Palladium-Catalyzed α-Arylation of Carboxylic Acid and Amino Acid Esters

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Supporting Information

Experimental Section

General Methods. Reactions were conducted using standard drybox techniques. However, P(*t*-Bu)$_3$ is available as a solution in toluene (Strem), lithium hexamethyldisilazide is available as a solution in hexanes, sodium hexamethyldisilazide is available as a solution in toluene (Aldrich), and Pd(dba)$_2$ can be weighed in air without decomposition. Thus, addition of these reagents to a degassed solution of toluene and aryl halide using standard syringe techniques provides an alternative procedure to the ones described below. When tested, equivalent yields by GC were obtained without use of the drybox. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker DPX 400 MHz spectrometer with tetramethylsilane or residual protiated solvent used as a reference and coupling constants reported in Hertz (Hz). Elemental analyses were performed by Robertson Microlabs, Inc., Madison, NJ and by Atlantic Microlabs, Inc., Norcross, GA. Chromatographic purifications were performed by flash chromatography using silica gel (200-400 mesh) from Natland International Corporation. Yields for final products in all tables refer to isolated yields and are the average of at least two runs. Spectroscopic data and combustion analyses are reported for all new compounds. Previously reported products were isolated in greater than 95% purity as determined by ^{1}H NMR and capillary gas chromatography (GC). All ^{13}C NMR spectra were proton decoupled. GC analyses were performed on a HP-6890 instrument using a DB-1301 narrow bore column for high temperature ramp applications (max. 120 ˚C/min). GCMS spectra

were recorded on a HP5890 instrument equipped with a HP5971A Mass Spectral Analyzer using a HP-1 methyl silicone column. All reagents and bases were purchased from Aldrich and used without further purification. $Pd(dba)_2$,[1] Ethyl *N*-(diphenylmethylene)glycinate,[2] and Ethyl *N*-(4-methoxybenzylidene)glycinate[3] were prepared according to literature procedures. Dioxane was purchased as anhydrous grade and stored in a drybox. Toluene and tetrahydrofuran were distilled from sodium and benzophenone and were stored in a dry box.

General Procedure for the Arylation of Esters.

To a screw-capped vial containing carbene ligand **2** or P^tBu_3 (0.0050 mmol), $Pd(dba)_2$ (0.0050 mmol), and LiHMDS (2.3 mmol, for *t*-butyl acetate) or NaHMDS (2.3 mmol, for t-buty propionate) was added aryl halide (1.0 mmol) and ester (1.1 mmol) followed by toluene (2.5 mL). The vial was sealed with a cap containing a PTFE septum and removed from the dry box. The heterogeneous reaction mixture was stirred at room temperature and monitored by GC. Upon consumption of aryl halide, the crude reaction was diluted with Et_2O and was quenched with aqueous NH_4Cl. The organic phase was washed with a saturated NaCl solution, dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The organic solution was concentrated *in vacuo*. The residue was then purified by chromatography on silica gel using 5% EtOAc in Hexane.

***tert*-Butyl (4-*tert*-butylphenyl)acetate, (Table 1, entry 1).**

^1H NMR ($CDCl_3$): δ 7.26 (d, J = 8.4 Hz, 2H), 7.12 (d, J = 8.2 Hz, 2H), 3.43 (s, 2H), 1.37 (s, 9H), 1.24 (s, 9H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 171.60, 150.00, 132.00, 129.25, 125.80, 81.12, 42.38, 34.83, 31.76, 28.49. Anal. Calcd for $C_{16}H_{24}O_2$: C, 77.38; H, 9.74. Found: C, 77.63; H, 9.73.

***tert*-Butyl phenylacetate, (Table 1, entry 2).** [4]

^{1}H NMR ($CDCl_3$): δ 7.23-7.17 (m, 5H), 3.45 (s, 2H), 1.36 (s, 9H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 171.62, 135.41, 129.88, 129.12, 127.50, 81.47, 43.35, 28.72.

***tert*-Butyl mesitylacetate, (Table 1, entry 3).**

^{1}H NMR ($CDCl_3$): δ 6.77 (s, 2H), 3.48 (s, 2H), 2.21 (s, 6H), 2.94 (s, 3H), 1.35 (s, 9H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 171.50, 137.54, 136.82, 129.92, 129.45, 81.22, 36.91, 28.70, 21.57, 20.87. Anal. Calcd for $C_{15}H_{22}O_2$: C, 76.88; H, 9.46. Found: C, 76.98; H, 9.29.

