Supporting Information

Palladium-Catalyzed Carbonylative Cyclization of Aryl Alkenes/Alkenols: A New Reaction Mode for the Synthesis of Electron-Rich Chromanes

Shuang Li,[†] Fuzhuo Li,[†] Jianxian Gong,^{*,†} and Zhen Yang^{*,†,‡,§}

[†]Laboratory of Chemical Genomics, School of Chemical Biology and Biotechnology, Peking University Shenzhen Graduate School, Shenzhen, 518055, China,

[‡]Key Laboratory of Bioorganic Chemistry and Molecular Engineering of Ministry of Education and Beijing National Laboratory for Molecular Science (BNLMS), and Peking-Tsinghua Center for Life Sciences, Peking University. Beijing 100871, China

[§]Key Laboratory of Marine Drugs, Chinese Ministry of Education, School of Medicine and Pharmacy, Ocean University of China, 5 Yushan Road, Qingdao 266003, China

*E-mail: <u>zyang@pku.edu.cn</u> *E-mail: <u>gongjx@pku.edu.cn</u>.

Table of Contents

Part 1: General information	S3
Part 2: General procedure and characteristic data for aryl alkene substrates	S4
Part 3: General procedure and characteristic data for aryl alkenol substrates	S10
Part 4: General procedure and characteristic data for products 5a-5p, 6a-6g	S16
Part 5: General procedure and characteristic data for products 8a-8i	S25
Part 6: References	S29
Part 7: NMR spectra	S30

Part 1: General Information

Unless otherwise noted, all the reactions were carried out under a nitrogen atmosphere under anhydrous conditions and all the chemicals were purchased commercially and used without further purification. The Pd catalysts were purchased from Strem and copper(II) chloride were purchased from Acros. Anhydrous tetrahydrofuran (THF) was distilled from sodium-benzophenone, 1, 2-dichloroethane (DCE), dichloromethane (DCM) were distilled from calcium hydride. MeOH was distilled from sodium. All other solvents were purchased as ACS reagents and used without further purification.

Reactions were monitored by thin-layer chromatography (TLC) carried out on 0.25 mm Tsingdao silica gel plates (GF-254) using UV light as visualizing agent and an ethanolic solution of phosphomolybdic acid and cerium sulfate, and heat as developing agents. Tsingdao silica gel (60, particle size 0.040-0.063 mm) was used for flash column chromatography.

NMR spectra were recorded on either a Brüker Advance 400 (¹H: 400 MHz, ¹³C: 100 MHz) or Brüker Advance 500 (¹H: 500 MHz, ¹³C: 125 MHz). The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad.

IR spectra were recorded on an IRPrestige-21 FTIR spectrometer. High resolution mass spectrometric (HRMS) data were obtained using Brüker Apex IV RTMS.





General Procedure A for the preparation of aryl alkene substrates.



To a stirred solution of 4-bromo-1-butene (2.7 g, 20 mmol, 2.0 equiv) in CH₃CN (25 mL) at room temperature was added corresponding phenol (10 mmol, 1.0 equiv) and K₂CO₃ (4.14 g, 30 mmol, 3.0 equiv). The mixture was heated to reflux for 16 h and then cooled down to room temperature. H₂O (40 mL) was added and and the mixture was extracted with EtOAc (3 x 30 mL). The organic extract was washed with brine, dried over Na₂SO₄, and concentrated *in vacuo*. Purification of the residue by flash column chromatography (SiO₂, hexane/AcOEt = 8/1 for **4a-4g**; hexane/AcOEt = 40/1 for **4i**, **4j**) afforded the desired product. Substrates **4a-4j** were prepared using this method^[1].



Substrate **4a** (1.41 g, colorless oil) was obtained in 68% yield, following general procedure A. ¹H NMR (400 MHz, CDCl₃) δ = 6.10 (s, 3H), 5.98 – 5.84 (m, 1H), 5.22 – 5.10 (m, 2H), 3.99 (t, *J* = 6.7 Hz, 2H), 3.77 (s, 6H), 2.61 – 2.47 (m, 2H); ¹³C NMR (100 MHz, CDCl₃) δ = 161.5, 160.8, 134.5, 117.5, 93.4, 93.0, 67.2, 55.3, 33.6 ppm; IR ν_{max} (film): 3082, 2999, 2940, 2840, 1600, 1471, 1429, 1386, 1205, 1193, 1150, 1066, 991, 920, 819, 680 cm⁻¹; HRMS (ESI) m/z calcd for C₁₂H₁₇O₃ [M+H]⁺: 209.1172; found: 209.1171.



Substrate **4b** (1.76 g, colorless oil) was obtained in 74% yield, following general procedure A. ¹H NMR (400 MHz, CDCl₃) δ = 6.14 (s, 2H), 5.95-5.84 (m, 1H), 5.25 – 4.93 (m, 2H), 3.97 (t, *J* = 6.7 Hz, 2H), 3.82 (s, 6H), 3.77 (s, 3H), 2.57 – 2.48 (m, 2H); ¹³C NMR (100 MHz, CDCl₃) δ = 155. 6, 153. 7, 134.4, 132.3, 117.1, 92.3, 67.6, 61.0, 56.1, 33.7 ppm; IR v_{max} (film): 3076, 2999, 2939, 2835, 1600, 1501, 1463, 1421, 1228, 1196, 1157, 1126, 1085, 1000, 920, 808, 775 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₉O₄ [M+H]⁺: 239.1278; found: 239.1278.



Substrate **4c** (1.49 g, colorless oil) was obtained in 67% yield, following general procedure A from the known phenol^[2].

¹H NMR (400 MHz, CDCl₃) δ = 6.16 (s, 2H), 5.99-5.88 (m, 1H), 5.23 – 5.07 (m, 2H), 4.03 (t, *J* = 6.7 Hz, 2H), 3.80 (d, *J* = 12.8 Hz, 6H), 2.60-2.53 (m, 2H), 2.04 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 158.7, 158.2, 134.5, 117.0, 106.8, 91.2, 67.3, 55.7, 33.7, 7.7 ppm; IR *v*_{max} (film): 2999, 2940, 2870, 1610, 1597, 1500, 1460, 1415, 1226, 1195, 1140, 1055, 999, 918, 855 cm⁻¹; HRMS (APCI) m/z calcd for C₁₃H₁₉O₃ [M+H]⁺: 223.1329; found: 223.1331.



Substrate **4d** (1.21 g, colorless oil) was obtained in 58% yield, following general procedure A. ¹H NMR (400 MHz, CDCl₃) $\delta = 6.76$ (d, J = 8.7 Hz, 1H), 6.52 (d, J = 2.8 Hz, 1H), 6.39 (dd, J = 8.7, 2.8 Hz, 1H), 5.94-5.84 (m, 1H), 5.20-5.09 (m, 2H), 3.96 (t, J = 6.7 Hz, 2H), 3.84 (d, J = 8.4 Hz, 6H), 2.56-2.49 (m, 2H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 153.5$, 149.8, 143. 5, 134.5, 116.9, 111.7, 103.8, 100.9, 67.7, 56.4, 55.8, 33.7 ppm; IR v_{max} (film):3078, 2999, 2935, 2820, 1641, 1612,1596, 1512, 1463, 1452, 1280, 1261, 1228, 1200, 1163, 1138, 1028, 916, 833, 762 cm⁻¹; HRMS (ESI) m/z calcd for C₁₂H₁₇O₃ [M+H]⁺: 209.1172; found: 209.1172.



Substrate 4e (1.17 g, colorless oil) was obtained in 61% yield, following general procedure A.

