C-H Bond Functionalization via Hydride Transfer: Synthesis of Dihydrobenzopyrans from *ortho*-Vinylaryl Alkyl Ethers

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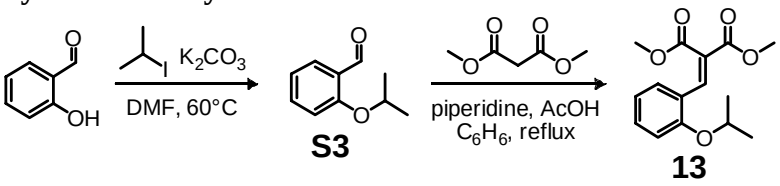
Supporting Information

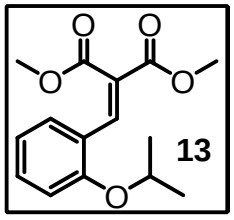
I. General Introduction and Materials.

All reactions were carried out under an argon atmosphere in oven dried glassware or 10 mL glass sample vials when noted. Argon was purified by passage through Drierite. Solvents were dried by passage through alumina columns prior to use. Nuclear Magnetic Resonance spectra were recorded on Bruker 300, 400 or 500 Fourier transform NMR spectrometers. Spectra were recorded in $CDCl_3$ solutions and were referenced to TMS (0.0 ppm) or the solvent residual peak in $CDCl_3$ (7.26 and 77.16 for ^1H and ^{13}C NMR, respectively). IR spectra were taken on NaCl plates using a Perkin-Elmer Spectrum 2000 FTIR spectrometer. Flash chromatography was performed on SILICYCLE silica gel (230-400 mesh). Mass spectra were recorded on a JEOL LCmate (Ionization mode: APCI+).

II. Synthesis of Starting Materials.

Synthesis of aryl ether 13.

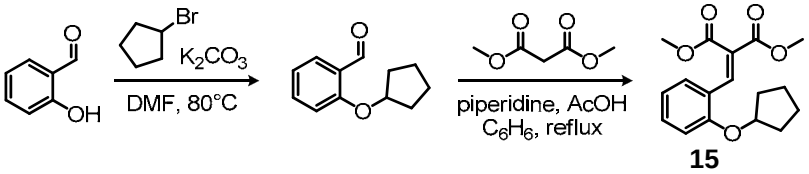


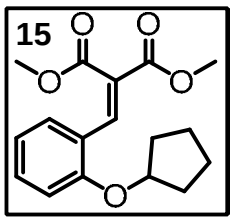


To a glass vial containing a magnetic stir bar and a solution of commercially available salicylaldehyde (1.00 g, 8.19 mmol) in DMF (5 mL) was added potassium carbonate (6.0 g, 43 mmol) followed by 2-iodopropane (1.2 mL, 12 mmol). The vial was sealed with a Teflon-lined cap and heated in an oil bath set to 60 °C. After stirring vigorously for 12 hours, the reaction was diluted with 50 mL of ether and the solids were removed by filtration. The organic layer was washed three times with water (25 mL), then brine and dried over sodium sulfate. The crude aldehyde, **S3** (for purification and spectral data, see page S6)**,** was concentrated under reduced pressure and redissolved in benzene (20 mL). To this solution was added dimethyl malonate (1.1 mL, 9.6 mmol), piperidine (0.5 ml, 5 mmol) and acetic acid (0.5 mL, 9 mmol) successively. The reaction flask was fitted with a Dean-Stark trap and the solution was refluxed overnight. After allowing the reaction to cool to room temperature, the solution was diluted with ether and washed once with a saturated solution of sodium bicarbonate then once with brine. The organic phase was then dried over sodium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (5:1 hexanes/ether) gave ether **13** (2.13 g, 7.64 mmol, 93% over two steps) as a pale yellow oil. IR (neat) 2978, 2950, 1736, 1724, 1623, 1597, 1483, 1454, 1437, 1372, 1266, 1218, 1121, 1066, 947, 755 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 8.14 (s, 1H), 7.35-7.31 (m, 2H), 6.92-6.87 (m, 2H), 4.58 (sept, *J*=6.0 Hz, 1H), 3.84 (s, 3H), 3.79 (s, 3H), 1.36 (d, *J*=6.0 Hz, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) 167.5, 165.0, 157.0, 139.6, 132.1,

129.1, 125.1, 123.5, 120.6, 114.0, 71.5, 52.6, 52.6, 22.2; MS (LR-APCI): calculated for $C_{15}H_{18}O_5$ 278.1, measured 279.3.

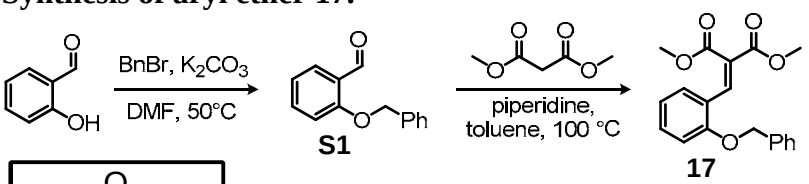
Synthesis of aryl ether 15.

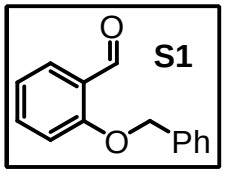




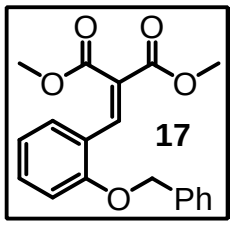
To a glass vial containing a magnetic stir bar and solution of commercially available salicylaldehyde (0.958 g, 7.84 mmol) in DMF (5 mL) was added potassium carbonate (1.2 g, 11 mmol) followed by bromocyclopentane (1.2 mL, 11 mmol). The vial was sealed with a Teflon-lined cap and heated in an oil bath set to 80 °C. After stirring vigorously for 4 hours, the reaction was diluted with ethyl acetate and washed two times with saturated sodium bicarbonate, once with water and once with brine. The crude aldehyde was concentrated under reduced pressure and redissolved in benzene (30 mL). To this solution was added dimethyl malonate (0.9 mL, 8 mmol), piperidine (0.1 ml, 1 mmol) and acetic acid (0.1 mL, 2 mmol), successively. The reaction flask was fitted with a Dean-Stark trap and the solution was refluxed overnight. After allowing to cool to room temperature, the reaction was diluted with ethyl acetate and washed once with 1M HCl, once with saturated sodium bicarbonate and once with brine. The organic phase was then dried over sodium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (15:1 hexanes/ethyl acetate) gave ether **15** (1.67 g, 7.64 mmol, 70% over two steps) as a pale yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.12 (s, 1H), 7.34-7.31 (m, 2H), 6.91-6.86 (m, 2H), 4.83-4.78 (m, 1H), 3.84 (s, 3H), 3.79 (s, 3H), 1.91-1.77 (m, 6H), 1.67-1.59 (m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) 167.6, 165.0, 157.1, 139.5, 132.1, 128.9, 124.8, 123.0, 120.3, 113.6, 80.4, 52.6, 33.0, 24.1; MS (LR-APCI): calculated for $C_{17}H_{20}O_5$ 304.1, measured 304.3.

Synthesis of aryl ether 17.



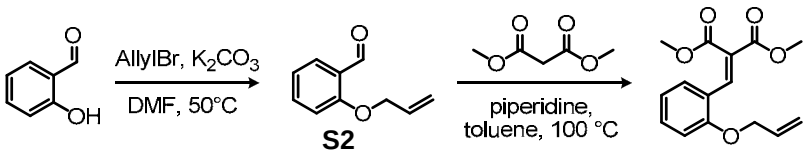


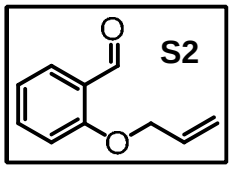
To a solution of commercially available salicylaldehyde (6.52 g, 53.4 mmol) in DMF (60 mL) was added potassium carbonate (14.9 g, 108 mmol) followed by benzyl bromide (7.6 mL, 64 mmol). The flask was capped with a rubber septum and heated in an oil bath set to 50 °C. After stirring vigorously for 11 hours, the reaction was diluted with ethyl acetate and washed once with ammonium chloride, twice with water and once with brine. After drying over sodium sulfate, the crude aldehyde was concentrated under reduced pressure. Purification of the crude material via flash chromatography (10:1 hexanes/ethyl acetate) gave known[1] aldehyde **S1** (9.8 g, 46 mmol, 86%) as a pale yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 10.54 (s, 1H), 7.83 (dd, *J*=8.0 Hz, *J*=2 Hz, 1H), 7.49-7.45 (m, 1H), 7.41-7.29 (m, 5H), 7.01-6.96 (m, 2H), 5.12 (s, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) 189.5, 161.0, 136.1, 135.9, 128.7, 128.3, 128.2, 127.2, 125.1, 120.9, 113.0, 70.4; MS (LR-APCI): calculated for $C_{14}H_{12}O_2$ 212.1, measured 212.6.