***tert*-Butyl 1,1'-biphenyl-4-ylacetate, (Table 1, entry 4).**

^{1}H NMR ($CDCl_3$): δ 7.61-7.54 (m, 4H), 7.44 (m, 2H), 7.35 (d, J = 7.8 Hz, 2H), 7.34 (m, 1H), 3.58 (s, 2H), 1.47 (s, 9H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 171.32, 141.31, 140.19, 134.15, 130.02, 129.13, 127.61, 127.58, 127.46, 81.31, 42.64, 28.67. Anal. Calcd for $C_{18}H_{20}O_2$: C, 80.56; H, 7.51. Found: C, 80.61; H, 7.27.

***tert*-Butyl 3-methoxyphenylacetate, (Table 1, entry 5).**

^{1}H NMR ($CDCl_3$): δ 7.15 (t, J = 7.8 Hz, 1H), 6.79-6.71 (m, 3H), 3.73 (s, 3H), 3.42 (s, 2H), 1.37 (s, 9H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 171.48, 160.30, 136.83, 130.08, 122.26, 115.44, 113.11, 81.50, 55.85, 43.39, 28.72. Anal. Calcd for $C_{13}H_{18}O_3$: C, 70.24; H, 8.16. Found: C, 70.50; H, 8.31.

***tert*-Butyl 2-methoxyphenylacetate, (Table 1, entry 6).**

^{1}H NMR ($CDCl_3$): δ 7.11 (m, 1H), 7.03 (dd, J = 7.5, 1.6 Hz, 1H), 6.77 (td, J = 7.5, 1.0 Hz, 1H), 6.73 (d, J = 8.2 Hz, 1H), 3.68 (s, 3H), 3.40 (s, 2H), 1.31 (s, 9H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 171.70, 157.90, 131.18, 128.67, 124.24, 120.81, 110.76, 80.75, 55.73, 37.67, 28.46. Anal. Calcd for $C_{13}H_{18}O_3$: C, 70.24; H, 8.16. Found: C, 70.25; H, 8.28.

***tert*-Butyl 2-naphthylacetate, (Table 1, entry 7).**

^{1}H NMR ($CDCl_3$): δ 7.85-7.83 (m, 3H), 7.76 (s, 1H), 7.52-7.45 (m, 3H), 3.73 (s, 2H), 1.48 (s, 9H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 171.58, 134.16, 133.08, 132.94, 128.72, 128.51, 128.35, 128.30, 128.12, 126.69, 126.32, 81.61, 43.55, 28.74. Anal. Calcd for $C_{16}H_{18}O_2$: C, 79.31; H, 7.49. Found: C, 79.69; H, 7.55.

***tert*-Butyl 4-methoxyphenylacetate, (Table 1, entry 8).**

^{1}H NMR ($CDCl_3$): δ 7.11 (d, J = 8.4 Hz, 2H), 6.78 (d, J = 8.5 Hz, 2H), 3.72 (s, 3H), 3.39(s, 2H), 1.36 (s, 9H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 171.72, 158.88, 130.61, 127.20, 114.26, 81.08, 55.64, 42.10, 28.45. Anal. Calcd for $C_{13}H_{18}O_3$: C, 70.24; H, 8.16. Found: C, 70.54; H, 8.14.

***tert*-Butyl hydratropate, (Table 1, entries 9, 10).**[5]

^{1}H NMR ($CDCl_3$): δ 7.26-7.20 (m, 3H), 7.16 (m, 2H), 3.53 (q, J = 7.2 Hz, 1H), 1.37 (d, J = 7.2 Hz, 3H), 1.32 (s, 9H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 174.54, 141.83, 129.12, 128.07, 127.48, 81.12, 47.12, 28.60, 19.22.

***tert*-Butyl 2-(2-methylphenyl)propanoate, (Table 1, entry 11).**

^{1}H NMR ($CDCl_3$): δ 7.19 (d, J = 7.3 Hz, 1H), 7.12-7.03 (m, 3H), 3.77 (q, J = 7.1 Hz, 1H), 2.29 (s, 3H), 1.35 (d, J = 7.1 Hz, 3H), 1.31 (s, 9H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 174.56, 140.08, 136.08, 130.72, 127.02, 126.65 (2C), 80.78, 42.57, 28.34, 20.04, 18.12. Anal. Calcd for $C_{14}H_{20}O_2$: C, 76.33; H, 9.15. Found: C, 76.59; H, 9.25.