¹H NMR (400 MHz, CDCl₃) $\delta = 6.36$ (s, 2H), 6.31 (s, 1H), 5.98-5.88 (m, 1H), 5.27 – 5.06 (m, 2H), 4.01 (t, J = 6.7 Hz, 2H), 3.78 (d, J = 4.3 Hz, 3H), 2.59-2.52 (m, 2H), 2.32 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 160.7$, 160.0, 140.1, 134.5, 116.9, 107.7, 107.2, 98.0, 67.1, 55.2, 33.6, 21.8 ppm; IR v_{max} (film): 3078, 2978, 2922, 2872, 1641, 1597, 1468, 1386, 1344, 1321, 1281, 1197, 1153, 1064, 991, 919, 827, 681 cm⁻¹; HRMS (ESI) m/z calcd for C₁₂H₁₇O₂ [M+H]⁺:193.1223; found: 193.1223.



Substrate **4f** (1.12 g, colorless oil) was obtained in 63% yield, following general procedure A. ¹H NMR (500 MHz, CDCl₃) δ = 7.19 (t, *J* = 8.2 Hz, 1H), 6.66 – 6.43 (m, 3H), 6.09 – 5.77 (m, 1H), 5.32 – 5.04 (m, 2H), 4.02 (t, *J* = 6.7 Hz, 2H), 3.80 (d, *J* = 0.7 Hz, 3H), 2.59-2.54 (m, 2H); ¹³C NMR (125 MHz, CDCl₃) δ = 160.9, 160.2, 134.5, 129.9, 117.0, 106.7, 106.4, 101.1, 67.2, 55.3, 33.7 ppm; IR *v*_{max} (film): 3078, 3000, 2937, 2835, 1641, 1600, 1496, 1473, 1450, 1330, 1286, 1261, 1197, 1149, 1041, 991, 916, 831, 686 cm⁻¹; HRMS (APCI) m/z calcd for C₁₁H₁₅O₂ [M+H]⁺: 179.1067; found: 179.1067.



Substrate **4g** (943 mg, colorless oil) was obtained in 49% yield, following general procedure A. ¹H NMR (400 MHz, CDCl₃) $\delta = 6.71$ (d, J = 8.5 Hz, 1H), 6.51 (d, J = 2.5 Hz, 1H), 6.33 (dd, J = 8.5, 2.5 Hz, 1H), 5.98 – 5.80 (m, 3H), 5.20-5.10 (m, 2H), 3.95 (t, J = 6.7 Hz, 2H), 2.55-2.49 (m, 2H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 154.4$, 148.2, 141.6, 134.5, 116.9, 107.9, 105.8, 101.1, 98.2, 68.2, 33.7 ppm; IR v_{max} (film): 3076, 2980, 2883, 1633, 1500, 1489, 1473, 1388, 1271, 1242, 1190, 1136, 1103, 1037, 920, 815 cm⁻¹; HRMS (APCI) m/z calcd for C₁₁H₁₃O₃ [M+H]⁺: 193.0859; found: 193.0858.



Substrate **4i** (712 mg, colorless oil) was obtained in 40% yield, following general procedure A. ¹H NMR (400 MHz, CDCl₃) δ = 6.64 (s, 1H), 6.58 (s, 2H), 6.00-5.89 (m, 1H), 5.30 – 5.02 (m, 2H), 4.03 (t, *J* = 6.7 Hz, 2H), 2.60-2.54 (m, 2H), 2.33 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) δ = 158.9, 139.1, 134.6, 122.5, 116.9, 112.3, 67.0, 33.7, 21.4 ppm; IR *v*_{max} (film): 2918, 2868, 1610, 1593, 1468, 1323, 1286, 1168,1153, 1066, 990, 916, 827, 686 cm⁻¹; HRMS (ESI) m/z calcd for C₁₂H₁₇O [M+H]⁺: 177.1274; found: 177.1274.



Substrate **4j** (1.19 g, colorless oil) was obtained in 60% yield, following general procedure A. ¹H NMR (400 MHz, CDCl₃) δ = 7.84 – 7.73 (m, 3H), 7.48 (ddd, *J* = 8.2, 6.9, 1.2 Hz, 1H), 7.37 (ddd, *J* = 8.1, 6.9, 1.2 Hz, 1H), 7.23 – 7.14 (m, 2H), 6.06-5.94 (m, 1H), 5.29-5.16 (m, 2H), 4.17 (t, *J* = 6.7 Hz, 2H), 2.69-2.2.62 (m, 2H); ¹³C NMR (100 MHz, CDCl₃) δ = 156.8, 134.6, 134.5, 129.4, 128.9, 127.7, 126.7, 126.3, 123.6, 119.0, 117.1, 106.7, 67.2, 33.6 ppm; IR v_{max} (film): 3059, 2926, 2872, 1625, 1600, 1512, 1463, 1388, 1259, 1215, 1178, 1120, 1033, 918, 837, 810, 746 cm⁻¹; HRMS (APCI) m/z calcd for C₁₄H₁₅O [M+H]⁺: 199.1117; found: 199.1117.

General Procedure B for the preparation of aryl alkene substrates.



To a solution of 3,5-dimethoxy phenol (1.54 g, 10 mmol, 1.0 equiv) in THF (25 mL) at 0 $^{\circ}$ C was added corresponding alcohol (15 mmol, 1.5 equiv) and triphenylphosphine (3.93 g, 15 mmol, 1.5 equiv) sequentially. Then DEAD reagent (diethyl azodicarboxylate, 2.61 g, 15 mmol, 1.5 equiv) was added dropwise and the mixture was heated to 60 $^{\circ}$ C for 16 h. After cooled to room temperature, the mixture was concentrated *in vacuo*. Purification of the residue by flash column chromatography (SiO₂, hexane/AcOEt = 10/1 for **4k**, **4l**, **4n**; hexane/AcOEt = 40/1 for **4m**, **4o**) afforded the desired product. Substrates **4k-4o** were prepared using this method^[3].



Substrate **4k** (1.22 g, colorless oil) was obtained in 55% yield, following general procedure B. ¹H NMR (400 MHz, CDCl₃) δ = 6.10 (s, 3H), 5.71 – 5.57 (m, 1H), 5.55 – 5.36 (m, 1H), 3.94 (t, *J* = 7.0 Hz, 2H), 3.77 (s, 6H), 2.54 (q, *J* = 6.9 Hz, 2H), 1.70 – 1.66 (m, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 161.5, 160.8, 126.6, 125.6, 93.4, 92.9, 67.4, 55.3, 27.0, 12.9 ppm; IR *v*_{max} (film): 3012, 2937, 2839, 1600, 1471, 1438, 1195, 1153, 1066, 819, 680 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₉O₃ [M+H]⁺: 223.1329; found: 223.1327.



Substrate 4l (1.01 g, colorless oil) was obtained in 45% yield, following general procedure B.