To a glass vial containing a solution of **S1** (940 mg, 4.43 mmol) in toluene (5 mL) was added dimethyl malonate (0.6 mL, 6 mmol), piperidine (0.1 mL, 1 mmol) and molecular sieves. The vial was sealed with a Teflon line cap and heated to 100 °C for 12 hours. The reaction was diluted with ethyl acetate and washed once with water and once with brine. The organic phase was dried over magnesium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (10:1 to 6:1 hexanes/ethyl acetate) gave ether **17** (1.13 g, 3.46 mmol, 78%) as a pale yellow solid. ^{1}H NMR ($CDCl_3$, 300 MHz) δ 8.22 (s, 1H), 7.43-7.30 (m, 7H), 6.95-6.90 (m, 2H), 5.15 (s, 2H), 3.84 (s, 3H), 3.78 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) 167.4, 164.9, 157.4, 139.1, 136.6, 132.2, 129.1, 128.8, 128.2, 127.2, 125.6, 122.9, 121.1, 112.9, 70.6, 52.7, 52.6; MS (LR-APCI): calculated for $C_{19}H_{18}O_5$ 326.1, measured 327.3.

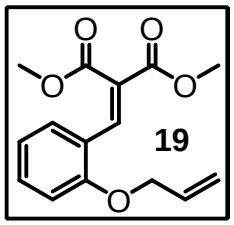
Synthesis of aryl ether 19.





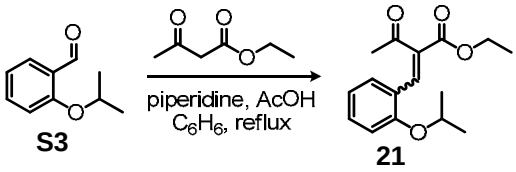
[1] Lin, C. F.; Yang, J. S.; Chang, C. Y.; Kuo, S. C.; Lee, M. R.; Huang, L. J. *Bioorg. Med. Chem.* **2005**, *13*, 1537-1544.

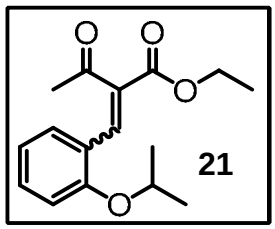
To a solution of commercially available salicylaldehyde (5.25 g, 43.0 mmol) in DMF (60 mL) was added potassium carbonate (12.1 g, 87.5 mmol) followed by allyl bromide (4.4 mL, 52 mmol). The flask was capped with a rubber septum and heated in an oil bath set to 50 °C. After stirring vigorously for 10 hours, the reaction was diluted with ethyl acetate and washed once with ammonium chloride, twice with water and once with brine. After drying over sodium sulfate, the crude aldehyde was concentrated under reduced pressure. The resulting crude oil was distilled (5 mmHg, 106-107 °C) to give known[2] aldehyde **S2** (6.08 g, 37.5 mmol, 87%) as a pale yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 10.54 (s, 1H), 7.84 (dd, *J*=7.6 Hz, *J*=2 Hz, 1H), 7.55-7.50 (m, 1H), 7.05-6.97 (m, 2H), 6.13-6.03 (m, 1H), 5.48-5.43 (m, 1H), 5.36-5.32 (m, 1H), 4.67-4.65 (m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) 189.4, 160.8, 135.8, 132.3, 128.2, 125.0, 120.7, 117.9, 112.8, 69.0; MS (LR-APCI): calculated for $C_{10}H_{10}O_2$ 162.1, measured 162.4.



To a glass vial containing a solution of **S2** (940 mg, 4.43 mmol) in toluene (5 mL) was added dimethyl malonate (0.6 mL, 6 mmol), piperidine (0.1 mL, 1 mmol) and molecular sieves. The vial was sealed with a Teflon line cap and heated to 100 °C for 12 hours. The reaction was diluted with ethyl acetate then washed once with water and once with brine. The organic phase was dried over magnesium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (10:1 to 6:1 hexanes/ethyl acetate) gave **19** (1.13 g, 3.46 mmol, 78%) as a pale yellow solid. ^{1}H NMR ($CDCl_3$, 300 MHz) δ 8.22 (s, 1H), 7.43-7.30 (m, 2H), 6.95-6.90 (m, 2H), 5.15 (s, 2H), 3.84 (s, 3H), 3.78 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) 167.4, 164.9, 157.3, 139.2, 132.9, 132.2, 129.1, 125.5, 122.7, 120.9, 117.9, 112.5, 69.4, 52.7, 52.6; MS (LR-APCI): calculated for $C_{15}H_{16}O_5$ 276.1, measured 277.3.

Synthesis of aryl ether 21.

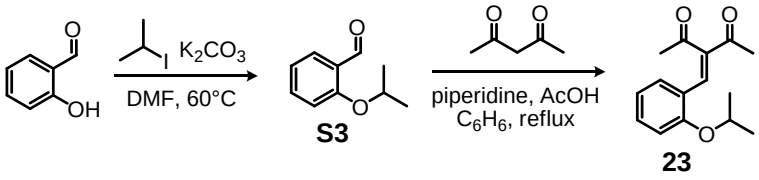


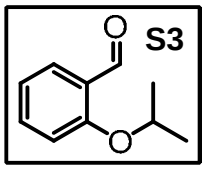


[2] Predhan, P. K.; Jaisankar, P.; Pal, B.; Dey, S.; Giri, V. S. *Synth. Commun.* **2004**, *34*, 2863-2872.

To a solution of **S3** (734 mg, 4.47 mmol) in benzene (20 mL) was added ethyl acetoacetate (0.57 mL, 4.5 mmol), piperidine (0.1 ml, 1 mmol) and acetic acid (0.1 mL, 2 mmol), successively. The reaction flask was fitted with a Dean-Stark trap and the solution was refluxed overnight. After allowing to cool to room temperature, the reaction mixture was diluted with ethyl acetate and washed once with 1 M HCl, once with saturated sodium bicarbonate and once with brine. The organic phase was dried over sodium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (12:1 hexanes/ethyl acetate) gave ethers **21** (1.04 g, 3.75 mmol, 84%) as a red oil, which contained a 1:2 mixture of olefin isomers (the geometry of each isomer was not determined). IR (neat) 3071, 2979, 2929, 1706 (b), 1665, 1607, 1483, 1454, 1379, 1301, 1243, 1115, 1048, 949, 858, 754, 605, 548 cm^{-1} ^1H NMR ($CDCl_3$, 400 MHz) major isomer: δ7.98 (s, 1H), 7.41-7.39 (m, 1H), 7.34-7.31 (m, 1H), 6.93-6.85 (m, 2H), 4.62-4.56 (m, 1H), 4.32-4.26 (m, 2H), 2.43 (s, 3H), 1.37 (d, *J*=6.0 Hz, 6H), 1.23 (t, *J*=7.2 Hz, 3H); minor isomer: δ 8.03 (s, 1H), 7.34-7.25 (m, 2H), 6.93-6.85 (m, 2H), 4.62-4.56 (m, 1H), 4.32-4.26 (m, 2H), 2.29 (s, 3H), 1.37 (d, *J*=6.0 Hz, 6H), 1.33 (t, *J*=7.2 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) (mixture of cis and trans isomers) 203.4, 195.3, 168.0, 164.8, 156.8, 156.7, 137.6, 137.1, 134.3, 133.5, 132.1, 131.8, 130.0, 129.1, 123.4, 120.5, 113.8, 71.3, 61.4, 61.3, 31.2, 26.5, 22.1, 14.2, 13.9; MS (LR-APCI): calculated for $C_{16}H_{20}O_4$ 276.1, measured 277.1.