***tert*-Butyl mesitylpropanoate, (Table 1, entry 12).**

^{1}H NMR ($CDCl_3$): δ 6.84 (s, 2H), 3.99 (q, J = 7.2 Hz, 1H), 2.29 (s, 6H), 2.27 (s, 3H), 1.43 (s, 9H), 1.40 (d, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 175.03, 136.58, 136.53, 136.22, 130.20, 80.95, 41.78, 28.64, 21.44, 21.05, 16.20. Anal. Calcd for $C_{16}H_{24}O_2$: C, 77.38; H, 9.74. Found: C, 77.65; H, 9.60.

***tert*-Butyl 2-(7-methxoy-2-naphthyl)propanoate, (Table 1, entry 13).**[6]

^{1}H NMR ($CDCl_3$): δ 7.74 (d, J = 8.7 Hz, 1H), 7.73 (d, J = 8.4 Hz, 1H), 7.44 (d, J = 8.5 Hz, 1H), 7.18 (m, 3H), 3.93 (s, 3H), 3.77 (q, J = 7.1 Hz, 1H), 1.56 (d, J = 7.1 Hz, 3H), 1.42 (s, 9H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 174.66, 158.15, 137.01, 134.19, 129.93, 129.58, 127.59, 127.00, 126.43, 119.47, 106.17, 81.15, 55.94, 47.03, 28.61, 19.22.

Ethyl 2-(4-*tert*-butylphenyl)-3-methylbutanoate, (Table 1, entry 14).

^{1}H NMR ($CDCl_3$): δ 7.23 (d, J = 8.4 Hz, 2H), 7.18 (d, J = 8.4 Hz, 2H), 4.00 (m, 2H), 3.03 (d, J = 10.6 Hz, 1H), 2.24 (m, 1H), 1.23 (s, 9H), 1.15 (t, J = 7.1 Hz, 3H), 0.96 (d, J = 6.5 Hz, 3H), 0.63 (d, J = 6.7 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 174.87, 150.57, 136.03, 128.74, 125.94, 61.06,

60.36, 35.09, 32.70, 32.04, 22.08, 21.03, 14.87. Anal. Calcd for $C_{17}H_{26}O_2$: C, 77.82; H, 9.99. Found: C, 77.85; H, 9.78.

Methyl (4-*tert*-butylphenyl)(cyclohexyl)acetate, (Table 1, entry 15).

^{1}H NMR ($CDCl_3$): δ 7.23 (d, J = 8.4 Hz, 2H), 7.16 (d, J = 8.4 Hz, 2H), 3.56 (s, 3H), 3.13 (d, J = 10.7 Hz, 1H), 1.93 (m, 1H), 1.68 (m, 2H), 1.54 (m, 2H), 1.25 (m, 1H), 1.24 (s, 9H), 1.06 (m, 2H), 0.98 (m, 1H), 0.80 (m, 1H), 0.65 (m, 1H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 175.27, 150.61, 135.40, 128.81, 126.00, 59.02, 52.31, 41.72, 35.10, 32.68, 32.03, 31.16, 27.01, 26.69, 26.67. Anal. Calcd for $C_{19}H_{28}O_2$: C, 79.12; H, 9.78. Found: C, 79.30; H, 9.73.

General Procedure for the Arylation of Ethyl *N*-(diphenylmethylene)glycinate

To a screw-capped vial containing imine or amino ester (1.1 mmol) and aryl halide (1.0 mmol) was added phosphine (0.040 mmol), $Pd(dba)_2$ (0.020 mmol), and K_3PO_4 (3.0 mmol) followed by toluene (3 mL). The vial was sealed with a cap containing a PTFE septum and removed from the dry box. The heterogeneous reaction mixture was stirred at the required temperature and monitored by GC. Upon consumption of aryl halide, the crude reaction was filtered through a plug of Celite and concentrated *in vacuo*. The residue was then purified by chromatography on silica gel using 1% *v*/*v* Et_3N/hexanes.

Ethyl (4-tert-butylphenyl)(dimethylamino)acetate, (Table 1, entry 16).