¹H NMR (400 MHz, CDCl₃) δ = 6.10 (s, 3H), 4.92 – 4.75 (m, 2H), 4.05 (t, *J* = 6.9 Hz, 2H), 3.77 (s, 6H), 2.50 (t, *J* = 6.8 Hz, 2H), 1.81 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 161.5, 160.8, 142.1, 111.9, 93.4, 92.9, 66.4, 55.3, 37.1, 22.8 ppm; IR v_{max} (film): 2937, 2839, 1600, 1462, 1386, 1205, 1152, 1065, 893, 821, 682 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₉O₃ [M+H]⁺: 223.1329; found: 223.1333



Substrate **4m** (1.08 g, colorless oil) was obtained in 38% yield, following general procedure B. ¹H NMR (400 MHz, CDCl₃) δ = 7.49 – 7.27 (m, 5H), 6.10 (d, *J* = 2.0 Hz, 2H), 6.06 (d, *J* = 2.0 Hz, 1H), 5.95-5.84 (m, 1H), 5.24 – 5.05 (m, 3H), 3.72 (s, 6H), 2.87 – 2.71 (m, 1H), 2.71 – 2.47 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 161.3, 159.9, 141.3, 134.1, 128.5, 127.6, 126.0, 117.6, 94.9, 93.1, 79.9, 55.2, 42.8 ppm; IR ν_{max} (film): 3000, 2937, 2837, 1600, 1473, 1429, 1354, 1205, 1151, 1062, 920, 817, 758, 700 cm⁻¹; HRMS (ESI) m/z calcd for C₁₈H₂₁O₃ [M+H]⁺: 285.1485; found: 285.1485



Substrate **4n** (933 mg, colorless oil) was obtained in 42% yield, following general procedure B. ¹H NMR (400 MHz, CDCl₃) $\delta = 6.09$ (s, 3H), 5.92-5.81 (m, 1H), 5.17-5.09 (m, 2H), 4.42-4.37 (m, 1H), 3.77 (s, 6H), 2.59 – 2.44 (m, 1H), 2.43 – 2.26 (m, 1H), 1.32 (d, J = 6.1 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 161.5$, 159.7, 134.1, 117.5, 94.6, 92.9, 73.2, 55.3, 40.5, 19.4 ppm; IR v_{max} (film): 2976, 2935, 2839, 1600, 1471, 1427, 1205, 1151, 1066, 920, 819, 750, 682 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₉O₃ [M+H]⁺: 223.1329; found: 223.1327.



Substrate **4o** (1.56 g, colorless oil) was obtained in 55% yield, following general procedure B ¹H NMR (400 MHz, CDCl₃) δ = 7.42 – 7.22 (m, 5H), 6.20 – 6.04 (m, 4H), 5.21 (dd, J = 15.7, 14.5 Hz, 2H), 4.23 – 4.14 (m, 2H), 3.85 (dd, J = 13.7, 6.9 Hz, 1H), 3.77 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) δ = 161.5, 160.7, 140.8, 138.3, 128.6, 128.1, 126.9, 116.6, 93.6, 93.2, 71.1, 55.4, 49.0 ppm; IR v_{max} (film): 3001, 2954, 2875, 1597, 1458, 1427, 1340, 1205, 1193, 1151, 1062, 912, 817, 744, 700 cm⁻¹; HRMS (ESI) m/z calcd for C₁₈H₂₁O₃ [M+H]⁺: 285.1485; found: 285.1488.



To a stirred solution of 1-(3-hydroxy-2-methylphenoxy)-3-butene^[3] (891 mg, 5 mmol, 1.0 equiv) in THF (60 mL) at 0 °C was added NaH (300 mg, 7.5 mmol, 1.5 equiv, 60% w/w) slowly. The reaction mixture was allowed to warm up to ambient temperature and stirred for 2h, then iodomethane (1.06 g, 7.5 mmol, 1.5 equiv) was added and stirred for another 22h. The reaction was quenched with saturated aqueous ammonium chloride (20 mL), extracted with EtOAc (3 x 20 mL), dried over Na₂SO₄, filtered, and concentrated *in vacuo*. Purification by flash column chromatography (SiO₂, hexane/AcOEt = 10/1) afforded the desired product **4h** (1.59 g, colorless oil) in 83% yield.

¹H NMR (400 MHz, CDCl₃) δ = 7.11 (t, *J* = 8.3 Hz, 1H), 6.54 (dd, *J* = 8.3, 1.0 Hz, 2H), 6.00-5.89 (m, 1H), 5.23 – 5.05 (m, 2H), 4.03 (t, *J* = 6.6 Hz, 2H), 3.84 (s, 3H), 2.67 – 2.46 (m, 2H), 2.13 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 158.4, 157.6, 134.7, 126.1, 116.8, 114.9, 104.7, 103.5, 67.7, 55.7, 33.9, 8.2 ppm; IR v_{max} (film): 3075, 2933, 2835, 1595, 1467, 1436, 1386, 1276, 1251, 1174, 1122, 916, 765, 705 cm⁻¹; HRMS (APCI) m/z calcd for C₁₂H₁₇O₂ [M+H]⁺: 193.1223; found: 193.1225.



To a stirred solution of diethyl allylmalonate (1.50 g, 7.5 mmol, 1.5 equiv) in THF (60 mL) at 0 $^{\circ}$ C was added NaH (300 mg, 7.5 mmol, 1.5 equiv, 60% w/w) slowly. The reaction mixture was allowed to warm up to ambient temperature and stirred for 2h, then 3,5-dimethoxybenzyl bromide(1.16 g, 5 mmol, 1.0 equiv) was added and stirred for another 22h. The reaction was quenched with saturated aqueous ammonium chloride (20 mL), extracted with EtOAc (3 x 20 mL), dried over Na₂SO₄, filtered, and concentrated *in vacuo*. Purification by flash column chromatography (SiO₂, hexane/AcOEt = 4/1) afforded the desired product **4p** (2.81 g, white solid) in 80% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.33 (t, *J* = 2.2 Hz, 1H), 6.27 (d, *J* = 2.2 Hz, 2H), 5.89 – 5.63 (m, 1H), 5.27 – 5.00 (m, 2H), 4.34 – 4.08 (m, 4H), 3.74 (s, 6H), 3.17 (s, 2H), 2.59 (d, *J* = 7.3 Hz, 2H), 1.32 – 1.18 (m, 6H); ¹³C NMR (100 MHz, CDCl₃) δ = 170.7, 160.5, 138.2, 132.8, 119.2, 108.1, 98.7, 61.3, 58.7, 55.1, 38.1, 36.3, 14.0 ppm; IR *v*_{max} (film): 2990, 2945, 1732, 1600, 1463, 1431, 1288, 1205, 1150, 1070, 925, 856, 835 cm⁻¹; HRMS (ESI) m/z calcd for C₁₉H₂₇O₆ [M+H]⁺: 351.1802; found: 351.1804.



Part 3: General procedure and characteristic data for aryl alkenol substrates

General Procedure C for the preparation of aryl ester substrates



To a stirred solution of ethyl bromoacetate (3.34 g, 20 mmol, 2.0 equiv) in acetone (30 mL) at room temperature, corresponding phenol (10 mmol, 1.0 equiv) and K_2CO_3 (4.14 g, 30 mmol, 3.0 equiv) were added sequentially. The mixture was then reflux for 24 h. After cooled down to rt. H₂O (30 mL) was added and the mixture was extracted with EtOAc (3 x 30 mL). The organic layer was washed with brine, dried over Na₂SO₄, and concentrated *in vacuo*. Purification of the residue by flash column chromatography (SiO₂, hexane/AcOEt = 5/1) afforded the desired product. Substrates **9a-9e** were prepared using this method ^[4].

General Procedure D for the preparation of aryl alkenol substrates



To a stirred solution of **9** (5 mmol, 1.0 equiv) in DCM (20 mL) at -78 °C was added DIBAL-H (1.5M in toluene, 3.67 mL, 5.5 mmol, 1.1 equiv) dropwise and stirred for 2 h at -78 °C. Quenched with saturate potassium sodium tartrate at -78 °C and warmed up to ambient temperature. The organic layer was separated and the aqueous solution was extracted with EtOAc (3 x 20 mL). Combine the organic layers, dried over Na₂SO₄, filtered and concentrated *in vacuo*. The crude product was used without purification.