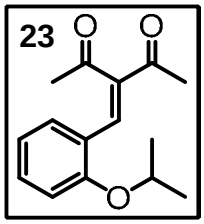
Synthesis of aryl ether 23.





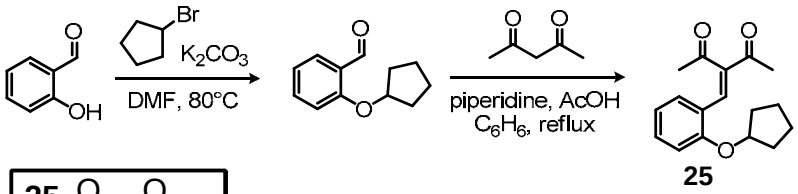
To a solution of commercially available salicylaldehyde (10.67 g, 87.37 mmol) in DMF (50 mL) was added potassium carbonate (18.5 g, 134 mmol) followed by 2-iodopropane (12 mL, 120 mmol). The flask was capped with a rubber septum and initially stirred at room temperature for 12 hours then heated to 60 °C for 4 hours. The reaction was diluted with ethyl acetate then washed twice with water and once with brine. After drying over sodium sulfate, the crude aldehyde was concentrated under reduced pressure. The resulting crude oil was distilled (5 mmHg, 98-100 °C) to give known[3] aldehyde **S3** (12.7 g, 77.3 mmol, 88%) as a pale yellow oil. ^1H NMR ($CDCl_3$, 300 MHz) δ 10.50 (s, 1H), 7.81 (dd, *J*=7.8 Hz, *J*=2 Hz, 1H), 7.53-7.47 (m, 1H), 6.99-6.94 (m, 2H), 4.67 (sept, *J*=6.0 Hz, 1H), 1.39 (d, *J*=6.0 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 190.0, 160.6, 135.8, 128.2, 125.7, 120.3, 114.0, 71.0, 21.9; MS (LR-APCI): calculated for $C_{10}H_{12}O_2$ 164.1, measured 164.7.

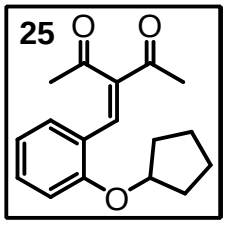
[3] Leardini, R.; McNab, H.; Minozzi, M.; Nanni, D.; Reed, D.; Wright, A. G. *J. Chem. Soc., Perkin Trans. 1*, **2001**, 2704-2710.



To a solution of **S3** (1.08 g, 6.59 mmol) in benzene (30 mL) was added pentane-2,4-dione (0.67 mL, 6.5 mmol), piperidine (0.1 ml, 1 mmol) and acetic acid (0.1 mL, 2 mmol), successively. The reaction flask was fitted with a Dean-Stark trap and the solution was refluxed overnight. The reaction mixture was then cooled to room temperature, diluted with ethyl acetate and washed once with 1 M HCl, once with saturated sodium bicarbonate and once with brine. The organic phase was then dried over sodium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (10:1 hexanes/ethyl acetate) gave ether **23** (450 mg, 1.8 mmol, 28%) as a red oil. IR (neat) 2976, 2930, 1711, 1690, 1658, 1598, 1481, 1451, 1380, 1304, 1248, 1169, 1116, 951, 756 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.90 (s, 1H), 7.37-7.33 (m, 1H), 7.28-7.26 (m, 1H), 6.94-6.87 (m, 2H), 4.62 (sept, *J*=6.0 Hz, 1H), 2.42 (s, 3H), 2.24 (s, 3H), 1.39 (d, *J*=6.0 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 205.7, 196.9, 156.6, 142.1, 136.3, 132.2, 130.0, 123.2, 120.7, 113.7, 71.3, 31.6, 26.6, 22.2; MS (LR-APCI): calculated for $C_{15}H_{18}O_3$ 246.1, measured 246.6.

Synthesis of aryl ether 25.

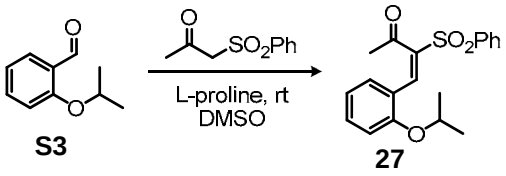


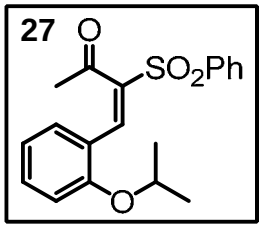


To a glass vial containing a magnetic stir bar and a solution of commercially available salicylaldehyde (1.32 g, 10.8 mmol) in DMF (2 mL) was added potassium carbonate (2.43 g, 17.6 mmol) followed bromocyclopentane (1.5 mL, 14 mmol). The vial was sealed with a Teflon-lined cap and heated in an oil bath set to 80 °C. After stirring vigorously for 18 hours, the reaction was diluted with ethyl acetate and the organic layer was washed twice with saturated sodium bicarbonate, and once with brine. After drying over sodium sulfate, the crude aldehyde was concentrated under reduced pressure and redissolved in benzene (30 mL). To this solution was added pentane-2,4-dione (0.82 mL, 8.0 mmol), piperidine (0.1 ml, 1 mmol) and acetic acid (0.1 mL, 2 mmol) successively. The reaction flask was fitted with a Dean-Stark trap and the solution was refluxed overnight. The reaction mixture was then cooled to room temperature, diluted with ethyl acetate and washed once with 1 M HCl, once with sodium bicarbonate and once with brine. The organic phase was then dried over sodium sulfate and concentrated under

reduced pressure. Purification of the crude material via flash chromatography (25:1 to 20:1 hexanes/ethyl acetate) gave ether **25** (1.24 g, 4.55 mmol, 42% over two steps) as a red oil. ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.89 (s, 1H), 7.38-7.32 (m, 1H), 7.28-7.25 (m, 1H), 6.94-6.85 (m, 2H), 4.88-4.83 (m, 1H), 2.42 (s, 3H), 2.25 (s, 3H), 1.97-1.65 (m, 8H); ^{13}C NMR ($CDCl_3$, 75 MHz) 205.9, 197.0, 156.7, 142.0, 136.2, 132.2, 129.9, 122.8, 120.5, 113.5, 80.3, 33.0, 31.7, 26.6, 24.1; MS (LR-APCI): calculated for $C_{17}H_{20}O_3$ 272.1, measured 272.4.

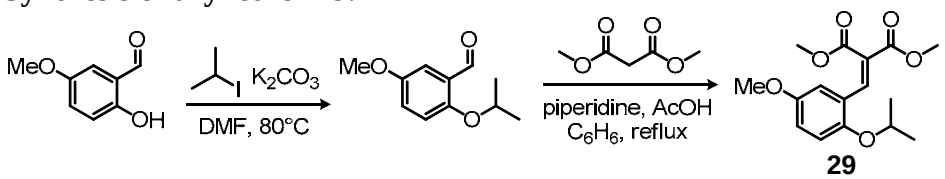
Synthesis of aryl ether 27.

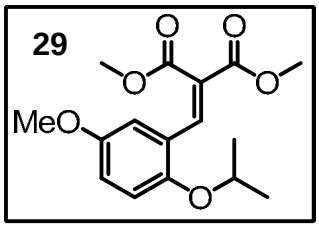




To a solution of **S3** (384 mg, 2.34 mmol) in DMSO (2 mL) was added (phenylsulfonyl)acetone (468 mg, 2.29 mmol) and L-proline (25 mg, 0.22 mmol). The reaction was stirred at room temperature for 14 hours then diluted with ethyl acetate and washed once with 1 M HCl, once with saturated sodium bicarbonate and once with brine. The organic phase was then dried over sodium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (8:1 to 4:1 hexanes/ethyl acetate) gave a single olefin isomer (geometry was not determined), **27** (430 mg, 1.25 mmol, 53%), as a yellow solid. IR (thin film) 3062, 2971, 2921, 1694, 1603, 1479, 1450, 1355, 1309, 1251, 1148, 1119, 1086, 949, 755, 726, 648, 618, 527 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 8.24 (s, 1H), 7.92 (d, *J*=7.5 Hz, 2H), 7.65-7.52 (m, 3H), 7.41-7.35 (m, 1H), 7.14-7.11 (m, 1H), 6.96-6.85 (m, 2H), 4.61 (sept, *J*=6.0 Hz, 1H), 2.21 (s, 3H), 1.36 (d, *J*=6.0 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 199.1, 156.8, 141.2, 140.6, 138.3, 133.6, 133.0, 130.6, 129.1, 128.6, 122.1, 120.8, 114.0, 71.8, 31.7, 22.1; MS (LR-APCI): calculated for $C_{19}H_{20}O_4S$ 344.1, measured 344.1.

