

Supporting Information

General. Unless otherwise stated, all reactions were carried out under strictly anhydrous, air-free conditions. All reagents used were commercially available from Aldrich, Fluka, and Novabiochem. The jacketed addition funnels¹ were purchased from ChemGlass. All solvents were dried and distilled by standard procedures. All acid chlorides were distilled by standard procedures. Imine **3** was prepared by a known literature precedent.² Physical data, identity, and absolute configuration of β -lactams **4a**, **4c**, **4d**, **4e**, and **4f** were consistent with literature precedent.³ ¹H and ¹³C NMR spectra were acquired on a Varian Unity Plus 400 MHz instrument in CDCl₃. The ¹H (400 MHz) and ¹³C (101 MHz) chemical shifts are given in parts per million (δ) with respect to internal TMS standard or residual solvents peaks. FTIR spectra were recorded on a Bruker IFS-55 spectrometer and optical rotations were recorded on a Perkin Elmer 120 polarimeter at room temperature. Enantiomeric ratios were obtained using a Regis Technologies (*R,R*)-Whelk-01 chiral analytical HPLC column.

Cis-(3*R*,4*R*)-1-*p*-toluenesulfonyl-3-phenyl-4-ethoxycarbonylazetidione (4a). White crystalline solid recrystallized from Et₂O/hexanes: mp = 109-112 °C; [α]_D = -21.1° (c = 0.0075, CH₂Cl₂); ¹H NMR (CDCl₃); δ 8.02 (d, 2H), 7.40 (d, 2H), 7.27 (m, 3H), 7.10 (m, 2H), 4.99 (d, 1H), 4.89 (d, 1H), 4.48 (m, 2H), 2.48 (s, 3H), 0.75 (t, 3H) ppm; ¹³C NMR (CDCl₃) δ 170.2, 169.3, 129.2, 129.1, 128.4, 105.2, 88.6, 87.5, 62.1, 59.6, 58.6, 30.0, 22.2, 13.8, 8.2 ppm; IR (CH₂Cl₂): 3021, 2963, 1800, 1751, 1369, 1263, 1217, 1171, 1090, 1014; HPLC (15% CH₂Cl₂/0.5% HOAc/hexanes, 1.0 mL/min) (*R,R*) = 10.56, (*R,S*) = 8.23, (*S,R*) = 14.17, (*S,S*) = 18.75 min. Identity and absolute configuration of compound determined via single crystal X-ray diffraction.³

Cis-(3*R*,4*R*)-1-benzoyl-3-phenyl-4-ethoxycarbonylazetidione (4b). White crystalline solid recrystallized from Et₂O/hexanes: mp = 140-141 °C; [α]_D = -18.6° (c = 0.005, CH₂Cl₂); ¹H NMR (CDCl₃); δ 8.13 (d, 2H), 7.55 (m, 1H), 7.53 (m, 2H), 7.34 (m, 5H), 5.06 (d, 1H), 4.86 (d, 1H), 3.84 (q, 2H), 0.84 (t, 3H) ppm; ¹³C NMR (CDCl₃) δ 168.9, 162.8, 133.7, 123.0, 129.5, 129.2, 128.7, 128.5, 128.3, 127.2, 126.6, 62.2, 61.5, 56.7, 55.8 ppm; IR (CHCl₃): 2959, 2929, 2871, 1798, 1745, 1679, 1261; HPLC (10% CH₂Cl₂/0.5% HOAc/hexanes, 1.0 mL/min) (*R,R*) = 49.23, (*R,S*) = 12.77, (*S,R*) = 27.30, (*S,S*) = 57.60 min. Anal Calcd for C₁₉H₁₇NO₄: C, 70.6; H, 5.30; N, 4.33. Found C, 70.3; H, 5.31; N, 4.34. The identity and absolute configuration of this compound was determined by derivitization of compound **4a**. Optically pure β -lactam **4a** (10 mg) was stirred with SmI₂⁴ in THF (3 mL) overnight.³ The THF was removed *in vacuo* and the residue was taken up in CHCl₃. The solution was washed with water (3 X 3 mL). The organic layer was dried with MgSO₄, filtered through Celite, and concentrated. The residue was dissolved in pyridine and allowed to stir with a catalytic amount of DMAP overnight. The solution was diluted with CHCl₃ and washed with 10% NaHCO₃ solution (3 X 3 mL). The organic layer was dried with MgSO₄, filtered through Celite, and concentrated. After flash column chromatography of the residue, β -lactam **4b** was isolated (6.2 mg, 71 % yield) with an optical rotation equivalent to that of **4a**.

Cis-(3*S*,4*S*)-1-*p*-toluenesulfonyl-3-phenyl-4-ethoxycarbonylazetidione (4c). White crystalline solid recrystallized from Et₂O/hexanes; [α]_D = +19.2° (c = 0.0075, CH₂Cl₂); all other physical data consistent with other enantiomer **4a**.