To a stirred solution of the crude product in THF (25 mL) at 0 °C, vinylmagnesium bromide (1.0M in THF, 10 mL, 10 mmol, 2.0 equiv) was added dropwise. The reaction mixture was allowed to warm up to ambient temperature and stirred for 2h, quenched with saturated aqueous ammonium chloride (20 mL), extracted with EtOAc (3 x 20 mL), dried over Na₂SO₄, filtered and concentrated *in vacuo*. Purification by flash column chromatography (SiO₂, hexane/AcOEt = 3/1) afforded the desired product. Substrates **7a-7e** were prepared using this method.



Substrate **9a** (1.60 g, colorless oil) was obtained in 76% yield, following general procedure C ¹H NMR (500 MHz, CDCl₃) δ = 7.18 (t, *J* = 8.2 Hz, 1H), 6.56 (dd, *J* = 8.2, 2.0 Hz, 1H), 6.52 – 6.46 (m, 2H), 4.60 (s, 2H), 4.27 (q, *J* = 7.1 Hz, 2H), 3.78 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (125 MHz, CDCl₃) δ = 168.9, 160.9, 159.1, 123.0, 107.5, 106.4, 101.4, 65.5, 61.3, 55.3, 14.2 ppm; IR *v*_{max} (film): 2981, 2837, 1759, 1595, 1492, 1294, 1197, 1152, 1087, 1035, 835,763, 686cm⁻¹; HRMS (ESI) m/z calcd for C₁₁H₁₄NaO₄ [M+Na]⁺:233.0784; found:233.0783.



Substrate **7a** (417 mg, colorless oil) was obtained in 43% yield, following general procedure D ¹H NMR (400 MHz, CDCl₃) δ = 7.19 (t, *J* = 8.2 Hz, 1H), 6.59 – 6.44 (m, 3H), 6.02 – 5.90 (m, 1H), 5.51 – 5.41 (m, 1H), 5.33 – 5.25 (m, 1H), 4.59 – 4.51 (m, 1H), 4.01 (dd, *J* = 9.5, 3.4 Hz, 1H), 3.88 (dd, *J* = 9.5, 7.7 Hz, 1H), 3.79 (s, 3H), 2.60 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 160.9, 159.7, 136.1, 130.0, 117.2, 106.9, 106.7, 101.2, 71.7, 71.2, 55.3 ppm; IR v_{max} (film): 3421, 2933, 1603, 1495, 1450, 1288, 1260, 1201, 1148, 1049, 927, 835, 763, 686 cm⁻¹; HRMS (ESI) m/z calcd for C₁₁H₁₄NaO₃ [M+Na]⁺:217.0835; found:217.0834.



Substrate **9b** (1.87 g, colorless oil) was obtained in 78% yield, following general procedure C. ¹H NMR (400 MHz, CDCl₃) δ = 6.12 (t, *J* = 2.1 Hz, 1H), 6.09 (d, *J* = 2.1 Hz, 2H), 4.57 (s, 2H), 4.27 (q, *J* = 7.1 Hz, 2H), 3.76 (s, 6H), 1.30 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 168.7, 161.5, 159.6, 93.8, 93.5, 65.3, 61.4, 55.3, 14.1 ppm; IR *v*_{max} (film): 2980, 2840, 1761, 1600, 1477, 1273, 1200, 1150, 1070, 1028, 943, 821, 680 cm⁻¹; HRMS (ESI) m/z calcd for C₁₂H₁₇O₅ [M+H]⁺: 241.1071; found: 241.1070.



Substrate **7b** (460 mg, white solid) was obtained in 41% yield, following general procedure D. ¹H NMR (400 MHz, CDCl₃) $\delta = 6.11$ (s, 3H), 5.99-5.90 (m, 1H), 5.48-5.42 (m, 1H), 5.31-5.27 (m, 1H), 4.57 – 4.49 (m, 1H), 3.99 (dd, J = 9.5, 3.4 Hz, 1H), 3.86 (dd, J = 9.5, 7.7 Hz, 1H), 3.77 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 161.5$, 160.3, 136.0, 117.2, 93.5, 93.5, 71.7, 71.1, 55.3 ppm; IR v_{max} (film): 3460, 2937, 1600, 1475, 1446, 1200, 1160, 1068, 930, 820, 682 cm⁻¹; HRMS (ESI) m/z calcd for C₁₂H₁₇O₄ [M+H]⁺: 225.1121; found: 225.1120.



Substrate **9c** (2.06 g, white solid) was obtained in 81% yield, following general procedure C. ¹H NMR (400 MHz, CDCl₃) δ = 6.15 (s, 2H), 4.60 (s, 2H), 4.28 (q, *J* = 7.1 Hz, 2H), 3.79 (s, 6H), 2.01 (s, 3H), 1.31 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 168.9, 158.7, 157.1, 107.8, 91.3, 65.7, 61.3, 55.7, 14.2, 7.7 ppm; IR ν_{max} (film): 2937, 1757, 1598, 1498, 1452, 1413, 1190, 1155, 1139, 1083, 1033, 960, 810 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₉O₅ [M+H]⁺: 255.1227; found: 255.1226.



Substrate **7c** (477 mg, white solid) was obtained in 40% yield, following general procedure D. ¹H NMR (400 MHz, CDCl₃) $\delta = 6.16$ (s, 2H), 6.01-5.92 (m, 1H), 5.47 (dt, J = 17.3, 1.4 Hz, 1H), 5.30 (dt, J = 10.6, 1.4 Hz, 1H), 4.62 – 4.48 (m, 1H), 4.01 (dd, J = 9.4, 3.5 Hz, 1H), 3.89 (dd, J = 9.3, 7.6 Hz, 1H), 3.79 (s, 6H), 2.03 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 158.7$, 157.8, 136.2, 117.1, 107.3, 91.3, 71.9, 71.3, 55.7, 7.7 ppm; IR v_{max} (film): 3421, 2935, 2837, 1597, 1498, 1452, 1413, 1228, 1197, 1139, 1056, 929, 810 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₉O₄ [M+H]⁺: 239.1278; found: 239.1290.



Substrate **9d** (2.16 g, white solid) was obtained in 80% yield, following general procedure C. ¹H NMR (400 MHz, CDCl₃) $\delta = 6.16$ (s, 2H), 4.57 (s, 2H), 4.32 – 4.20 (m, 2H), 3.83 – 3.80 (m, 6H), 3.78 – 3.75 (m, 3H), 1.35 – 1.25 (m, 3H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 168.8$, 154.4, 153.7, 133.0, 92.6, 65.9, 61.4, 60.9, 56.1, 14.2 ppm; IR v_{max} (film): 2980, 2840, 1755,1600, 1506, 1455, 1420, 1220, 1190, 1161, 1123, 1110, 960, 812, 780 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₉O₆ [M+H]⁺: 271.1176; found: 271.1175.