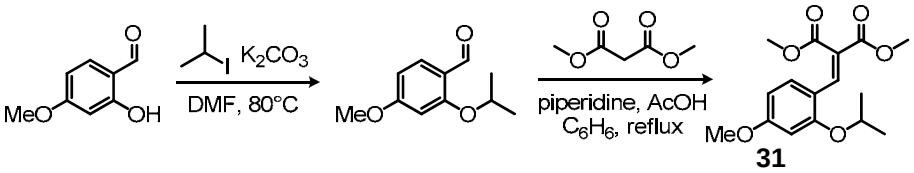
Synthesis of aryl ether 29.

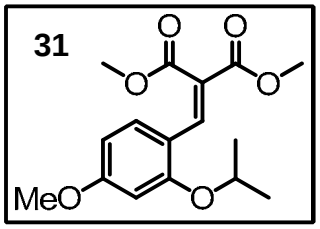




To a glass vial containing a magnetic stir bar and a solution of commercially available 5-methoxysalicylaldehyde (1.21 g, 7.95 mmol) in DMF (5 mL) was added potassium carbonate (6.0 g, 43 mmol) followed by 2-iodopropane (1.2 mL, 12 mmol). The vial was sealed with a Teflon-lined cap and heated in an oil bath set to 80 °C. After stirring vigorously for 12 hours, the reaction was diluted with ether and the organic layer was washed twice with water and once with brine. The organic phase was dried over sodium sulfate, concentrated under reduced pressure and redissolved in benzene (20 mL). To this solution was added dimethyl malonate (1.1 mL, 9.6 mmol), piperidine (0.5 ml, 5 mmol) and acetic acid (0.5 mL, 10 mmol), successively. The reaction flask was fitted with a Dean-Stark trap and the solution was refluxed overnight. The reaction mixture was cooled to room temperature and diluted with ether, washed once with 1 M HCl, once with sodium bicarbonate and once with brine. The organic phase was dried over sodium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (4:1 to 3:1 hexanes/ether) gave ether **29** (2.20 g, 7.14 mmol, 90% over two steps) as a yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.10 (s, 1H), 6.92-6.85 (m, 3H), 4.42 (sept, *J*=6.0 Hz, 1H), 3.84 (s, 3H), 3.81 (s, 3H), 3.73 (s, 3H), 1.32 (d, *J*=6.0 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 167.5, 164.9, 153.6, 151.4, 139.3, 125.3, 124.4, 118.4, 116.5, 113.1, 72.8, 55.8, 52.7, 22.2; MS (LR-APCI): calculated for $C_{16}H_{20}O_6$ 308.1, measured 308.5.

Synthesis of aryl ether 31.

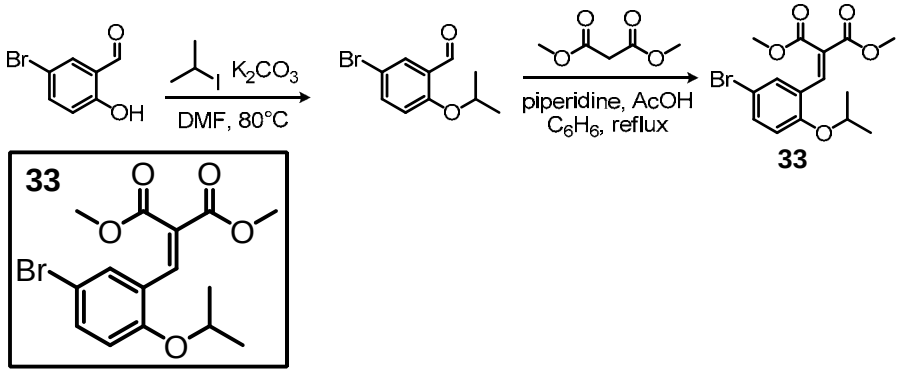




To a glass vial containing a magnetic stir bar and a solution of commercially available 4-methoxysalicylaldehyde (1.21 g, 7.95 mmol) in DMF (5 mL) was added potassium carbonate (6.0 g, 43 mmol) followed by 2-iodopropane (1.2 mL, 12 mmol). The vial was sealed with a Teflon-lined cap and heated in an oil bath set to 80 °C. After stirring vigorously for 12 hours, the reaction was diluted with ether and the organic layer was washed twice with water, once with brine dried over sodium sulfate. The crude aldehyde was concentrated under reduced pressure and redissolved in benzene (20 mL). To this solution was added dimethyl malonate (1.1 mL, 9.6

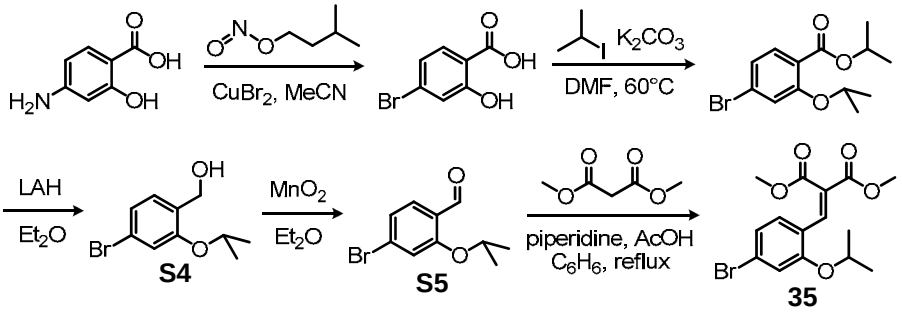
mmol), piperidine (0.5 ml, 5 mmol) and acetic acid (0.5 mL, 10 mmol), successively. The reaction flask was fitted with a Dean-Stark trap and the solution was refluxed overnight. The reaction mixture was then cooled to room temperature and diluted with ether. The organic phase was washed once with 1 M HCl, once with sodium bicarbonate and once with brine. The organic phase was then dried over sodium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (4:1 to 3:1 hexanes/ether) gave ether **31** (2.31 g, 7.50 mmol, 94% over two steps) as a yellow oil. ^{1}H NMR ($CDCl_3$, 300 MHz) δ 8.11 (s, 1H), 7.31-7.26 (m, 1H), 6.46-6.43 (m, 2H), 4.54 (sept, *J*=6.0 Hz, 1H), 3.83-3.81 (m, 9H), 1.37 (d, *J*=6.0 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 168.2, 165.3, 163.3, 158.6, 138.9, 130.2, 122.3, 116.2, 105.5, 100.7, 71.5, 55.6, 52.5, 22.1; MS (LR-APCI): calculated for $C_{16}H_{20}O_6$ 308.1, measured 308.2.

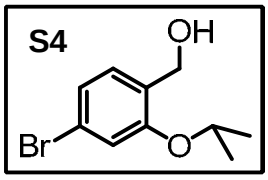
Synthesis of aryl ether 33.