^{1}H NMR ($CDCl_3$): δ 7.28 (s, 4H), 4.10 (m, 2H), 3.75 (s, 1H), 2.17 (s, 6H), 1.24 (s, 9H), 1.16 (t, J = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 172.65, 151.89, 134.09, 128.94, 126.10, 75.82, 61.53, 44.22, 35.21, 31.98, 14.81. Anal. Calcd for $C_{16}H_{25}NO_2$: C, 72.97; H, 9.57; N, 5.32. Found: C, 72.97; H, 9.46; N, 5.26.

Ethyl *N*-(diphenylmethylene)-2-phenylglycinate, (Table 2, entries 1 and 2).[2]

^{1}H NMR ($CDCl_3$): δ 7.74-7.71 (m, 2H), 7.46-7.42 (m, 5H), 7.40-7.24 (m, 6H), 7.11-7.06 (m, 2H), 5.13 (s, 1H), 4.19-4.09 (m, 2H), 1.18 (t, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 171.43, 170.14, 139.38, 139.21, 136.16, 130.42, 128.95, 128.75, 128.51, 128.42, 127.99, 127.89, 127.68, 127.65, 69.65, 61.12, 14.07.

***tert*-Butyl *N*-(diphenylmethylene)-2-phenylglycinate, (Table 2, entry 3).**

^{1}H NMR ($CDCl_3$): δ 7.79-7.76 (m, 2H), 7.50-7.46 (m, 5H), 7.43-7.25 (m, 6H), 7.16-7.12 (m, 2H), 5.02 (s, 1H), 1.36 (s, 9H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 170.46, 169.60, 139.61, 139.48, 136.31, 130.27, 128.86, 128.62, 128.42, 128.24, 127.92, 127.86, 127.67, 127.41, 81.16, 70.16, 27.85. Anal. Calcd. for $C_{25}H_{25}NO_2$: C, 80.83; H, 6.78; N, 3.77. Found: C, 80.64: H, 6.61: N, 3.79.

Ethyl *N*-(diphenylmethylene)-2-(2-methylphenyl)glycinate, (Table 2, entries 4 and 5).

^{1}H NMR ($CDCl_3$): δ 7.76-7.73 (m, 2H), 7.64-7.62 (m, 1H), 7.46-7.42 (m, 3H), 7.41-7.33 (m, 3H), 7.23-7.16 (m, 2H), 7.12-7.07 (m, 3H), 5.16 (s, 1H), 4.20-4.09 (m, 2H), 2.09 (s, 3H), 1.20 (t, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 171.70, 170.04, 139.39, 138.08, 136.54, 135.93, 130.40, 130.29, 128.93, 128.83, 128.67, 128.59, 128.01, 127.56, 127.44, 126.17, 66.63, 61.10, 19.32, 14.14. Anal. Calcd. for $C_{24}H_{23}NO_2$: C, 80.64; H, 6.49; N 3.92. Found: C, 80.44: H, 6.43: N, 3.97.

Ethyl *N*-(diphenylmethylene)-2-(4-methoxyphenyl)glycinate, (Table 2, entries 6 and 7)[7]

^{1}H NMR ($CDCl_3$): δ 7.76-7.74 (m, 2H), 7.48-7.46 (m, 3H), 7.43-7.33 (m, 5H), 7.14-7.11 (m, 2H), 6.91-6.88 (m, 2H), 5.12 (s, 1H), 4.19-4.09 (m, 2H), 3.81 (s, 3H), 1.22 (t, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 171.69, 169.80, 159.06, 139.42, 136.18, 131.45, 130.36, 128.97, 128.90, 128.72, 128.49, 127.97, 127.66, 113.79, 69.00, 61.06, 55.19, 14.10.

Ethyl *N*-(diphenylmethylene)-2-(4-fluorophenyl)glycinate, (Table 2, entries 8 and 9).

^{1}H NMR ($CDCl_3$): δ 7.73-7.70 (m, 2H), 7.48-7.37 (m, 6H), 7.35-7.31 (m, 2H), 7.10-7.07 (m, 2H), 7.04-6.98 (m, 2H), 5.11 (s, 1H), 4.19-4.07 (m, 2H), 1.19 (t, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 171.30, 170.38, 162.30 (d, J = 245.9 Hz), 139.26, 136.08, 135.01 (d, J = 3.1 Hz), 130.56, 129.54, (d, J = 8.2 Hz), 128.95, 128.85, 128.59, 128.05, 127.60, 115.29 (d, J = 21.4 Hz), 68.82, 61.25, 14.08. Anal. Calcd. for $C_{23}H_{20}FNO_2$: C, 76.44; H, 5.58; N, 3.88. Found: C, 76.26: H, 5.63: N, 3,84.