Substrate **7d** (445 mg, white solid) was obtained in 35% yield, following general procedure D. ¹H NMR (500 MHz, CDCl₃) $\delta = 6.16$ (s, 2H), 5.98 – 5.84 (m, 1H), 5.44 (d, J = 17.3 Hz, 1H), 5.27 (d, J = 10.6 Hz, 1H), 4.57 – 4.43 (m, 1H), 3.97 (dd, J = 9.3, 3.5 Hz, 1H), 3.85 (dd, J = 9.3, 7.6 Hz, 1H), 3.82 (s, 6H), 3.77 (s, 3H); ¹³C NMR (125 MHz, CDCl₃) $\delta = 155.1$, 153.8, 136.2, 132.8, 117.1, 92.7, 72.3, 71.2, 61.0, 56.1 ppm; IR ν_{max} (film): 3462, 2937, 2839, 1595, 1501, 1450, 1421, 1226, 1195, 1132, 1056, 1006, 927, 812, 779 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₉O₅ [M+H]⁺: 255.1227; found: 255.1228.



Substrate **9e** (2.04 g, colorless oil) was obtained in 85% yield, following general procedure C. ¹H NMR (400 MHz, CDCl₃) δ = 6.74 (d, *J* = 8.8 Hz, 1H), 6.59 (d, *J* = 2.8 Hz, 1H), 6.33 (dd, *J* = 8.7, 2.9 Hz, 1H), 4.55 (s, 2H), 4.25 (q, *J* = 7.1 Hz, 2H), 3.82 (d, *J* = 9.1 Hz, 6H), 1.28 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 169.0, 152.4, 149.9, 144.2, 111.4, 103.7, 101.3, 66.0, 61.3, 56.3, 55.8, 14.1 ppm; IR v_{max} (film): 2981, 2833, 1757, 1610, 1512, 1455, 1261, 1226, 1190, 1165, 1083, 1026, 935, 834, 765 cm⁻¹; HRMS (ESI) m/z calcd for C₁₂H₁₇O₅ [M+H]⁺: 241.1071; found: 241.1070



Substrate **7e** (412 mg, white solid) was obtained in 37% yield, following general procedure D. ¹H NMR (400 MHz, CDCl₃) δ = 6.75 (d, *J* = 8.7 Hz, 1H), 6.54 (d, *J* = 2.5 Hz, 1H), 6.39 (dd, *J* = 8.7, 2.5 Hz, 1H), 5.98-5.89 (m, 1H), 5.43 (dd, *J* = 17.3, 1.1 Hz, 1H), 5.26 (dd, *J* = 10.6, 0.9 Hz, 1H), 4.52 (d, J = 6.9 Hz, 1H), 3.96 (dd, J = 9.4, 3.3 Hz, 1H), 3.89 – 3.78 (m, 7H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 153.0$, 149.8, 143.8, 136.2, 117.0, 111.7, 104.1, 101.0, 72.3, 71.2, 56.4, 55.8 ppm; IR v_{max} (film): 3479, 2933, 2833, 1610, 1597, 1514, 1450, 1261, 1228, 1199, 1163, 1139, 1026, 933, 835, 765 cm⁻¹; HRMS (ESI) m/z calcd for C₁₂H₁₆NaO₄ [M+Na]⁺: 247.0941; found: 247.0942

General Procedure E for the preparation of aryl alkenol substrates



To a stirred solution of chloroacetone (1.85 g, 20 mmol, 2.0 equiv) in acetone (30 mL) at room temperature was added corresponding phenol(10 mmol, 1.0 equiv) and $K_2CO_3(4.14 \text{ g}, 30 \text{ mmol}, 3.0 \text{ equiv})$. The mixture was reflux for 24h, then cooled to room temperature. H₂O (20 mL) was added and the mixture was extracted with EtOAc (3 x 20 mL). The organic extract was washed with brine, dried over Na₂SO₄, and concentrated *in vacuo*. The crude product was used without purification^[5].

To a stirred solution of the crude product in THF (25 mL) at 0 °C, vinylmagnesium bromide (1.0M in THF, 20 mL, 20 mmol, 2.0 equiv) was added dropwise. The reaction mixture was allowed to warm up to ambient temperature and stirred for 2 h, quenched with saturated aqueous ammonium chloride (20 mL), extracted with EtOAc (3 x 20 mL). Combine the organic layers, dried over Na₂SO₄, filtered, and concentrated *in vacuo*. Purification by flash column chromatography (SiO₂, hexane/AcOEt = 8/1) afforded the desired product.



Substrate **7f** (1.36 g, colorless oil) was obtained in 57% yield, following general procedure E. ¹H NMR (400 MHz, CDCl₃) δ = 6.10 (s, 3H), 6.06 – 5.95 (m, 1H), 5.40 (dd, *J* = 17.3, 1.1 Hz, 1H), 5.20 (dd, *J* = 10.8, 1.1 Hz, 1H), 3.83 (q, *J* = 8.9 Hz, 2H), 3.77 (s, 6H), 1.40 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 161.5, 160.5, 141.7, 114.1, 93.5, 93.5, 74.8, 72.4, 55.3, 24.4 ppm; IR *v*_{max} (film): 3460, 2935, 2841, 1600, 1475, 1200, 1156, 1064, 927, 821, 682 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₈NaO₄ [M+Na]⁺: 261.1067; found: 261.1094.



Substrate **7g** (1.47 g, colorless oil) was obtained in 55% yield, following general procedure E. ¹H NMR (400 MHz, CDCl₃) $\delta = 6.16$ (s, 2H), 6.02 (dd, J = 17.3, 10.8 Hz, 1H), 5.41 (dd, J = 17.3, 1.1 Hz, 1H), 5.21 (dd, J = 10.8, 1.1 Hz, 1H), 3.89 – 3.74 (m, 11H), 1.41 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 155.3$, 153.7, 141.7, 132.6, 114.1, 92.4, 75.3, 72.4, 61.0, 56.1, 24.5 ppm; IR v_{max} (film): 3460, 2937,2839, 1598, 1500, 1460, 1421, 1230, 1197, 1124, 1053, 1006, 926, 812, 783 cm⁻¹; HRMS (ESI) m/z calcd for $C_{14}H_{20}NaO_5$ [M+Na]⁺: 291.1203; found: 291.1202.



To a stirred solution of LDA (2.0M in THF, 6 mL, 12 mmol, 1.2 equiv) in THF (20 mL) at -78 $^{\circ}$ C was added ethyl isobutyrate (1.39 g, 12 mmol, 1.2 equiv) slowly and stirred for 2 h at -78 $^{\circ}$ C. Then 3,5-dimethoxybenzyl bromide (2.31 g, 10 mmol, 1.0 equiv) in THF (5 mL) was added dropwise to this solution at -78 $^{\circ}$ C. The reaction mixture was stirred for 2 h at -78 $^{\circ}$ C, then was allowed to warm up to ambient temperature and stirred for another 20 h. The reaction was quenched with saturated aqueous ammonium chloride (20 mL) and the mixture was extracted with EtOAc (3 x 20 mL). Combine the organic layers, dried over Na₂SO₄, filtered, and concentrated *in vacuo*. Purification by flash column chromatography (SiO₂, hexane/AcOEt = 8/1) afforded the desired product **9f** (1.82 g, colorless oil) in 68% yield ^[6].

¹H NMR (500 MHz, CDCl₃) δ = 6.33 (t, *J* = 2.3 Hz, 1H), 6.28 (d, *J* = 2.3 Hz, 2H), 4.13 (q, *J* = 7.1 Hz, 2H), 3.76 (s, 6H), 2.80 (s, 2H), 1.25 (t, *J* = 7.1 Hz, 3H), 1.19 (s, 6H); ¹³C NMR (125 MHz, CDCl₃) δ = 177.5, 160.4, 140.3, 108.3, 98.4, 60.4, 55.2, 46.5, 43.4, 25.1, 14.2 ppm; IR v_{max} (film): 2976, 2837, 1726, 1597, 1463, 1429, 1201, 1151, 1066, 1028, 846, 702 cm⁻¹; HRMS (ESI) m/z calcd for C₁₅H₂₃O₄ [M+H]⁺: 267.1591; found: 267.1591.



