Scheme SI–2.

General Procedure for the One Pot Tandem Catalytic Asymmetric Epoxidation–Pd-Catalyzed Epoxide Opening Process. To a stirred mixture of MS 4A [250 mg (1000 mg/mmol of starting material); MS 4A was dried for 3 h at 180 °C under reduced pressure.] was added (*S*)-BINOL (7.2 mg, 0.025 mmol) and triphenylphosphine oxide (20.9 mg, 0.075 mmol) as a THF solution (2.5 mL), and then Sm(O-*i*-Pr)₃ (0.25 mL, 0.025 mmol, 0.1 M solution in THF) was added to the reaction mixture at room temperature. After being stirred for 45 min at the same temperature, TBHP (0.077 mL, 0.6 mmol, 3.9 M solution in toluene) was added. After being stirred for 10 min, **2k** (40.3 mg, 0.25 mmol) was added directly and the mixture was stirred at room temperature. After complete consumption of the starting material (21 h), Pd-C (10%, 13.3 mg, 0.0125 mmol) and MeOH (1.3 mL) were added directly and the reaction mixture was stirred under hydrogen atmosphere (1 atm) for 2 h. After dilution with ethyl acetate (10 mL), the resulting mixture was filtered through a short pad of celite, and then quenched with 2% citric acid (2.5 mL). The water layer was extracted with ethyl acetate (10 mL), the combined organic layers were washed with brine (5 mL) and dried over sodium sulphate. After concentration in *vacuo*, the residue was purified by flash chromatography (SiO₂, hexane/ethyl acetate = 1/1 to 1/3) to give α -hydroxy amide **6k** (43.4 mg, 97%) as a white yellow solid. The enantiomeric excess of **6k** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 1.0 mL/min, *t_R* 14.5 min ((2*R*)-isomer) and 28.5 min ((2*S*)-isomer), detection at 254 nm]; [α]_D²² +98.5 [c 0.95 CHCl₃(97% ee)].

(2*R*)-2-Hydroxy-*N*-benzyl-3-phenyl-propionamide (6l**):** The enantiomeric excess of **6l** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS, *i*-PrOH/hexane 1/4, flow rate 1.0 mL/min, *t_R* 13.5 min ((2*R*)-isomer) and 26.5 min ((2*S*)-isomer), detection at 254 nm]; [α]_D²⁴ +70.7 [c 1.28 CHCl₃(98% ee)].

(2*R*)-2-Hydroxy-*N,N*-dimethyl-3-phenyl-propionamide (6m**):** The enantiomeric excess of **6m** was determined by chiral stationary-phase HPLC analysis after converting into the corresponding triethylsilyl ether. [DAICEL CHIRALCEL OD-H, *i*-PrOH/hexane 2/98, flow rate 1.0 mL/min, *t_R* 9.1 min (minor isomer) and 13.3 min (major isomer), detection at 254

nm]; $[\alpha]_D^{25} -24.4$ [c 1.21 CHCl₃(99% ee)].

(2R)-3-(4-Fluoro-phenyl)-2-hydroxy-N-methyl-propionamide (6n): white solid; IR (KBr) ν 3296, 1669, 1638, 1514, 1415, 1232, 1159, 1100, 818 cm⁻¹; ¹H NMR (CDCl₃) δ 2.78 (d, J = 5.0 Hz, 2H), 2.84 (dd, J = 14.0, 8.2 Hz, 1H), 3.16 (dd, J = 14.0, 4.0 Hz, 1H), 4.25 (dd, J = 8.2, 4.0 Hz, 1H), 6.01 (s, 1H), 6.97–7.01 (m, 2H), 7.18–7.27 (m, 2H); ¹³C NMR (CDCl₃) δ 25.7, 40.0, 72.8, 115.3 (d, J = 20.6 Hz) (x 2), 131.0 (d, J = 8.3 Hz) (x 2), 132.6 (d, J = 3.1 Hz), 161.9 (d, J = 250 Hz), 173.3; ESI-MS m/z 220 [M+Na⁺]; HRMS (M⁺) Calcd for C₁₀H₁₂FNO₂: 197.0852. Found 197.0857. The enantiomeric excess of **6n** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 1.0 mL/min, t_R 15.7 min ((2R)-isomer) and 25.8 min ((2S)-isomer), detection at 254 nm]; $[\alpha]_D^{27} +84.6$ [c 0.73 CHCl₃(99% ee)].