Ethyl *N*-(diphenylmethylene)-2-(4-cyanophenyl)glycinate, (Table 2, entries 10 and 11).

^{1}H NMR ($CDCl_3$): δ 7.73-7.71 (m, 2H), 7.64-7.58 (m, 4H), 7.48-7.33 (m, 6H), 7.09-7.07 (m, 2H), 5.17 (s, 1H), 4.19-4.08 (m, 2H), 1.19 (t, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 171.42, 170.30, 144.28, 138.94, 135.80, 132.23, 130.84, 129.03, 128.98, 128.78, 128.71, 128.13, 127.47, 118.78, 111.57, 69.12, 61.62, 14.04. Anal. Calcd. for $C_{24}H_{20}N_2O_2$: C, 78.24; H, 5.47; N, 7.60. Found: C, 78.44: H, 5.44: N, 7.62.

Ethyl *N*-(diphenylmethylene)-2-(4-methoxycarbonylphenyl)glycinate, (Table 2, entry 12).

^{1}H NMR ($CDCl_3$): δ 8.02-7.99 (m, 2H), 7.74-7.71 (m, 2H), 7.54-7.52 (m, 2H), 7.46-7.32 (m, 6H), 7.10-7.07 (m, 2H), 5.19 (s, 1H), 4.17-4.10 (m, 2H), 3.89 (s, 3H), 1.18 (t, J = 7.2 Hz, 3H).

$^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 170.92, 170.78, 166.86, 144.18, 139.16, 135.97, 130.66, 129.74, 129.50, 128.98, 128.93, 128.63, 128.08, 127.97, 127.56, 69.38, 61.39, 52.08, 14.04. Anal. Calcd. for $C_{25}H_{23}NO_4$: C, 74.79; H, 5.77; N, 3.49. Found: C, 74.44: H, 5.84: N, 3.47.

Ethyl *N*-(diphenylmethylene)-2-(4-trifluoromethylphenyl)glycinate, (Table 2, entries 13 and 14). ^{1}H NMR ($CDCl_3$): δ 7.74-7.71 (m, 2H), 7.59 (s, 4H), 7.46-7.38 (m, 4H), 7.36-7.32 (m, 2H), 7.11-7.08 (m, 2H), 5.19 (s, 1H), 4.21-4.08 (m, 2H), 1.19 (t, J = 7.6 Hz, 3H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 171.05, 170.72, 143.09, 139.14, 135.98, 130.73, 129.90 (q, J = 32.5 Hz), 129.01, 128.78, 128.69, 128.39, 128.12, 127.58, 125.39 (q, J = 3.4 Hz), 124.16 (q, J = 272.0 Hz), 69.21, 61.50, 14.06. Anal. Calcd. for $C_{24}H_{20}F_3NO_2$: C, 70.06; H, 4.90; N, 3.40. Found: C, 70.14: H, 4.95: N, 3.40.

Ethyl *N*-(diphenylmethylene)-2-(biphenyl-4-yl)glycinate, (Table 2, entry 15).

^{1}H NMR ($CDCl_3$): δ 7.76-7.73 (m, 2H), 7.59-7.50 (m, 6H), 7.47-7.30 (m, 9H), 7.14-7.11 (m, 2H), 5.18 (s, 1H), 4.22-4.10 (m, 2H), 1.21 (t, J = 7.2 Hz, 3H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 171.45, 170.27, 140.83, 140.57, 139.40, 139.26, 136.18, 130.47, 129.00, 128.81, 128.73, 128.57, 128.31, 128.03, 127.71, 127.24, 127.20, 127.08, 69.40, 61.25, 14.12. Anal. Calcd. for $C_{29}H_{25}NO_2$: C, 83.03; H, 6.01; N, 3.34. Found: C, 82.67: H, 6.04: N, 3.35.