To a stirred solution of **9f** (5 mmol, 1.0 equiv) in DCM (20 mL) at -78 $^{\circ}$ C was added DIBAL-H (1.5M in toluene, 3.67 mL, 5.5 mmol, 1.1 equiv) dropwise and stirred for 2h at -78 $^{\circ}$ C. Then quenched with saturate potassium sodium tartrate at -78 $^{\circ}$ C and warmed up to ambient temperature. The organic layer was separated and the aqueous solution was extracted with EtOAc (3 x 20 mL). Combine the organic layers, dried over Na₂SO₄, filtered, and concentrated *in vacuo*, the crude product was used without purification.

To a stirred solution of the crude product in THF (25 mL) at 0 °C, vinylmagnesium bromide (1.0M in THF, 10 mL, 10 mmol, 2.0 equiv) was added dropwise. The reaction mixture was allowed to warm up to ambient temperature and stirred for 2 h. Quenched with saturated aqueous ammonium chloride (20 mL), extracted with EtOAc (3 x 20 mL). Combine the organic layers, dried over Na₂SO₄, filtered, and concentrated *in vacuo*. Purification by flash column chromatography (SiO₂, hexane/AcOEt = 6/1) afforded the desired product **7h** (448 mg, colorless oil) in 36% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.37 (d, *J* = 2.2 Hz, 2H), 6.35 (d, *J* = 2.2 Hz, 1H), 5.99 (ddd, *J* = 17.2, 10.5, 6.7 Hz, 1H), 5.32 – 5.08 (m, 2H), 3.83 (d, *J* = 6.7 Hz, 1H), 3.78 (s, 6H), 2.72 (d, *J* = 12.9 Hz, 1H), 2.46 (d, *J* = 12.9 Hz, 1H), 0.92 (s, 3H), 0.86 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 160.1, 141.1, 137.9, 116.7, 109.0, 97.8, 79.2, 55.2, 44.8, 38.5, 23.5, 22.4 ppm; IR v_{max} (film):3470, 2962, 1598, 1463,

1429, 1346, 1294, 1207, 1154, 1064, 993, 927, 837 cm⁻¹; HRMS (ESI) m/z calcd for $C_{15}H_{22}NaO_3$ [M+Na]⁺: 273.1461; found: 273.1457.



To a stirred solution of LDA (2.0M in THF, 6 ml, 12 mmol, 1.2 equiv) in THF (20 mL) at -78 $^{\circ}$ C was added cyclohexanecarboxylic acid ethyl ester (1.87 g, 12 mmol, 1.2 equiv) slowly and stirred for 2h at -78 $^{\circ}$ C. Then 3,5-dimethoxybenzyl bromide (2.31 g, 10 mmol, 1.0 equiv) in THF (5 mL) was added to this solution at -78 $^{\circ}$ C. The reaction mixture was stirred for 2h at -78 $^{\circ}$ C and was allowed to warm up to ambient temperature and stirred for another 20 h. Quenched with saturated aqueous ammonium chloride (20 mL), extracted with EtOAc (3 x 20 mL). Combine the organic layers, dried over Na₂SO₄, filtered, and concentrated *in vacuo*. The crude product was used without purification^[6].

To a stirred solution of the crude product in DCM (20 mL) at -78 °C was added DIBAL-H (1.5M in toluene, 16.67 mL, 25 mmol, 2.5 equiv) dropwise and stirred for 3h at -78 °C. The reaction was quenched with saturate potassium sodium tartrate at -78 °C and warmed up to ambient temperature. The organic layer was separated and the aqueous solution was extracted with EtOAc (3 x 20 mL). Combine the organic layers, dried over Na₂SO₄, filtered, and concentrated *in vacuo*. Purification by flash column chromatography (SiO₂, hexane/AcOEt = 8/1) afforded the desired product **9g** (1.66 g, colorless oil) in 63% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.39 (d, *J* = 2.3 Hz, 2H), 6.33 (t, *J* = 2.3 Hz, 1H), 3.77 (s, 6H), 3.38 (s, 2H), 2.61 (s, 2H), 1.61 – 1.51 (m, 2H), 1.51 – 1.39 (m, 4H), 1.35 (t, *J* = 5.6 Hz, 4H); ¹³C NMR (100 MHz, CDCl₃) δ = 160.3, 141.1, 108.7, 97.7, 67.2, 55.2, 42.1, 38.5, 32.5, 26.3, 21.6 ppm; IR ν_{max} (film): 2927, 2856, 1598, 1462, 1429, 1344, 1292, 1203, 1147, 1060, 931, 840 cm⁻¹; HRMS (ESI) m/z calcd for C₁₆H₂₅O₃ [M+H]⁺: 265.1798; found: 265.1798.



To a stirred solution of **9g** (4 mmol, 1.0 equiv) in DCM (20 mL) at 0° C was added DMP (Dess-Martin periodinane) reagent (2.04 g, 4.8 mmol, 1.2 equiv). The reaction mixture was allowed to warm up to ambient temperature, and stirred for 3h. Then filtration and the residue was washed with DCM. Combine the organic layers, washed with saturated aqueous NaHCO₃ solution, dried over Na₂SO₄, concentrated *in vacuo* and the crude product was used without purification.

To a stirred solution of the crude product in THF (25 mL) at 0 $^{\circ}$ C was added vinylmagnesium bromide (1.0M in THF, 8 mL, 8 mmol, 2.0 equiv) dropwise. The reaction mixture was allowed to warm up to ambient temperature and stirred for 2h, quenched with saturated aqueous ammonium chloride (20 mL), extracted with EtOAc (3 x 20 mL), dried over Na₂SO₄, filtered, and concentrated *in vacuo*. Purification by flash column chromatography (SiO₂, hexane/AcOEt = 15/1) afforded the desired product **7i** (660 mg, colorless oil) in 57% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.41 (d, *J* = 2.3 Hz, 2H), 6.34 (d, *J* = 2.3 Hz, 1H), 6.09 - 5.01 (m, 1H), 5.29-5.21 (m, 2H), 4.08 (t, *J* = 5.4 Hz, 1H), 3.78 (s, 6H), 2.77 - 2.66 (m, 2H), 1.64 - 1.50 (m, 4H), 1.49

- 1.41 (m, 4H), 1.40 - 1.25 (m, 2H); ¹³C NMR (100 MHz, CDCl₃) δ = 160.2, 141.3, 137.8, 116.8, 109.1, 97.7, 75.9, 55.2, 40.9, 38.6, 31.1, 30.3, 26.2, 21.5, 21.4 ppm; IR v_{max} (film): 3475, 2927, 2866, 1595, 1458, 1427, 1344, 1313, 1294, 1203, 1147, 1058, 925, 837, 750, 709 cm⁻¹; HRMS (ESI) m/z calcd for C₁₈H₂₆NaO₃ [M+Na]⁺: 313.1774; found: 313.1771.