Cis-(3*R*,4*R*)-1-*p*-toluenesulfonyl-3-ethyl-4-ethoxycarbonylazetidione (4d). Clear viscous oil; [α]_D = +54.1° (c = 0.0088, CH₂Cl₂); ¹H NMR (CDCl₃) δ 7.93 (d, 2H), 7.36 (d, 2H), 4.72 (d, 1H), 4.21 (m, 2H), 3.44 (m, 1H), 2.47 (s, 3H), 1.81 (m, 2H), 1.26 (t, 3H), 1.00 (t, 3H) ppm; ¹³C NMR (CDCl₃) δ 167.8, 164.6, 161.4, 145.8, 135.8, 130.1, 128.3, 62.4, 58.1, 54.9, 22.1, 14.6, 11.9 ppm; IR (CH₂Cl₂): 3072, 2934, 1800, 1750, 1599, 1459, 1366, 1270, 1207, 1171, 1090, 1021; HPLC (4% *i*-PrOH/hexanes, 1.0 mL/min) (*R,R*) = 33.24, (*R,S*) = 36.64, (*S,R*) = 43.38, (*S,S*) = 39.23 min. All other data were consistent with literature precedent.⁵

Cis-(3*R*,4*R*)-1-*p*-toluenesulfonyl-3-phenoxy-4-ethoxycarbonylazetidione (4e). White crystalline solid recrystallized from Et₂O/hexanes: mp = 130-131 °C; [α]_D = +65.0° (c = 0.0026, CH₂Cl₂); ¹H NMR (CDCl₃) δ 7.99 (d, 2H), 7.39 (d, 2H), 7.28 (m, 2H), 7.05 (m, 1H), 6.23 (d, 2H), 5.50 (d, 1H), 5.06 (d, 1H), 4.13 (m, 2H), 2.47 (s, 3H), 1.06 (t, 3H) ppm; ¹³C NMR (CDCl₃) δ 173.2, 165.7, 150.2, 146.3, 130.2, 130.0, 128.63, 116.0, 94.8, 80.7, 62.7, 60.7, 39.3, 22.2, 14.2 ppm; IR (CH₂Cl₂): 3052, 2925, 1810, 1750, 1599, 1495, 1373, 1267, 1232, 1173, 1089; HPLC (30% CH₂Cl₂/0.5% HOAc/hexanes, 1.0 mL/min) (*R,R*) = 8.64, (*R,S*) = 6.36, (*S,R*) = 7.09, (*S,S*) = 9.63 min. Anal Calcd for C₁₉H₁₉NO₆S: C, 58.6; H, 4.92; N, 3.60. Found C, 58.6; H, 4.91; N, 3.57.

Cis-(3*R*,4*R*)-1-*p*-toluenesulfonyl-3-acetoxy-4-ethoxycarbonylazetidione (4f). White crystalline solid recrystallized from Et₂O/hexanes: mp = 86-87 °C; [α]_D = +27.5° (c = 0.0083, CH₂Cl₂); ¹H NMR (CDCl₃) δ 7.96

¹ Jacketed addition funnel has a 25 mL capacity with an 8 mm outer diameter drain outlet.

² Tschäen, D. H.; Turos, E.; Weinreb, S. M. *J. Org. Chem.* **1984**, *49*, 5058-5064.

³ Taggi, A. E.; Hafez, A. M.; Wack, H.; Young, B.; Drury III, W. J.; Lectka, T. *J. Am. Chem. Soc.* **2000**, *122*, 7831-7832.

⁴ Girard, P.; Namy, J. L.; Kagan, H. B. *J. Am. Chem. Soc.*, **1980**, *102*, 2693-2698.

⁵ Firestone, R. A.; Barker, P. L.; Pisano, J. M.; Ashe, B. M.; Dahlgren, M. E. *Tetrahedron* **1990**, *46*, 2255.

(d, 2H), 7.39 (d, 2H), 6.07 (d, 1H), 5.96 (d, 1H), 4.20 (m, 2H), 2.48 (s, 3H), 2.05 (s, 3H), 1.22 (t, 3H) ppm; ¹³C NMR (CDCl₃) δ 168.5, 165.5, 159.9, 146.3, 135.3, 130.2, 128.5, 73.8, 62.7, 59.9, 22.1, 20.3, 14.4 ppm; IR (CH₂Cl₂): 3021, 2963, 1814, 1765, 1373, 1266, 1217, 1172, 1090, 1016; HPLC (15% CH₂Cl₂/0.5% HOAc/hexanes, 1.0 mL/min) (*R,R*) = 9.45, (*R,S*) = 7.49, (*S,R*) = 8.15, (*S,S*) = 10.95 min. Anal Calcd for C₁₅H₁₇NO₇S: C, 50.7; H, 4.82; N, 3.94. Found C, 50.8; H, 4.77; N, 3.91.