Ethyl *N*-(diphenylmethylene)-2-(naphthalen-1-yl)glycinate, (Table 2, entry 16).[8]

^{1}H NMR ($CDCl_3$): δ 8.26-8.22 (m, 1H), 7.94-7.90 (m, 1H), 7.87 (d, 8.4 Hz, 1H), 7.83-7.80 (m, 2H), 7.67, (d, 6.8 Hz, 1H), 7.56-7.45 (m, 7H), 7.43-7.38 (m, 2H), 7.19-7.17 (m, 2H), 5.85 (s, 1H), 4.26-4.14 (m, 2H), 1.19 (t, J = 7.2 Hz, 3H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 171.75, 170.27,

139.43, 136.12, 135.49, 134.00, 131.16, 130.46, 129.03, 128.77, 128.58, 128.56, 128.41, 128.02, 127.76, 126.91, 125.95, 125.50, 125.45, 124.60, 67.83, 61.25, 14.07.

Ethyl *N*-(diphenylmethylene)-2-(naphthalen-2-yl)glycinate, (Table 2, entry 17).

^{1}H NMR ($CDCl_3$): δ 7.83-7.78 (m, 4H), 7.77-7.74 (m, 2H), 7.63 (dd, *J* = 8.8, 2.0 Hz, 1H), 7.48-7.32 (m, 8H), 7.12-7.09 (m, 2H), 5.30 (s, 1H), 4.21-4.08 (m, 2H), 1.18 (t, *J* = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 171.47, 170.43, 139.42, 136.74, 136.18, 133.31, 132.97, 130.49, 129.02, 128.83, 128.56, 128.12, 128.07, 128.04, 128.03, 127.72, 127.63, 126.75, 125.97, 125.94, 69.83, 61.25, 14.11. Anal. Calcd. for $C_{27}H_{23}NO_2$: C, 82.42; H, 5.89; N, 3.56. Found: C, 82.13: H, 5.92: N, 3.56.

Ethyl *N*-(diphenylmethylene)-2-(4-phenoxyphenyl)glycinate, (Table 2, entry 18).

^{1}H NMR ($CDCl_3$): δ 7.72-7.69 (m, 2H), 7.44-7.27 (m, 10H), 7.10-7.04 (m, 3H), 7.01-6.92 (m, 4H), 5.10 (s, 1H), 4.18-4.07 (m, 2H), 1.18 (t, 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 171.48, 170.12, 157.00, 156.80, 139.34, 136.15, 133.99, 130.48, 129.70, 129.29, 128.95, 128.79, 128.55, 128.02, 127.65, 123.28, 118.99, 118.63, 69.01, 61.17, 14.11. Anal. Calc'd. for $C_{29}H_{25}NO_3$: C, 79.98; H, 5.79; N, 3.22. Found: C, 79.96: H, 5.67: N, 3.17.

Ethyl *N*-(diphenylmethylene)-2-[4-(1,3-Dioxolane)phenyl]glycinate, (Table 2, entry 19).

^{1}H NMR ($CDCl_3$): δ 7.73-7.70 (m, 2H), 7.46-7.30 (m, 6H), 7.12-7.07 (m, 2H), 7.06 (d, *J* = 1.6 Hz, 1H), 6.82-6.79 (m, 1H), 6.73 (d, *J* = 8.0 Hz, 1H), 5.92 (ABq, *J* = 1.6 Hz, 2H), 5.04 (s, 1H), 4.19-4.07 (m, 2H), 1.19 (t, *J* = 7.2 Hz, 3H). ^{13}C{^{1}H} ($CDCl_3$): δ 171.49, 170.02, 147.65, 147.10, 139.33, 136.12, 133.06, 130.46, 128.94, 128.78, 128.54, 128.01, 127.65, 121.16, 108.50, 108.07,

100.99, 69.22, 61.16, 14.10. Anal. Calcd. for $C_{24}H_{21}NO_4$: C, 74.40; H, 5.64; N, 3.62. Found: C, 73.82: H, 5.58: N, 3.62.

Ethyl *N*-(diphenylmethylene)-2-(pyridin-3-yl)glycinate, (Table 2, entries 20 and 21). ^{1}H NMR ($CDCl_3$): δ 8.53 (br s, 2H), 7.93-7.90 (m, 1H), 7.73-7.70 (m, 2H), 7.48-7.46 (m, 3H), 7.45-7.27 (m, 4H), 7.12-7.09 (m, 2H), 5.16 (s, 1H), 4.20-4.09 (m, 2H), 1.20 (t, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$) δ 171.19, 170.63, 149.30, 149.09, 139.01, 135.87, 135.76, 134.94, 130.73, 129.01, 128.95, 128.73, 128.09, 127.49, 123.51, 67.28, 61.50, 14.05. Anal. Calcd. for $C_{22}H_{20}N_2O_2$: C, 76.72; H, 5.85; N, 8.13. Found: C, 76.51: H, 5.82: N, 8.09.