(2R)-2-Hydroxy-N-methyl-3-*p*-tolyl-propionamide (6o): white solid; IR (KBr) ν 3351, 2923, 1628, 1541, 1412, 1329, 1081, 805, 473 cm⁻¹; ¹H NMR (CDCl₃) δ 2.33 (s, 3H), 2.81 (d, J = 5.0 Hz, 3H), 2.83 (dd, J = 14.0, 8.3 Hz, 1H), 3.19 (dd, J = 14.0, 4.0 Hz, 1H), 4.26 (dd, J = 8.3, 4.0 Hz, 1H), 6.52 (s, 1H), 7.13 (m, 4H); ¹³C NMR (CDCl₃) δ 21.0, 25.7, 40.5, 72.9, 129.3 (x 2), 129.4 (x 2), 133.6, 136.6, 173.3; ESI-MS m/z 216 [M+Na⁺]; HRMS (M⁺) Calcd for C₁₁H₁₅NO₂: 193.1103. Found 193.1104. The enantiomeric excess of **6o** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AD, *i*-PrOH/hexane 1/4, flow rate 1.0 mL/min, t_R 11.2 min (major isomer) and 24.3 min (minor isomer), detection at 254 nm]; $[\alpha]_D^{26} +72.7$ [c 0.66 CHCl₃(97% ee)].

Experimental Procedure for the Synthesis of 12a Using One Pot Tandem Catalytic Asymmetric Epoxidation–Peptide Coupling–Pd-Catalyzed Epoxide Opening Process. To a mixture of (*S*)-BINOL (7.2 mg, 0.025 mmol), triphenylphosphine oxide (20.9 mg, 0.075 mmol) and MS 4A [250 mg (1000 mg/mmol of starting material); MS 4A was not dried.] in dry THF (2.5 mL) was added a solution of La(O-*i*-Pr)₃ (0.125 mL, 0.025 mmol, 0.2 M solution in THF) at room temperature. After being stirred for 45 min at the same temperature, TBHP (0.12 mL, 0.6 mmol, 5 M solution in decane) was added. After being stirred for 10 min, α,β -unsaturated imidazolide **10** (68.6 mg, 0.25 mmol) was added directly and the mixture was stirred at room temperature. After complete consumption of the starting material (3 h), L-leucine methyl ester (0.06 mL, 0.375 mmol) and hexafluoroacetone hydrate (0.44 mL, solvent ratio: THF/hexafluoroacetone = 6/1) was added. After the resulting mixture was stirred for 48 h at the same temperature, Pd-C (10%, 13.3 mg, 0.0125 mmol) and MeOH (1.3 mL) were added directly and the reaction mixture was stirred under hydrogen atmosphere (1 atm) for 4 h. After dilution with ethyl acetate (10 mL), the resulting mixture was filtered through a short pad of celite, and then quenched with 2% citric acid (2.5 mL). The water layer was extracted with ethyl acetate (10 mL), the combined organic layers were washed with brine (5 mL) and dried over sodium sulphate. After concentration in *vacuo*, the residue was purified by flash chromatography (SiO₂,

hexane/ethyl acetate = 10/1 to 3/1) to give roughly purified **12a**. The diastereomeric ratio was determined by measuring ^1H NMR of this sample in C_6D_6 . The crude sample was further purified by flash chromatography (SiO_2 , hexane/ethyl acetate = 2/1) to give **12a** (54.2 mg, 74%) as a white solid. IR (KBr) ν 3348, 2955, 1722, 1645, 1529, 1437, 1296, 1260, 1092, 742, 696, 497 cm^{-1} ; ^1H NMR (CDCl_3) δ 0.90 (d, J = 5.5 Hz, 3H), 0.92 (d, J = 5.1 Hz, 3H), 1.49–1.65 (m, 3H), 2.44 (br-s, 1H), 2.88 (dd, J = 14.0, 8.8 Hz, 1H), 3.22 (dd, J = 14.0, 4.2 Hz, 1H), 3.73 (s, 3H), 4.30 (dd, J = 8.5, 4.2 Hz, 1H), 4.61 (ddd, J = 9.0, 8.6, 5.0 Hz, 1H), 6.75 (d, J = 8.6 Hz, 1H), 7.22–7.32 (m, 5H); ^{13}C NMR (CDCl_3) δ 21.8, 22.7, 24.8, 40.8, 41.5, 50.3, 52.3, 72.8, 127.1, 128.8 ($\times$ 2), 129.4 ($\times$ 2), 136.6, 172.3, 173.0; ESI-MS m/z 316 [$\text{M}+\text{Na}^+$]; HRMS (M^+) Calcd for $\text{C}_{16}\text{H}_{23}\text{NO}_4$: 293.1627. Found 293.1624. The enantiomeric excess of **12a** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 0.5 mL/min, t_{R} 12.9 min (major isomer) and 31.3 min (minor isomer), detection at 254 nm]; $[\alpha]_{\text{D}}^{25}$ +51.2 [c 0.68 CHCl_3 (99% ee)].