Procedure for Washing and Drying BEMP (5).⁶ The BEMP resin (5 g) is placed onto a fine-fritted filter. The polymer is first rinsed with 10 g of phosphazene base P₄-t-Bu in 100 mL of THF/MeCN (1:1), until the last eluted base fraction was free from Cl⁻ (AgNO₃/dil. HNO₃). The BEMP is then rinsed with THF/MeCN until all soluble base has been extracted. The BEMP is dried *in vacuo* at 100-150 °C overnight. The vacuum hose should contain a sintered glass plate.

Procedure for Washing and Drying Catalyst Resin (6). The resin (3 g) is placed on a fine fritted filter. The beads are first washed with methanol (3 X 50 mL), CH₂Cl₂ (3 X 50 mL), then Et₂O (3 X 50 mL). The catalyst is dried *in vacuo* overnight.

***N-p*-Toluenesulfonylchloroglycine ethyl ester (9a).** *p*-Toluenesulfamide (5.0 g, 29.2 mmol) was mixed with ethyl glyoxylate² (3.0 g, 29.2 mmol) in toluene and refluxed for 12 h. The product crashed out of solution when the toluene was cooled to room temperature and filtered off. To a suspension of *N-p*-toluenesulfonylhydroxyglycine ethyl ester (2.8 g, 20 mmol) in CH₂Cl₂ (10 mL) at ambient temperature was added oxalyl chloride (5.6 g, 44 mmol). The mixture was stirred 12 h followed by removal of the excess oxalyl chloride and solvent by reduced pressure rotary evaporation. The resulting solid was dried under high vacuum to afford quantitatively 11.1 g of the desired *N-p*-toluenesulfonylchloroglycine ethyl ester **9a**. White crystalline solid recrystallized from Et₂O/hexanes: mp = 107-108 °C; ¹H NMR (CDCl₃) δ 7.79 (d, 2H), 7.31 (d, 2H), 6.10 (d, 1H), 5.96 (d, 1H), 4.28 (q, 2H), 2.42 (s, 3H), 1.30 (t, 3H) ppm; ¹³C NMR (CDCl₃) δ 166.3, 145.7, 137.7, 130.7, 128.7, 65.6, 64.5, 22.7, 14.9 ppm; IR (CHCl₃): 1748, 1628, 1597, 1350, 1305; Anal Calcd for C₁₁H₁₂NO₃Cl: C, 45.3; H, 4.84; N, 4.80; Cl, 12.2. Found C, 45.5; H, 4.85; N, 4.79, Cl, 12.1.

***N*-Benzoylchloroglycine ethyl ester (9b).** Benzamide (3.54 g, 29.2 mmol) was mixed with ethyl glyoxylate² (3.0 g, 29.2 mmol) in toluene and refluxed for 12 h. The reaction was worked up by removal of the solvent and any excess glyoxylate *in vacuo* and the residue recrystallized from EtOAc/hexanes. To a suspension of *N*-benzoylhydroxyglycine ethyl ester (2.8 g, 20 mmol) in CH₂Cl₂ (10 mL) at ambient temperature was added thionyl chloride (4.5 g, 44 mmol). The mixture was stirred 12 h followed by removal of the excess thionyl chloride and solvent by reduced pressure rotary evaporation. The resulting solid was dried under high vacuum to afford quantitatively 11.1 g of the desired *N*-benzoylchloroglycine ethyl ester **9b**. White crystalline solid recrystallized from Et₂O/hexanes: mp = 67-69 °C; ¹H NMR (CDCl₃): δ 7.85 (d, 1H), 7.57 (m, 1H), 7.49 (m, 3H), 6.49 (d, 1H), 4.35 (m, 2H), 1.36 (t, 3H) ppm; ¹³C NMR (CDCl₃) δ 166.5, 166.0, 132.7, 132.2, 128.7, 128.4, 127.4, 63.2, 60.5 ppm; IR (CHCl₃): 1744, 1685, 1508, 1484, 1338; Anal Calcd for C₁₁H₁₂NO₃Cl: C, 54.7; H, 5.00; N, 5.80; Cl, 14.7. Found C, 54.9; H, 5.80; N, 5.79, Cl, 14.5.

Procedure for Washing and Drying Scavenger Resin (10). The resin (2 g) is placed on a fine-fritted filter. The beads are first washed with Et₃N (20 mL) in a THF solution (100 mL). The beads are then washed with CH₂Cl₂ (3 X 50 mL) and Et₂O (3 X 50 mL). The scavenger resin is dried *in vacuo* overnight.

⁶ Schwesinger, R.; Willaredt, J.; Schlemper, H.; Keller, M.; Schmitt, D.; Fritz, H. *Chem. Ber.* **1994**, *127*, 2435-2454.