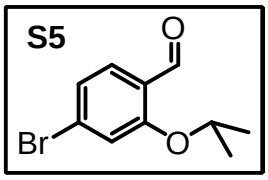
To a glass vial containing a magnetic stir bar and a solution of commercially available 5-bromosalicylaldehyde (1.12 g, 5.55 mmol) in DMF (4 mL) was added potassium carbonate (1.41 g, 10.2 mmol) followed by 2-iodopropane (0.78 mL, 7.8 mmol). The vial was sealed with a Teflon-lined cap and heated in an oil bath set to 80 °C. After stirring vigorously for 4 hours, the reaction was diluted with ethyl acetate and the organic layer was washed twice with saturated sodium bicarbonate and once with brine. The crude aldehyde was concentrated under reduced pressure and redissolved in benzene (20 mL). To this solution was added dimethyl malonate (0.65 mL, 5.7 mmol), piperidine (0.1 ml, 1 mmol) and acetic acid (0.1 mL, 2 mmol) successively. The reaction flask was fitted with a Dean-Stark trap and the solution was refluxed overnight. The reaction mixture was cooled to room temperature and diluted with ethyl acetate and washed once with 1 M HCl, once with sodium bicarbonate and once with brine. The organic phase was then dried over sodium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (15:1 hexanes/ethyl acetate) gave ether **33** (1.20 g, 3.36 mmol, 61% over two steps) as a pale yellow oil. ^{1}H NMR ($CDCl_3$, 300 MHz) δ 8.00 (s, 1H), 7.43-7.39 (m, 2H), 6.80-6.77 (m, 1H), 4.53 (sept, *J*=6.0 Hz, 1H), 3.85 (s, 3H), 3.82 (s, 3H), 1.35 (d, *J*=6.0 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 166.9, 164.6, 155.9, 137.9, 134.5, 131.7, 126.3, 125.3, 115.5, 112.6, 71.9, 52.8, 52.7, 22.1; MS (LR-APCI): calculated for $C_{15}H_{17}BrO_5$ 356.0 and 358.0, measured 356.6 and 358.6.

Synthesis of aryl ether 35.

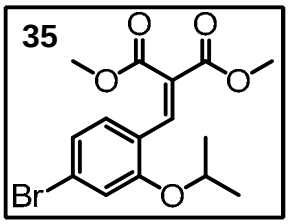




To a solution of copper(II) bromide (18.0 g, 80.6 mmol) in acetonitrile (100 mL) was added isoamyl nitrite (13 mL, 97 mmol) and cooled in an ice bath. To this solution was added 4-aminosalicylic acid (10.0 g, 65.5 mmol) portionwise and allowed to stir for two hours. The reaction was then allowed to warm to room temperature and poured into 1 M HCl (400 mL). The mixture was extracted twice with ether (400 mL) and the combined organic phases were washed with 1 M HCl then dried over magnesium sulfate. The solvent was removed under reduced pressure, redissolved in ether and extracted twice with 1 M sodium hydroxide. The aqueous phase was washed with ether then acidified to pH of 1 with 1 M HCl and the aqueous solution was extracted twice with ether. The combined organic phases were dried over magnesium sulfate and concentrated under reduced pressure. The crude intermediate was dissolved in DMF (100 mL) and potassium carbonate (60 g, 430 mmol) was added followed by 2-iodopropane (26 mL, 260 mmol). The mixture was heated to 60 °C and stirred vigorously for 12 hours. The reaction was then cooled to room temperature and diluted with ether (500 mL) and washed twice with water (300 mL). The organic phase was washed with brine and dried over sodium sulfate. The solvent was removed under reduced pressure and the crude ester was redissolved in dry ether (20 mL). This solution was added slowly via cannula to a suspension of LAH (1.95 g, 51.4 mmol) in ether (100 mL) at 0 °C. The reaction was allowed to warm to room temperature and stirred for 6 hours. The reaction was slowly quenched with ethyl acetate and a 1 M solution of sodium hydroxide. The biphasic mixture was filtered to remove the precipitate and the aqueous phase was extracted three times with ether. The combined organic phases were dried over sodium sulfate and concentrated under reduced pressure. The crude material was purified via chromatography (4:1 to 2:1 hexanes/ether) to give alcohol **S4** (3.52 g, 14.4 mmol, 22% over 3 steps) as a light brown oil. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.14 (d, *J*=8.0 Hz, 1H), 7.06-7.01 (m, 2H), 4.61-4.57 (m, 3H), 2.34-2.32 (m, 1OH), 1.37 (d, *J*=6.0 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 156.5, 130.0, 129.2, 123.5, 122.0, 116.0, 70.9, 61.9, 22.2; MS (LR-APCI): calculated for $C_{10}H_{13}BrO_2$ 244.0 and 246, measured 243.1 and 245.1.

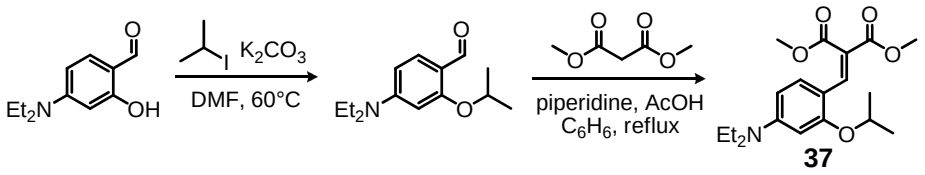


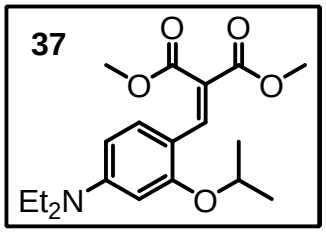
To a solution of alcohol **S4** (3.40 g, 13.9 mmol) in ether (30 mL) was added manganese(IV) oxide (6.0 g, 69 mmol) and the suspension was stirred at room temperature for 12 hours. An additional portion of manganese(IV) oxide (3.0 g, 35 mmol) was added and stirred for an additional 12 hours. The reaction was filtered through celite and concentrated under reduced pressure. The crude aldehyde was purified via flash chromatography (6:1 to 4:1 hexanes/ether) and recrystallized from hexanes/methylene chloride to give **S5** (1.16 g, 4.77 mmol, 34%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 10.4 (s, 1H), 7.68 (d, *J*=8.8 Hz, 1H), 7.15-7.12 (m, 2H), 4.66 (sept, *J*=6.0 Hz, 1H), 1.41 (d, *J*=6.0 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 189.3, 160.9, 130.5, 129.7, 124.7, 124.1, 117.5, 71.9, 22.0; MS (LR-APCI): calculated for $C_{10}H_{11}BrO_2$ 242.0 and 244.0, measured 242.9 and 244.9.



To a solution of aldehyde **S5** (1.15 g, 4.73 mmol) in benzene (20 mL) was added dimethyl malonate (640 mg, 4.84 mmol), piperidine (0.5 ml, 5 mmol) and acetic acid (0.5 mL, 10 mmol) successively. The reaction flask was fitted with a Dean-Stark trap and the solution was refluxed overnight. The reaction mixture was then cooled to room temperature and diluted with ether and washed once with 1 M HCl, once with sodium bicarbonate and once with brine. The organic phase was dried over sodium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (4:1 to 3:1 hexanes/ether) gave ether **35** (1.27 g, 3.56 mmol, 75%) as a yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.02, 7.19 (d, *J*=8.4 Hz, 1H), 7.06-7.02 (m, 2H), 4.55 (sept, *J*=6.0 Hz, 1H), 3.85 (s, 3H), 3.79 (s, 3H), 1.37 (d, *J*=6.0 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 167.3, 164.8, 157.3, 138.5, 130.0, 125.9, 125.6, 123.7, 122.3, 117.1, 72.0, 52.8, 52.7, 22.0; MS (LR-APCI): calculated for $C_{15}H_{17}BrO_5$ 356.0 and 358.0, measured 357.1 and 359.1.

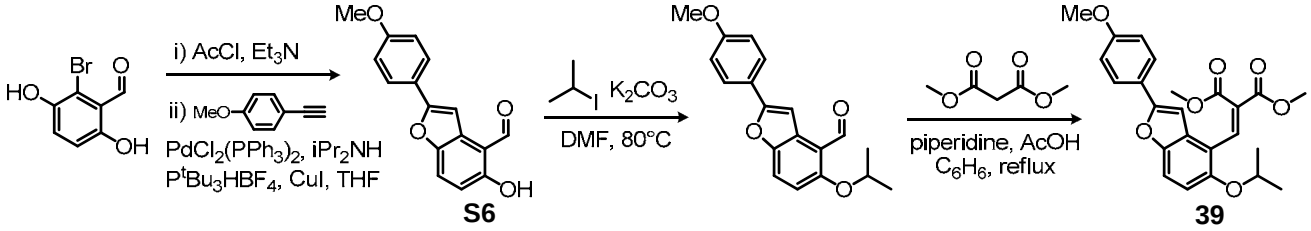
Synthesis of aryl ether 37.