(2S)-2-((2S)-Hydroxy-3-phenyl-propionylamino)-4-methyl-pentanoic acid methyl ester (L-3-phenyllactyl-L-Leu-OMe) (12b): white solid; IR (KBr) ν 3373, 3187, 2956, 1752, 1657, 1542, 1269, 1236, 1194, 1151, 1092, 706, 596 cm^{-1} ; ^1H NMR (CDCl_3) δ 0.86 (d, J = 4.9 Hz, 3H), 0.88 (d, J = 4.9 Hz, 3H), 1.40–1.49 (m, 2H), 1.54–1.59 (m, 1H), 2.90 (dd, J = 14.0, 7.6 Hz, 1H), 3.18 (dd, J = 14.0, 4.0 Hz, 1H), 3.69 (s, 3H), 4.33 (dd, J = 7.6, 4.0 Hz, 1H), 4.57 (ddd, J = 8.9, 8.3, 5.2 Hz, 1H), 6.84 (d, J = 8.3 Hz, 1H), 7.21–7.24 (m, 3H), 7.27–7.30 (m, 2H); ^{13}C NMR (CDCl_3) δ 21.8, 22.8, 24.6, 40.5, 41.3, 50.2, 52.3, 72.7, 126.9, 128.6 ($\times$ 2), 129.6 ($\times$ 2), 136.7, 172.5, 173.4; ESI-MS m/z 316 [$\text{M}+\text{Na}^+$]; HRMS (M^+) Calcd for $\text{C}_{16}\text{H}_{23}\text{NO}_4$: 293.1627. Found 293.1621. The enantiomeric excess of **12b** was determined by chiral stationary-phase HPLC analysis [DAICEL CHIRALPAK AS-H, *i*-PrOH/hexane 1/4, flow rate 0.5 mL/min, t_{R} 11.9 min (minor isomer) and 13.7 min (major isomer), detection at 254 nm]; $[\alpha]_{\text{D}}^{26}$ –66.9 [c 1.06 CHCl_3 (99% ee)].

Other Detailed Results and Discussion

Optimization of the Reaction Conditions

Table SI-1. Catalytic Asymmetric Epoxidation of **2a** Using (S)-La-BINOL-Ph₃As=O Complex: Effect of the amount of TBHP

$ \begin{array}{ccc} \text{Ph-CH}_2\text{-CH}_2\text{-CH=CH-C(=O)NH-CH}_3 & \xrightarrow[\text{THF, MS 4A, rt}]{\begin{array}{c} \text{(S)-La-BINOL-Ph}_3\text{As=O} \\ \text{complex (10 mol \%)} \\ \text{TBHP (X eq)} \end{array}} & \text{Ph-CH}_2\text{-CH}_2\text{-CH(O)-CH(O)-C(=O)NH-CH}_3 \\ \mathbf{2a} & & \mathbf{3a} \end{array} $					
entry	TBHP	time (h)	yield of 3a (%)	recovery of 2a (%)	ee (%)
1	1.1 eq	48	29	71	91
2	1.2 eq	48	93	–	97
3	1.5 eq	48	63	25	98
4	2.0 eq	48	57	33	97
5	2.4 eq	48	40	57	94

Table SI-2. Catalytic Asymmetric Epoxidation of **2a** Using (S)-Ln-BINOL-Ph₃As=O Complex: Effect of the Central Metal