Ethyl *N*-(diphenylmethylene)-2-(2-methoxyphenyl)glycinate, (Table 2, entry 22). ^{1}H NMR ($CDCl_3$): δ 7.72-7.69 (m, 2H), 7.54 (dd, J = 7.6, 2.0 Hz, 1H), 7.41-7.29 (m, 6H), 7.26-7.22 (m, 1H), 7.15-7.11 (m, 2H), 6.96 (dt, J = 7.6, 0.8 Hz, 1H), 6.81 (dd, J = 8.2, 0.8 Hz, 1H), 5.49 (s, 1H), 4.19-4.12 (m, 2H), 3.65 (s, 3H), 1.19 (t, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR (CD_3CN): δ 170.74, 170.47, 156.26, 139.08, 135.84, 130.27, 129.43, 128.52, 128.33, 128.19, 128.17, 127.89, 127.47, 127.25, 120.24, 110.53, 63.55, 60.49, 54.79, 13.17. Anal. Calcd. for $C_{24}H_{23}NO_3$: C, 77.19; H, 6.21; N, 3.75. Found: C, 77.20: H, 6.36: N, 3.76.

Ethyl *N*,*N*-dimethyl-2-phenylglycinate, (Table 1, entry 15).[9] ^{1}H NMR ($CDCl_3$): δ 7.45-7.42 (m, 2H), 7.37-7.31 (m, 3H), 4.25-4.09 (m, 2H), 3.84 (s, 1H), 2.25 (s, 6H), 1.21 (dt, J = 7.2, 0.8 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 171.78, 136.57, 128.69, 128.54, 128.33, 75.48, 60.93, 43.54, 14.10.

General Procedure for the Arylation of Ethyl *N*-(diphenylmethylene)glycinate

To a screw-capped vial containing imine (1.1 mmol) and aryl halide (1.0 mmol) was added phosphine (0.040 mmol), $Pd(dba)_2$ (0.020 mmol), and K_3PO_4 (3.0 mmol) followed by toluene (3 mL). The vial was sealed with a cap containing a PTFE septum and removed from the dry box. The heterogeneous reaction mixture was stirred at the required temperature and monitored by GC. Upon consumption of aryl halide, the crude reaction was filtered through a plug of Celite and concentrated *in vacuo*. The residue was dissolved in diethyl ether (5 mL) and hydrochloric acid (5 mL, 1.0 M), and the mixture was stirred for 12 h at room temperature. After separation, the aqueous layer was concentrated *in vacuo* and dichloromethane (20 mL) and triethylamine (10 mL) was added. The solvent was removed *in vacuo* and diethyl ether (20 mL) added. Following filtration to remove NH_4Cl and concentration of the resulting amine, the crude product was purified by chromatography on silica gel (10% *v*/*v* ethyl acetate/hexane).

Ethyl 2-phenylglycinate, (Table 2, enties 23 and 24).[10] ^{1}H NMR ($CDCl_3$): δ 7.40-7.37 (m, 5H), 4.59 (s, 1H), 4.24-4.08 (m, 2H), 1.95 (br s, 2H), 1.20 (t, J = 7.2 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 173.99, 140.43, 128.74, 127.93, 126.76, 61.31, 58.80, 14.08.

Ethyl 2-(4-methoxyphenyl)glycinate, (Table 2, entry 25).[11] ^{1}H NMR ($CDCl_3$): δ 7.32-7.28 (m, 2H), 6.90-6.86 (m, 2H), 4.55 (s, 1H), 4.24-4.08 (m, 2H), 3.80 (s, 3H), 1.86 (br s, 2H), 1.21 (t, J = 7.2 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 174.26, 159.26, 132.63, 127.92, 114.09, 61.25, 58.19, 55.28, 14.11.

Ethyl 2-(2-methylphenyl)glycinate, (Table 2, entry 26).[12] ^{1}H NMR ($CDCl_3$): δ 7.26-7.23 (m, 1H), 7.21-7.17 (m, 3H), 4.80 (s, 1H), 4.24-4.08 (m, 2H), 2.45 (s, 3H), 1.87 (br s, 2H), 1.20 (t, J =

7.2 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 174.61, 138.91, 136.00, 130.76, 127.78, 126.48, 125.96, 61.25, 55.27, 19.39, 14.09.