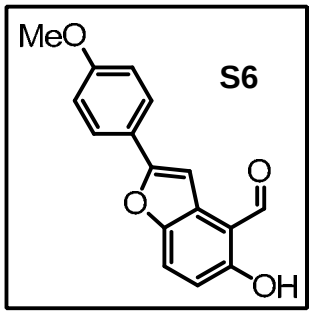




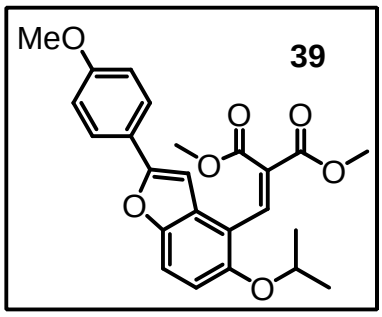
To a solution of commercially available 4-(diethylamino)salicylaldehyde (2.01 g, 10.4 mmol) in DMF (20 mL) was added potassium carbonate (7.5 g, 54 mmol) followed by 2-iodopropane (3.0 mL, 30 mmol). The reaction was heated in an oil bath set to 60 °C and stirred vigorously for 12 hours. The reaction was then diluted with ether and the organic layer was washed twice with water, once with brine and dried over sodium sulfate. The crude aldehyde was concentrated under reduced pressure and redissolved in benzene (20 mL). To this solution was added dimethyl malonate (1.20 mL, 10.5 mmol), piperidine (0.5 ml, 5 mmol) and acetic acid (0.5 mL, 10 mmol), successively. The reaction flask was fitted with a Dean-Stark trap and the solution was refluxed overnight. The reaction mixture was cooled to room temperature and diluted with ether and washed once with sodium bicarbonate and once with brine. The organic phase was dried over sodium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (3:1 to 1:1 hexanes/ether), followed by recrystallization from methylene chloride/hexanes gave **37** (2.97 g, 8.50 mmol, 82% over two steps) as yellow crystals. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.16 (s, 1H), 7.22 (d, *J*=8.8 Hz, 1H), 6.21 (dd, *J*=8.8 Hz, *J*=2 Hz, 1H), 6.09 (d, *J*=2 Hz, 1H), 4.52 (sept, *J*=6.0 Hz, 1H), 3.84 (s, 3H), 3.80 (s, 3H), 3.37 (q, *J*=7.2 Hz, 4H), 1.37 (d, *J*=6.0 Hz, 6H), 1.19 (t, *J*=7.2 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 169.2, 166.0, 159.4, 151.5, 139.0, 130.4, 117.7, 110.6, 104.8, 96.5, 71.4, 52.4, 52.2, 44.7, 22.3, 12.8; MS (LR-APCI): calculated for $C_{19}H_{27}NO_5$ 349.2, measured 350.3.

Synthesis of aryl ether 39.





To a solution of 2-bromo-3,5-dihydroxybenzaldehyde[4] (216 mg, 0.995 mmol) and triethylamine (0.30 mL, 2.1 mmol) in THF (1.5 mL) was added acetyl chloride (0.15 mL, 2.1 mmol). The reaction was stirred at room temperature for five minutes. To this mixture was added diisopropylamine (1.5 mL, 11 mmol), $PdCl_2(PPh_3)_2$ (15 mg, 0.021 mmol), $P^tBu_3HBF_4$ (30 mg, 0.10 mmol), CuI (20 mg, 0.11 mmol) and 1-ethynyl-4-methoxybenzene (265 mg, 2.00 mmol). The mixture was heated to 60 °C for six hours then cooled to room temperature. To this solution was added sodium hydroxide (600 mg) in 5:1 MeOH/water (5 mL). The mixture was stirred vigorously at 75 °C for two hours. After cooling to room temperature the solution was acidified with 1M HCl and the suspension was extracted three times with methylene chloride. After drying over magnesium sulfate, the solvent was removed under reduced pressure then passed through a plug of silica and recrystallized from methylene chloride/hexanes to give **S6** (167 mg, 0.622 mmol, 63%) as yellow/green crystals. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 11.39 (s, 1H), 10.35 (s, 1H), 7.81 (dd, *J*=7.2 Hz, *J*=2 Hz, 2H), 7.62 (d, *J*=8.4, 1H), 7.19 (s, 1H), 7.01 (dd, *J*=7.2 Hz, *J*=2 Hz, 2H), 6.83 (d, *J*=8.8 Hz, 1H), 3.88 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) 192.9, 160.9, 159.8, 148.8, 131.5, 127.0, 122.5, 120.1, 114.6, 113.1, 111.4, 96.2, 55.6; MS (LR-APCI): calculated for $C_{16}H_{12}O_4$ 268.1, measured 269.1.



To a glass vial containing a magnetic stir bar and a solution of aldehyde **S6** (784 mg, 2.92 mmol) in DMF (6 mL) was added potassium carbonate (3.0 g, 22 mmol) followed by 2-iodopropane (0.60 mL, 60 mmol). The vial was sealed with a Teflon-lined cap and heated in an oil bath set to 80 °C. After stirring vigorously for 12 hours, the reaction was diluted with ether and the organic layer was washed twice with water, once with brine. After drying over sodium sulfate, the crude aldehyde was concentrated under reduced pressure and redissolved in benzene (15 mL). To this solution was added dimethyl malonate (440 mg, 3.33 mmol), piperidine (0.5 ml, 5 mmol) and acetic acid (0.5 mL, 10 mmol) successively. The reaction flask was fitted with a Dean-Stark trap

[4] Hu, Y.; Li, C.; Kulkarni, B. A.; Strobel, G.; Lobkovsky, E.; Torczynski, R. M.; Porco, J. A. *Org. Lett.* **2001**, *3*, 1649-1652.

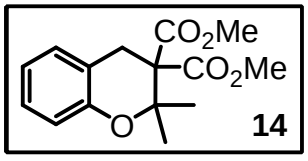
and the solution was refluxed overnight. The reaction mixture was then cooled to room temperature, diluted with ethyl acetate and washed once with 1 M HCl, once with sodium bicarbonate and once with brine. The organic phase was dried over sodium sulfate and concentrated under reduced pressure. Purification of the crude material via flash chromatography (1:1 to 4:1 methylene chloride/hexanes) gave ether **39** (823 mg, 1.94 mmol, 66% over two steps) as a pale yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.20 (s, 1H), 7.77 (d, *J*=9.2 Hz, 2H), 7.43 (d, *J*=9.2 Hz, 1H), 6.97 (d, *J*=9.2 Hz, 2H), 6.89-6.86 (m, 2H), 4.49 (sept, *J*=6.0 Hz, 1H), 3.90 (s, 3H), 3.86 (s, 3H), 3.61 (s, 3H), 1.33 (d, *J*=6.0 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 166.6, 165.5, 160.5, 158.0, 153.0, 149.7, 141.6, 130.0, 126.9, 126.7, 123.0, 116.9, 114.5, 113.3, 112.6, 99.1, 74.3, 55.5, 52.8, 52.3, 22.4; MS (LR-APCI): calculated for $C_{24}H_{24}O_7$ 424.2, measured 425.2.

III. General Procedure for Lewis Acid Catalyzed Hydride-Transfer Reactions

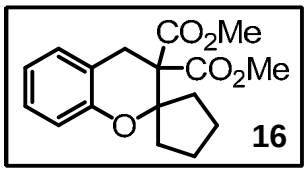
Scandium(III) triflate was purchased from Strem and used as received. Reactions were monitored by GC or TLC analysis using hexanes/ethyl acetate mixtures as the eluent (visualization using permanganate stain and/or cerric ammonium molybdate stain and/or UV light). The products typically have slightly higher R_f values than starting materials. All reactions were carried out in 10 mL sample vials with Teflon lined caps or 15 mL heavy wall pressure vessels sealed with O-ring and screw cap purchased from Chemglass equipped with magnetic stir bars. All glassware was dried in the oven and allowed to cool to room temperature under vacuum prior to use.