$ \begin{array}{ccc} \text{Ph-CH}_2\text{-CH}_2\text{-CH=CH-C(=O)NH-CH}_3 & \xrightarrow[\text{THF, MS 4A, rt}]{\begin{array}{c} \text{(S)-Ln-BINOL-Ph}_3\text{As=O} \\ \text{complex (10 mol \%)} \\ \text{TBHP (1.2 eq)} \end{array}} & \text{Ph-CH}_2\text{-CH}_2\text{-CH(O)-CH(O)-C(=O)NH-CH}_3 \\ \mathbf{2a} & & \mathbf{3a} \end{array} $				
entry	Ln	time (h)	yield of 3a (%)	ee (%)
1	La	24	85	97
2	Pr	8	96	99.1
3	Sm	8	97	99.4
4	Gd	24	71	94
5	Dy	8	94	98
6	Yb	24	25	65

Table SI-3. Catalytic Asymmetric Epoxidation of **2a** Using (S)-Ln-BINOL-Ph₃P=O Complex

$$\text{Ph-CH}_2\text{-CH=CH-C(=O)NHCH}_3 \xrightarrow[\text{THF, MS 4A, rt}]{\text{(S)-Ln-BINOL-Ph}_3\text{P=O complex (10 mol \%), TBHP (1.2 eq)}} \text{Ph-CH}_2\text{-CH(O)}\text{-CH}_2\text{-C(=O)NHCH}_3$$

2a **3a**

entry	Ln	Ph ₃ P=O (X mol %)	time (h)	yield of 3a (%)	ee (%)
1	Sm	10	24	35	92
2	Sm	30	24	65	96
3	La	30	24	42	95
4	Pr	30	24	48	95
5	Gd	30	24	49	91
6	Dy	30	24	91	97
7	Yb	30	24	Very Slow	ND

Table SI-4. Catalytic Asymmetric Epoxidation of **2k** Using (S)-La-BINOL-Ph₃As=O Complex: Effect of the Amount of TBHP

$$\text{Ph-CH=CH-C(=O)NHCH}_3 \xrightarrow[\text{THF, MS 4A, rt}]{\text{(S)-La-BINOL-Ph}_3\text{As=O complex (10 mol \%), TBHP (X eq)}} \text{Ph-CH(O)}\text{-CH}_2\text{-C(=O)NHCH}_3$$

2k **3k**

entry	TBHP	time (h)	yield of 3k (%)	recovery of 2k (%)	ee (%)
1	1.1 eq	48	31	60	99
2	1.2 eq	48	51	47	98
3	1.5 eq	48	27	73	98
4	2.0 eq	48	15	82	84
5	2.4 eq	48	11	—	ND

Table SI-5. Catalytic Asymmetric Epoxidation of **2k** Using (S)-Ln-BINOL-Ph₃As=O Complex: Effect of the Central Metal

$(S)\text{-Ln-BINOL-Ph}_3\text{As=O}$
 complex (10 mol %)
 TBHP (1.2 eq)
 THF, MS 4A, rt

2k → **3k**

entry	Ln	time (h)	yield of 3k (%)	recovery of 2k (%)	ee (%)
1	La	48	51	47	98
2	Pr	24	65	32	99.4
3	Sm	24	89	5	99.6
4	Gd	24	35	54	99.2
5	Dy	24	62	31	99.5
6	Yb	24	34	65	25

Table SI-6. Catalytic Asymmetric Epoxidation of **2k** Using (S)-Sm-BINOL-Ph₃P=O Complex or (S)-Dy-BINOL-Ph₃P=O Complex: Effect of MS 4A activation

$(S)\text{-Ln-BINOL-Ph}_3\text{P=O}$
 complex (10 mol %)
 TBHP (1.2 eq)
 THF, MS 4A, rt

2k → **3k**

entry	Ln	additive	MS 4A	time (h)	yield of 3k (%)	ee (%)
1	Sm	Ph ₃ As=O	wet MS 4A	18	53	99.6
2	Sm	Ph ₃ As=O	dried MS 4A ^a	18	80	99.2
3	Sm	Ph ₃ As=O	dried MS 4A ^b	18	95	98.8
4	Sm	Ph ₃ P=O	dried MS 4A ^b	9	92	97.1
5	Dy	Ph ₃ P=O	dried MS 4A ^b	9	97	90

^a MS 4A was dried for 3 h at 180 °C under reduced pressure and 4 eq of H₂O to the catalyst was added. ^b MS 4A was dried for 3 h at 180 °C under reduced pressure.