Ethyl 2-[4-(1,3-Dioxolane)phenyl]glycinate, (Table 2, entry 27). ^1H NMR ($CDCl_3$): δ 6.88 (d, *J* = 1.6 Hz, 1H), 6.85 (dd, *J* = 8.0, 1.6 Hz, 1H), 6.78 (d, *J* = 8.0 Hz, 1H), 5.96 (s, 2H), 4.51 (s, 1H), 4.24-4.09 (m, 2H), 1.94 (br s, 2H), 1.22 (t, *J* = 7.2 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 173.93, 147.92, 147.31, 134.31, 120.27, 108.38, 107.21, 101.16, 61.37, 58.47, 14.11. Anal. Calcd. for $C_{11}H_{13}NO_4$: C, 59.19; H, 5.87; N, 6.37. Found: C, 59.24: H, 5.88: N, 6.37.

Ethyl 2-(naphthalen-1-yl)glycinate, (Table 2, entry 28).[13] ^1H NMR ($CDCl_3$): δ 8.20-8.18 (m, 1H), 7.88-7.85 (m, 1H), 7.83-7.78 (m, 1H), 7.57-7.47 (m, 2H), 7.46-7.42 (m, 2H), 5.31 (s, 1H), 4.25-4.10 (m, 2H), 2.03 (br s, 2H), 1.15 (t, *J* = 7.2 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 174.61, 136.58, 134.08, 131.00, 128.89, 128.66, 126.51, 125.82, 125.41, 124.63, 123.41, 61.39, 56.00, 14.05.

Ethyl 2-(naphthalen-2-yl)glycinate, (Table 2, entry 29).[13] ^1H NMR ($CDCl_3$): δ 7.83-7.78 (m, 4H), 7.50-7.43 (m, 3H), 4.75 (s, 1H), 4.23-4.07 (m, 2H), 2.01 (br s, 2H), 1.18 (t, *J* = 6.8 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 173.92, 137.86, 133.34, 133.00, 128.56, 127.98, 127.66, 126.28, 126.12, 125.75, 124.70, 61.36, 58.96, 14.09.

Ethyl 2-(biphenyl-4-yl)glycinate, (Table 2, entry 30). ^1H NMR ($CDCl_3$): δ 7.58-7.56 (m, 4H), 7.47-7.40 (m, 4H), 7.35-7.31 (m, 1H), 4.63 (s, 1H), 4.25-4.09 (m, 2H), 1.97 (br s, 2H), 1.22 (t, *J* = 7.2 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 173.93, 140.81, 140.55, 139.40, 128.77, 127.45,

127.38, 127.19, 127.05, 61.36, 58.49, 14.10. Anal. Calcd. for $C_{16}H_{17}NO_2$: C, 75.27; H, 6.71; N, 5.49. Found: C, 75.02: H, 6.76: N, 5.41.

Ethyl 2-(4-trifluoromethylphenyl)glycinate, (Table 2, entries 31 and 32). ^{1}H NMR ($CDCl_3$): δ 7.63-7.61 (m, 2H), 7.54-7.52 (m, 2H), 4.67 (s, 1H), 4.25-4.10 (m, 2H), 1.89 (br s, 2H), 1.22 (t, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 173.31, 144.19, 130.17 (q, J = 32.6 Hz), 127.29, 125.68 (q, J = 3.7 Hz), 124.06 (q, J = 271.8 Hz), 61.69, 58.39, 14.07. Anal. Calcd. for $C_{11}H_{12}F_3NO_2$: C, 53.44; H, 4.89; N, 5.67. Found: C, 53.50: H, 4.95: N, 5.58.

Ethyl 2-(4-fluorophenyl)glycinate, (Table 2, entry 33). ^{1}H NMR ($CDCl_3$): δ 7.39-7.34 (m, 2H), 7.07-7.01 (m, 2H), 4.58 (s, 1H), 4.24-4.09 (m, 2H), 1.90 (br s, 2H), 1.21 (t, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 173.87, 162.40 (d, J = 246.2 Hz), 136.17, 128.48 (d, J = 7.9 Hz), 115.59 (d, J = 21.5 Hz), 61.42, 58.06, 14.08. Anal. Calcd. for $C_{10}H_{12}FNO_2$: C, 60.90; H, 6.13; N, 7.10. Found: C, 61.09: H, 6.01: N, 6.99.

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