Approximately 0.2-0.3 mmol of starting material was weighed out in reaction flask and temporarily topped with a pierceable cap then evacuated and backfilled with argon three times. The substrate was then dissolved in methylene chloride (0.025 M concentration). Scandium(III) triflate (0.1 equivalents or amount noted in Table 1 and Table 2 in the main text) was weighed out in air and quickly added to the reaction flask. The top was replaced with a Teflon lined cap or sealed tube top and heated in an oil bath set to 80 °C. Upon consumption of the starting material, the reaction was quenched with saturated sodium bicarbonate and vigorously shaken. The aqueous layer was extracted twice with methylene chloride and the combined organic phases were dried over sodium sulfate. The solvent was removed under reduced pressure and the crude material was purified by flash chromatography on silica gel to give the desired product. Reported yields are an average of three trials.

IV. Product Data for Dihydrobenzopyrans

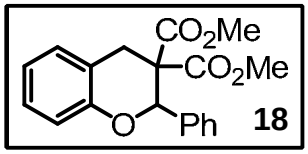


Dihydrobenzopyran **14** was isolated in 91% yield after chromatography (15:1 hexanes/ethyl acetate) as a pale yellow solid. IR (thin film) 2988, 2946, 1735, 1586, 1487, 1453, 1433, 1246 (b), 1056, 961, 738, 705 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 7.25-7.07 (m, 2H), 6.90-6.80 (m, 2H), 3.71 (s, 6H), 3.30 (s, 2H), 1.55 (s, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 169.7, 152.5, 128.7, 127.6, 120.7, 119.9, 117.3, 76.6, 57.9, 52.6, 30.8, 24.7; MS (LR-APCI): calculated for $C_{15}H_{18}O_5$ 278.1, measured 279.3.

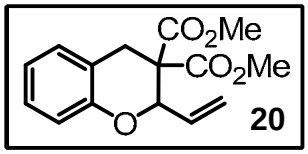


Dihydrobenzopyran **16** was isolated in 95% yield after chromatography (15:1 hexanes/ethyl acetate) as a yellow solid. ^1H NMR ($CDCl_3$, 400 MHz) δ 7.10-7.07 (m, 2H), 6.89-6.85 (m, 1H), 6.79-6.76 (m, 1H), 3.71 (s, 6H), 3.33 (s, 2H), 2.24-2.17 (m, 2H), 1.96-1.1.73 (m, 4H), 1.72-1.69

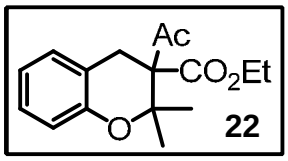
(m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) 169.8, 152.5, 128.8, 127.5, 120.9, 120.8, 117.6, 88.3, 57.4, 52.7, 35.2, 31.9, 24.4; MS (LR-APCI): calculated for $C_{17}H_{20}O_5$ 304.1, measured 304.4.



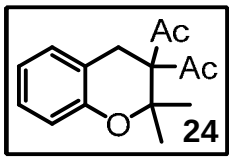
Dihydrobenzopyran **18** was isolated in 75% yield after chromatography (20:1 hexanes/ethyl acetate) as a pale yellow solid. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.28-7.24 (m, 3H), 7.20-7.10 (m, 4H), 6.94-6.88 (m, 2H), 5.99 (s, 1H), 3.66 (s, 3H), 3.63 (s, 3H), 3.34 (s, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) 169.4, 168.1, 153.3, 138.2, 129.5, 128.7, 128.5, 128.4, 126.9, 120.9, 118.4, 116.5, 78.1, 57.0, 53.3, 52.8, 27.7; MS (LR-APCI): calculated for $C_{19}H_{18}O_5$ 326.1, measured 326.6.



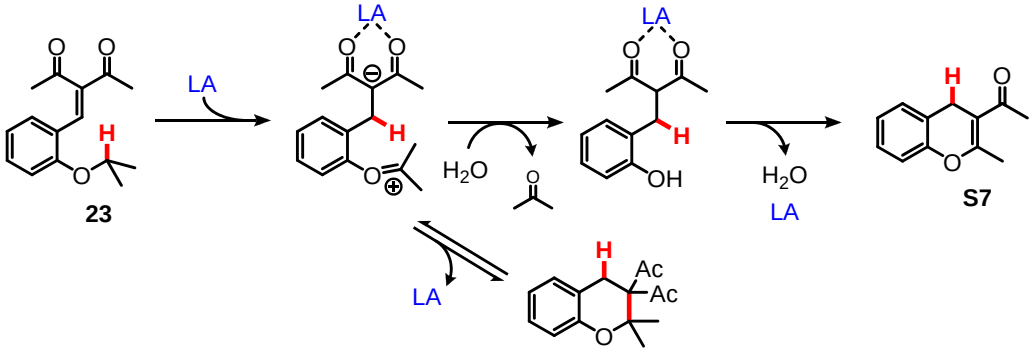
Dihydrobenzopyran **20** was isolated in 32% yield after chromatography (15:1 hexanes/ethyl acetate) as a pale yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.13-7.08 (m, 2H), 6.90-6.86 (m, 2H), 5.99-5.91 (m, 1H), 5.38-5.26 (m, 3H), 3.76 (s, 3H), 3.71 (s, 3H), 3.40 (d, *J*=16.4 Hz, 1H), 3.27 (d, *J*=16.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) 169.1, 168.5, 152.2, 132.6, 129.5, 128.0, 121.2, 119.9, 118.9, 116.9, 77.2, 56.0, 53.3, 53.1, 28.8; MS (LR-APCI): calculated for $C_{15}H_{16}O_5$ 276.1, measured 276.4.



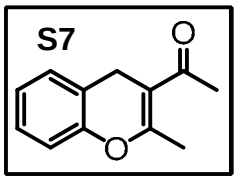
Dihydrobenzopyran **22** was isolated in 90% yield after chromatography (25:1 to 15:1 hexanes/ethyl acetate) as a pale yellow oil. IR (neat) 2979, 2937, 1735, 1718, 1586, 1491, 1454, 1362, 1247, 1218, 1181, 1148, 1110, 1052, 953, 759 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.15-7.11 (m, 2H), 6.91-6.88 (m, 1H), 6.83-6.81 (m, 1H), 4.21 (q, *J*=7.2 Hz, 2H), 3.34 (d, *J*=17 Hz, 1H), 3.14 (d, *J*=17 Hz, 1H), 2.14 (s, 3H), 1.54 (s, 3H), 1.48 (s, 3H), 1.24 (t, *J*=7.2 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) 203.6, 170.3, 152.7, 128.9, 127.9, 120.9, 119.9, 117.5, 76.8, 63.4, 61.6, 29.9, 28.2, 24.8, 24.8, 14.1; MS (LR-APCI): calculated for $C_{16}H_{20}O_4$ 276.1, measured 276.5.



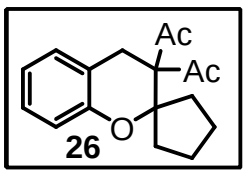
Dihydrobenzopyran **24** was isolated in 35% yield after chromatography (30:1 hexanes/ethyl acetate) as a pale yellow oil. IR (neat) 3046, 2988, 2938, 1715, 1694, 1586, 1487, 1453, 1355, 1268, 1242, 1185, 1139, 945, 887, 746, 705 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.20-7.15 (m, 2H), 6.97-6.92 (m, 1H), 6.87-6.84 (m, 1H), 3.22 (s, 2H), 2.11 (s, 6H), 1.44 (s, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 206.0, 152.9, 129.1, 128.3, 121.3, 119.8, 117.9, 77.2, 68.1, 29.0, 28.7, 24.6; MS (LR-APCI): calculated for $C_{15}H_{18}O_3$ 246.1, measured 246.7.



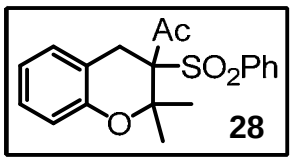
A significant side product, **S7**, which had a slightly higher R_f, was observed along with the desired product **24.** Greater amounts of **S7** were observed with longer reaction times. This product is formed via hydrolysis of the zwitterion intermediate, followed by intramolecular condensation of the ketone and phenol hydroxyl groups. Resubjecting **24** to the reaction conditions resulted in formation of **S7** indicating reversible C-C formation under the reaction conditions. NMR spectra of **S7** were taken immediately after isolation. Noticeable decomposition was observed in less than 24 hours at room temperature under high vacuum.