Part 4: General procedure and characteristic data for products 5a-5p, 6a-6g

General Procedure for the intermolecular palladium-catalyzed domino reactions of aryl alkenes



To a flame dried 10 mL Schlenk tube was added $PdCl_2(CH_3CN)_2$ (5.2 mg, 0.02 mmol, 0.1 equiv), $CuCl_2$ (94.1 mg, 0.7 mmol, 3.5 equiv) and then degassed by CO for 2 times. The dried DCE (2 mL) was added and the solution was cooled down to 0 °C. Substrate (0.2 mmol, 1.0 equiv) in 2 mL DCE was added and stirred for 3 min at 0 °C. ROH (1 mmol, 5 equiv) in DCE (1 mL) was added and the reaction mixture was stirred for 2 h at 0 °C, then warm up to ambient temperature and stirred for another 22 h. Filtration and the residue was washed with DCM. Concentrated *in vacuo*, purification by flash column chromatography (SiO₂, hexane/AcOEt = 6/1 for **5a-5h**, **5k**, **5l**, **5n**, **6d**; hexane/AcOEt = 20/1 for **5i**, **5j**, **5m**, **5o**, **6f**, **6g**; hexane/AcOEt = 10/1 for **6a-6c**, **6e**; hexane/AcOEt = 3/1 for **5p**) afforded the desired product.



Product 5a (47.9 mg, colorless oil) was obtained in 90% yield.

¹H NMR (400 MHz, CDCl₃) $\delta = 6.05$ (d, J = 2.4 Hz, 1H), 6.01 (d, J = 2.4 Hz, 1H), 4.26 – 4.17 (m, 1H), 4.09 – 3.99 (m, 1H), 3.79 (s, 3H), 3.75 (s, 3H), 3.71 (s, 3H), 3.45 – 3.35 (m, 1H), 2.96 – 2.85 (m, 1H), 2.35 (dd, J = 15.8, 11.1 Hz, 1H), 2.09 – 1.97 (m, 1H), 1.88 – 1.79 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 173.0$, 159.7, 158.6, 155.7, 105.7, 93.2, 91.4, 61.9, 55.4, 55.2, 51.5, 38.7, 26.1, 25.2 ppm; IR v_{max} (film): 2945, 1730, 1616, 1587, 1421, 1286, 1193, 1147, 1118, 1049, 810 cm⁻¹; HRMS (ESI) m/z calcd for C₁₄H₁₉O₅ [M+H]⁺: 267.1227; found: 267.1226



Product 5b (52.7 mg, colorless oil) was obtained in 89% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.16 (s, 1H), 4.24 – 4.13 (m, 1H), 4.05 – 3.96 (m, 1H), 3.94 (s, 3H), 3.78 (d, *J* = 3.9 Hz, 6H), 3.71 (s, 3H), 3.42 – 3.32 (m, 1H), 2.87 (dd, *J* = 15.8, 2.6 Hz, 1H), 2.40 (dd, *J* = 15.8, 11.1 Hz, 1H), 2.14 – 1.91 (m, 1H), 1.90 – 1.68 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 172.8, 152.9, 151.6, 150.6, 135.6, 109.9, 95.8, 61.9, 60.8, 60.8, 55.8, 51.5, 39.6, 26.2, 25.8 ppm; IR *v*_{max} (film):2937, 1734, 1610, 1585, 1489, 1411, 1193, 1136, 1107, 1026, 964, 923, 813 cm⁻¹; HRMS (ESI) m/z calcd for C₁₅H₂₀NaO₆ [M+Na]⁺: 319.1152; found: 319.1153.



Product 5c (46.5 mg, colorless oil) was obtained in 83% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.17 (s, 1H), 4.27 – 4.15 (m, 1H), 4.07 – 3.98 (m, 1H), 3.75 (d, J = 3.7 Hz, 6H), 3.71 (s, 3H), 3.43 – 3.33 (m, 1H), 2.96 (dd, J = 15.8, 2.8 Hz, 1H), 2.40 (dd, J = 15.8, 11.0 Hz, 1H), 2.14 – 2.02 (m, 4H), 1.87 – 1.79 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 173.0, 157.9, 157.5, 153.4, 111.6, 110.0, 95.4, 61.9, 60.6, 55.4, 51.5, 39.8, 26.5, 25.9, 8.7 ppm; IR v_{max} (film): 2947, 1734, 1614, 1587, 1479, 1442, 1408, 1280, 1193, 1132, 1110, 1010, 821 cm⁻¹; HRMS (ESI) m/z calcd for C₁₅H₂₀NaO₅ [M+Na]⁺: 303.1203; found: 303.1204.



Product 5d (45.8 mg, colorless oil) was obtained in 86% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.59 (s, 1H), 6.36 (s, 1H), 4.21 – 4.01 (m, 2H), 3.80 (d, J = 3.2 Hz, 6H), 3.71 (s, 3H), 3.35 – 3.19 (m, 1H), 2.76 (dd, J = 15.5, 4.8 Hz, 1H), 2.51 (dd, J = 15.5, 9.9 Hz, 1H), 2.19 – 2.06 (m, 1H), 1.84 – 1.75 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 172.7, 148.8, 148.5, 143.2, 114.8, 111.4, 100.8, 62.9, 56.4, 55.8, 51.7, 41.4, 30.1, 27.5 ppm; IR v_{max} (film): 2953, 1734, 1506, 1440, 1265, 1219, 1193, 1165, 1086, 1033, 850 cm⁻¹; HRMS (ESI) m/z calcd for C₁₄H₁₈NaO₅ [M+Na]⁺: 289.1046; found: 289.1045.



Product 5e (42.2 mg, colorless oil) was obtained in 84% yield.

¹H NMR (500 MHz, CDCl₃) δ = 6.36 (d, *J* = 2.5 Hz, 1H), 6.24 (d, *J* = 2.6 Hz, 1H), 4.29 - 4.20 (m, 1H), 4.16 - 4.08 (m, 1H), 3.74 (d, *J* = 3.5 Hz, 6H), 3.40 - 3.31 (m, 1H), 2.66 - 2.58 (m, 1H), 2.49 (dd, *J* = 4.16 - 4.08 (m, 1H), 4.16 - 4.08 (m, 1H), 3.74 (d, *J* = 3.5 Hz, 6H), 3.40 - 3.31 (m, 1H), 4.16 - 4.08 (m, 1H), 4.16 - 4.08 (m, 1H), 3.74 (d, *J* = 3.5 Hz, 6H), 3.40 - 3.31 (m, 1H), 4.16 - 4.08 (m, 1H), 4.16 - 4.08 (m, 1H), 3.74 (d, *J* = 3.5 Hz, 6H), 3.40 - 3.31 (m, 1H), 4.16 - 4.08 (m, 1H), 4.16 - 4.08 (m, 1H), 3.74 (d, *J* = 3.5 Hz, 6H), 3.40 - 3.31 (m, 1H), 4.16 - 4.08 (m, 1H), 4.16 - 4.08 (m, 1H), 5.74 (m

16.0, 11.5 Hz, 1H), 2.28 (s, 3H), 2.12 – 2.00 (m, 1H), 1.92 – 1.83 (m, 1H); ¹³C NMR (125 MHz, CDCl₃) δ = 172.5, 158.9, 155.2, 138.0, 115.2, 109.5, 99.4, 61.3, 55.1, 51.7, 39.1, 27.5, 26.0, 18.7 ppm; IR v_{max} (film): 2949, 1734, 1612, 1583, 1487, 1436, 1282, 1193, 1149, 1099, 1016, 840 cm⁻¹; HRMS (ESI) m/z calcd for C₁₄H₁₉O₄ [M+H]⁺: 251.1278; found: 251.1275.



Product 5f (39.7 mg, colorless oil) was obtained in 84% yield.