Experiments for the Pd-Catalyzed Epoxide Opening of 3k

Table SI-8. Detailed Data for the Pd-Catalyzed Epoxide Opening Reaction of **3k**

entry	additives	time (min)	Yield ^a (%)	ratio ^b (6k : 7k : 8k)	selectivity (6k/7k+8k)
1	–	60	100	100 : 6 : 3	11
2	MeOH ^c	10	100	100 : 8 : 2	10
3	MeOH ^c , MS 4A	10	100	100 : 0 : 4	25
4	MeOH ^c , Ph ₃ As=O (5 mol %)	120	7	ND	–
5	MeOH ^c , Ph ₃ P=O (15 mol %)	30	100	100 : 4 : 1	20
6	MeOH ^c , TBHP (1 eq)	30	100	100 : 4 : 3	14
7	MeOH ^c , 4-phenylimidazole (1 eq)	30	100	100 : 0 : 3	33
8	(S)-Sm-BINOL-Ph ₃ P=O complex (10 mol %)	90	100	100 : 0 : 23	4
9	(S)-Sm-BINOL-Ph ₃ P=O complex (10 mol %), MeOH ^c	60	100	100 : 0 : 5	20
10	(S)-Sm-BINOL-Ph ₃ P=O complex (10 mol %), TBHP (0.2 eq), MS 4A MeOH ^c	60	100	100 : 0 : 1	100
11	(S)-La-BINOL-Ph ₃ P=O complex (10 mol %), TBHP (0.2 eq), MS 4A 4-phenylimidazole (1 eq), MeOH ^c	60	100	100 : 0 : 2	50

^a Conversion Yield. ^b The ratio was determined by ¹H NMR analysis of the crude sample. ^c Solvent ratio: THF/MeOH = 2/1

Experiments for the Peptide Coupling Reaction

As shown in Table SI-9, the additive effects were examined in detail. Although the reaction was accelerated by the addition of DBU, partial racemization took place at the α-carbon in the L-leucine moiety, resulting in the decrease of the diastereomeric ratio (entry 10). Interestingly, the reaction was accelerated by use of some fluorine-containing solvents such as hexafluoroacetone and hexafluoroisopropanol (entries 13, 14). At present, the reason for the acceleration has not been clarified. However, considering the result shown in entry 15 (the reaction was carried out in the presence of acetone), it can be emphasized that, at least, the fluorine atom(s) would be influential in the acceleration mechanism. Further

investigation is now ongoing.

Table SI-9. Experiments for the Peptide Coupling Reaction

Reaction scheme: A phenyl-substituted oxazolidinone-2-carboxylate (with a *tert*-butyl ester) reacts with L-Leu-OMe (3 eq) in THF with an additive to form a peptide product where the oxazolidinone is coupled to the amino group of L-leucine methyl ester.

entry	solvent system	concentration	time for completion (h)
1	THF	0.1 M	24
2	THF	0.2 M	6
3	THF	0.4 M	3
4	THF-DMF (3 : 2)	0.2 M	>24
5	THF-DMSO (3 : 2)	0.2 M	>24
6	THF-HMPA (3 : 2)	0.2 M	>24
7	THF- <i>t</i> -BuOH (3 : 2)	0.2 M	6
8	THF-AcOEt (3 : 2)	0.2 M	12
8	THF-NEt ₃ (9 : 1)	0.2 M	12
9	THF-DMAP (5 mol %)	0.2 M	6
10 ^a	THF-DBU (9 : 1)	0.2 M	0.5
11	THF-C ₆ H ₅ F (9 : 1)	0.2 M	12
12	THF-H ₂ O (9 : 1)	0.2 M	8
13	THF- <div style="text-align: center;"> </div> (9 : 1)	0.2 M	4.5
14	THF- <div style="text-align: center;"> </div> (9 : 1)	0.2 M	3
15	THF- <div style="text-align: center;"> </div> (9 : 1)	0.2 M	15

^a Although the reaction was accelerated by the addition of DBU, partial racemization took place.

Determination of the absolute configurations of **3a**, **3b**, **3f**, **3j**, **6k** and **6m**.