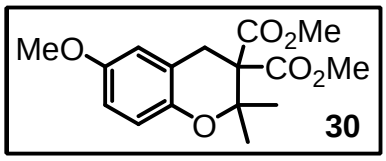
S7 was isolated in 33% yield after chromatography (30:1 hexanes/ethyl acetate, slightly higher R_f than the desired product) as a yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.17-7.10 (m, 2H), 7.05-7.01 (m, 1H), 6.91 (d, *J*=8.0 Hz, 1H), 3.67 (s, 2H), 2.34 (s, 3H), 2.31 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) 198.7, 160.0, 150.2, 128.9, 127.9, 124.3, 120.5, 116.2, 109.5, 30.1, 25.9, 20.1; MS (LR-APCI): calculated for $C_{12}H_{12}O_2$ 188.1, measured 188.7.



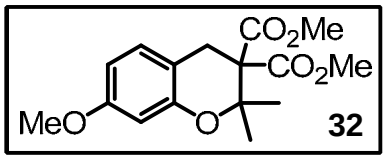
Dihydrobenzopyran **26** was isolated in 58% yield after chromatography (50:1 to 25:1 hexanes/ethyl acetate) as a pale yellow solid. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.17-7.12 (m, 2H), 6.94-6.90 (m, 1H), 6.80-6.78 (m, 1H), 3.25 (s, 2H), 2.13-2.09 (m, 8H), 1.81-1.72 (m, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 205.5, 152.9, 129.0, 128.0, 121.2, 121.0, 118.0, 89.2, 67.8, 35.3, 30.4, 28.7, 24.4; MS (LR-APCI): calculated for $C_{17}H_{20}O_3$ 272.1, measured 272.4.



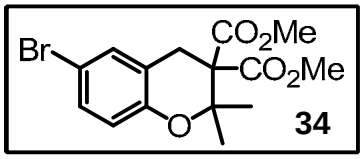
Dihydrobenzopyran **28** was isolated in 45% yield after chromatography (16:1 hexanes/ethyl acetate) as a pale yellow solid. IR (thin film) 3050, 2992, 1710, 1585, 1490, 1453, 1423, 1306, 1266, 1170, 1148, 1078, 895, 737 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.79-7.76 (m, 2H), 7.52-7.47 (m, 1H), 7.39-7.34 (m, 2H), 6.99-6.94 (m, 2H), 6.83-6.78 (m, 1H), 6.54-6.51 (d, *J*=8.1 Hz, 1H), 3.69 (d, *J*=18 Hz, 1H), 3.45 (d, *J*=18, 1H), 2.37 (s, 3H), 1.86 (s, 3H), 1.55 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) 200.5, 151.8, 138.4, 134.2, 130.6, 128.6, 128.6, 128.4, 127.9, 121.5, 119.5, 117.5, 79.9, 78.0, 30.5, 29.7, 26.3, 25.8; MS (LR-APCI): calculated for $C_{19}H_{20}O_4S$ 344.1, measured 344.9.



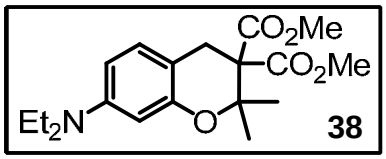
Dihydrobenzopyran **30** was isolated in 95% yield after chromatography (12:1) hexanes/ethyl acetate) as a pale yellow solid. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 6.74-6.63 (m, 3H), 3.74 (s, 3H), 3.71 (s, 6H), 3.26 (s, 2H), 1.53 (s, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 169.8, 153.6, 146.4, 120.6, 117.8, 113.6, 113.2, 76.5, 57.9, 55.7, 52.6, 31.2, 24.6; MS (LR-APCI): calculated for $C_{16}H_{20}O_6$ 308.1, measured 308.4.



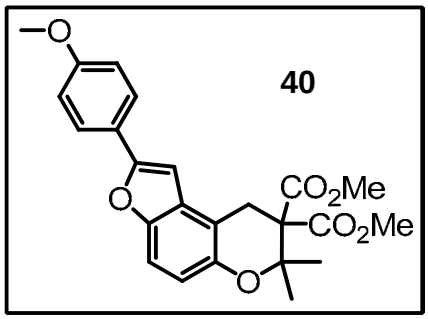
Dihydrobenzopyran **32** was isolated in 56% yield after chromatography (6:1) hexanes/ethyl acetate) as a pale yellow solid. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 6.97 (d, *J*=8.4 Hz, 1H), 6.47 (dd, *J*=8.4 Hz, *J*=2 Hz, 1H), 6.39 (d, *J*=2 Hz, 1H), 3.74 (s, 3H), 3.71 (s, 6H), 3.24 (s, 2H), 1.54 (s, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 169.8, 159.4, 153.2, 129.3, 111.6, 108.1, 101.8, 76.8, 57.9, 55.3, 52.6, 30.3, 24.8; MS (LR-APCI): calculated for $C_{16}H_{20}O_6$ 308.1, measured 309.3.



Dihydrobenzopyran **34** was isolated in 95% yield after chromatography (15:1 hexanes/ethyl acetate) as a pale yellow solid. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.21-7.19 (m, 2H), 6.69 (d, *J*=8.4 Hz, 1H), 3.72 (s, 6H), 3.26 (s, 2H), 1.53 (s, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 169.4, 151.6, 131.3, 130.6, 122.2, 119.1, 112.8, 77.0, 57.5, 52.8, 30.5, 24.6; MS (LR-APCI): calculated for $C_{15}H_{17}BrO_5$ 356.0 and 358.0, measured 356.8 and 358.8.



Undesired retro-Knoevenagel condensation[5] and decarboxylation reactions were observed with substrate **37** if water was not rigorously excluded from the reaction mixture. Therefore, the desired amount of $Sc(OTf)_3$ was weighed out into the reaction vial and heated to 140 °C under vacuum overnight prior to use. The substrate was dissolved in methylene chloride and dried over 4Å molecular sieves prior to use. The substrate solution was then transferred via cannula to the reaction vial containing dried Lewis acid under argon and the vial was capped with a Teflon lined cap. Dihydrobenzopyran **38** was isolated in 32% yield along with 40% recovered starting material after chromatography (8:1 hexanes/ethyl acetate) as a pale yellow solid. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 6.89 (d, *J*=8.4 Hz, 1H), 6.27 (dd, *J*=8.4 Hz, *J*=2.4 Hz, 1H), 6.14 (d, *J*=2.8 Hz, 1H), 3.71 (s, 6H), 3.28 (q, *J*=7.2 Hz, 4H), 3.21 (s, 2H), 1.54 (s, 6H), 1.13 (t, *J*=7.2, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) 170.0, 153.4, 148.0, 129.2, 106.4, 105.5, 99.9, 76.5, 58.1, 52.6, 44.4, 30.2, 24.9, 12.9; MS (LR-APCI): calculated for $C_{19}H_{27}NO_5$ 349.2, measured 349.9.



Dihydrobenzopyran **40** was isolated in 85% yield after chromatography (1:1 to 4:1 methylene chloride/hexanes) as a pale yellow solid. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.77 (d, *J*=8.8 Hz, 2H), 7.26-7.24 (m, 1H), 6.97 (d, *J*=8.8 Hz, 2H), 6.85 (s, 1H), 6.75 (d, *J*=8.8 Hz, 1H), 3.86 (s, 3H), 3.74 (s, 6H), 3.43 (s, 2H), 1.56, (s, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) 169.9, 160.0, 156.8, 149.5,

[5] Umeda, T.; Hirai, E. *Chem. Pharm. Bull.*, **1981**, *29*, 2753-2761.

148.0, 128.4, 126.4, 123.6, 114.4, 114.0, 110.9, 110.0, 98.0, 76.6, 57.7, 55.5, 52.7, 28.9, 24.6; MS (LR-APCI): calculated for $C_{24}H_{24}O_7$ 424.2, measured 425.2.