The absolute configurations of **3a**, **3b**, **3f** and **3j** were determined by comparing the measured optical rotations with the authentic samples, which were prepared from the corresponding α,β -unsaturated imidazolidines. Determination of the absolute configuration of **3a** is shown as a representative example (Scheme SI-1). The absolute configurations of **3b**, **3f** and **3j** were also determined using the same method. The absolute configurations of **6k** and **6m** were determined by comparing the measured optical rotations with the authentic

Scheme SI-1

Determination of the absolute configuration of **3a''**

Reaction scheme showing the determination of the absolute configuration of **3a''**. The starting material is (E)-1-(4-phenylbut-3-en-1-yl)-2-phenyl-1H-imidazole-5-carboxamide. It reacts with an (S)-catalyst to form a chiral intermediate, (S)-1-(4-phenylbut-3-en-1-yl)-2-phenyl-1H-imidazole-5-carboxylic acid tert-butyl ester. This intermediate then undergoes two different transformations:

- Transformation 1: Hydrolysis and esterification to form (S)-1-(4-phenylbut-3-en-1-yl)-2-phenyl-1H-imidazole-5-carboxylic acid methyl ester. Optical Rotation: (-) (*J. Am. Chem. Soc.* **2001**, 123, 9474.).
- Transformation 2: Hydrolysis and amide formation to form (S)-1-(4-phenylbut-3-en-1-yl)-2-phenyl-1H-imidazole-5-carboxamide. Optical Rotation (+). Absolute configuration was determined to be (2*R*, 3*S*).

Scheme SI-2

"Determination of the absolute configuration of **6k**"

Comparison of the Reactivity of α,β -Unsaturated Amides with α,β -Unsaturated Esters

In general, it is recognized that α,β -unsaturated amides are less reactive with nucleophiles, compared with α,β -unsaturated esters. In fact, molecular orbital calculation (HF/3-21G level with Gaussian 98 (Gaussian Inc.)) revealed that the energy of the lowest unoccupied molecular orbital (LUMO) of amide **A** was 0.59 eV (13.8 kcal/mol) higher than that of ester **B** (Figure SI-1). This result indicates that α,β -unsaturated amides are less reactive than α,β -unsaturated esters. However, an opposite tendency was observed in this catalytic asymmetric reaction. The result is shown in Scheme SI-3.

Figure SI-1. Molecular Orbital Calculations of **A** and **B**

Scheme SI-3. Catalytic Asymmetric Epoxidation of α,β -Unsaturated Amide **2a** and α,β -Unsaturated Ester **C**.

To get information to explain this result, we carried out the following experiments. The results are summarized in Table SI-10. We examined the effect of aging of the catalyst. When the catalyst, which was aged for 3 h by adding 10 eq of saturated ester **E** (entry 3), was utilized for epoxidation of **2a**, the nearly same result was obtained compared with the one of the control experiment (entry 2). However, interestingly, a decrease of the catalyst activity was observed when α,β -unsaturated ester **C** was used as an additive (entries 4, 5). These experimental results suggest that unfavorable complexation between the catalyst and α,β -unsaturated ester might occur in the reaction, resulting in the decrease of the catalyst activity. Although detailed investigation will be necessary, this finding should be a clue to clarify the point. Further studies are currently underway.

Table SI-10. The Effect of Aging of the Catalyst

<div style="display: flex; align-items: center; justify-content: center;"> <div style="text-align: center;"> <p>2a 3a</p> </div> <div style="margin-left: 20px;"> <p>Sm-BINOL-Ph₃As=O complex (10 mol %) TBHP, additive THF, MS 4A, rt</p> </div> </div>				
<div style="display: flex; align-items: center;"> <div style="margin-right: 20px;"> <p>Reaction Procedure</p> <p>Sm-BINOL-Ph₃As=O complex (10 mol %) in THF solution.</p> </div> <div style="flex-grow: 1;"> </div> </div>				
entry	additive	time for aging	yield	ee
1	—	0 h	99%	99.5% ee
2	—	3 h	99%	99.0% ee
3	<div style="display: flex; align-items: center;"> <div style="margin-left: 10px;"> <p>E</p> <p>(10 eq to cat)</p> </div> </div>	3 h	99%	99.2% ee
4	<div style="display: flex; align-items: center;"> <div style="margin-left: 10px;"> <p>C</p> <p>(10 eq to cat)</p> </div> </div>	3 h	32% (8%) ^a	97.1% ee
5	<div style="display: flex; align-items: center;"> <div style="margin-left: 10px;"> <p>C</p> <p>(10 eq to cat.)</p> </div> </div>	0 h	62% (0%) ^a	99.1% ee

^a Yield of the corresponding α,β -epoxy ester.