¹H NMR (400 MHz, CDCl₃) δ = 7.01 (d, *J* = 8.5 Hz, 1H), 6.47 (dd, *J* = 8.5, 2.6 Hz, 1H), 6.37 (d, *J* = 2.6 Hz, 1H), 4.24 – 4.10 (m, 2H), 3.76 (s, 3H), 3.72 (s, 3H), 3.36 – 3.26 (m, 1H), 2.77 (dd, *J* = 15.5, 4.8 Hz, 1H), 2.50 (dd, *J* = 15.5, 10.0 Hz, 1H), 2.20 – 2.08 (m, 1H), 1.85 – 1.75 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 172.6, 159.3, 155.3, 129.2, 116.7, 107.5, 101.6, 63.2, 55.2, 51.7, 41.2, 29.9, 27.4 ppm; IR *v*_{max} (film): 2937, 1734, 1618, 1577, 1500, 1436, 1247, 1193, 1157, 1114, 1012, 833 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₆NaO₄ [M+Na]⁺: 259.0941; found: 259.0941.



Product 5g (36.9 mg, colorless oil) was obtained in 74% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.55 (s, 1H), 6.34 (s, 1H), 5.86 (s, 2H), 4.21 – 4.01 (m, 2H), 3.72 (s, 3H), 3.31 – 3.18 (m, 1H), 2.73 (dd, *J* = 15.6, 4.7 Hz, 1H), 2.49 (dd, *J* = 15.6, 10.0 Hz, 1H), 2.18 – 2.04 (m, 1H), 1.82 – 1.73 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 172.5, 149.3, 146.8, 141.5, 115.9, 107.3, 100.9, 98.6, 63.0, 51.7, 41.5, 30.5, 27.3 ppm; IR ν_{max} (film): 2927, 1734, 1502, 1481, 1435, 1244, 1151, 1037, 935, 858, 746 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₄NaO₅ [M+Na]⁺: 273.0733; found: 273.0732



Product 5h (36.5 mg, white solid) was obtained in 73% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.92 (d, *J* = 8.5 Hz, 1H), 6.47 (d, *J* = 8.6 Hz, 1H), 4.32 – 4.08 (m, 2H), 3.81 (s, 3H), 3.73 (s, 3H), 3.38 – 3.29 (m, 1H), 2.79 (dd, *J* = 15.5, 4.8 Hz, 1H), 2.52 (dd, *J* = 15.5, 10.1 Hz, 1H), 2.18 – 2.08 (m, 1H), 2.06 (s, 3H), 1.85 – 1.76 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ =

172.7, 156.9, 153.1, 125.6, 117.0, 113.8, 103.1, 63.2, 55.6, 51.7, 41.4, 30.4, 27.4, 8.1 ppm; IR v_{max} (film): 2949, 1735, 1610, 1492, 1436, 1271, 1213, 1165, 1126, 1012, 792 cm⁻¹; HRMS (ESI) m/z calcd for C₁₄H₁₈NaO₄ [M+Na]⁺: 273.1097; found: 273.1095.



Product 5i (24.4 mg, white solid) was obtained in 52% yield.

¹H NMR (400 MHz, CDCl₃) $\delta = 6.59$ (s, 1H), 6.51 (s, 1H), 4.35 – 4.19 (m, 1H), 4.19 – 4.05 (m, 1H), 3.74 (s, 3H), 3.45 – 3.31 (m, 1H), 2.69 – 2.58 (m, 1H), 2.50 (dd, J = 16.0, 11.4 Hz, 1H), 2.28 (s, 3H), 2.24 (s, 3H), 2.16 – 2.00 (m, 1H), 1.94 – 1.83 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 172.5, 154.1, 137.4, 136.8, 123.5, 119.8, 115.2, 61.0, 51.7, 38.9, 27.6, 25.9, 20.9, 18.3 ppm; IR <math>v_{max}$ (film):2949, 1735, 1620, 1573, 1436, 1288, 1163, 1145, 1103, 1012, 839 cm⁻¹; HRMS (ESI) m/z calcd for C₁₄H₁₈NaO₃ [M+Na]⁺: 257.1148; found: 257.1148.



Product 5j (33.2 mg, white solid) was obtained in 65% yield.

¹H NMR (400 MHz, CDCl₃) δ = 7.91 (d, *J* = 8.5 Hz, 1H), 7.78 (d, *J* = 8.0 Hz, 1H), 7.64 (d, *J* = 8.9 Hz, 1H), 7.57 – 7.49 (m, 1H), 7.40 – 7.31 (m, 1H), 7.03 (d, *J* = 8.9 Hz, 1H), 4.43 – 4.34 (m, 1H), 4.32 – 4.22 (m, 1H), 4.00 – 3.90 (m, 1H), 3.80 (s, 3H), 3.05 – 2.95 (m, 1H), 2.62 (dd, *J* = 16.1, 11.6 Hz, 1H), 2.33 – 2.19 (m, 1H), 2.06 – 1.98 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 172.7, 151.9, 132.1, 129.23, 128.9, 128.7, 126.8, 123.2, 121.4, 119.1, 115.4, 61.5, 51.8, 39.6, 26.8, 25.7 ppm; IR *v*_{max} (film): 2951, 1734, 1610, 1590, 1490, 1450, 1365, 1249, 1217, 1197, 1149, 1101, 1049, 831 cm⁻¹; HRMS (ESI) m/z calcd for C₁₆H₁₆NaO₃ [M+Na]⁺: 279.0992; found: 279.0991.



Product 5k (29.8 mg, colorless oil) was obtained in 53% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.04 (s, 2H), 4.21 – 4.11 (m, 1H), 4.11 – 4.00 (m, 1H), 3.77 (s, 3H), 3.76 (s, 3H), 3.67 (s, 3H), 3.46 – 3.39 (m, 1H), 3.35 – 3.24 (m, 1H), 1.95 – 1.86 (m, 2H), 0.99 (d, *J* = 7.2 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 176.2, 159.6, 159.0, 156.9, 104.9, 93.4, 91.4, 64.1, 55.3,

55.2, 51.5, 41.4, 30.8, 24.5, 12.4 ppm; IR v_{max} (film): 2947, 1734, 1616, 1589, 1458, 1427, 1197, 1151, 1126, 1072, 815, 750 cm⁻¹; HRMS (ESI) m/z calcd for C₁₅H₂₁O₅ [M+H]⁺: 281.1384; found: 281.1382.



Product 51 (20.3 mg, white solid) was obtained in 36% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.05 (d, *J* = 2.4 Hz, 1H), 6.02 (d, *J* = 2.4 Hz, 1H), 4.17 – 4.08 (m, 1H), 4.08 – 3.99 (m, 1H), 3.79 (s, 3H), 3.74 (s, 3H), 3.58 (s, 3H), 2.89 (dd, *J* = 47.8, 14.1 Hz, 2H), 2.37 – 2.26 (m, 1H), 1.80 – 1.71 (m, 1H), 1.46 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 172.5, 159.9, 159.2, 156.2, 110.3, 93.8, 92.5, 62.8, 55.1, 55.1, 51.1, 43.6, 36.5, 32.8, 26.4 ppm; IR *v*_{max} (film): 2949, 1734, 1612,1583, 1436, 1419, 1199, 1149, 1123, 1062, 815 cm⁻¹; HRMS (ESI) m/z calcd for C₁₅H₂₁O₅ [M+H]⁺: 281.1384; found: 281.1387.



Product 5m (52.5 mg, white solid) was obtained in 77% yield.

¹H NMR (400 MHz, CDCl₃) δ = 7.49 – 7.29 (m, 6H), 6.18 (d, J = 2.4 Hz, 1H), 6.15 (d, J = 2.4 Hz, 0.17H), 6.12 (d, J = 2.5 Hz, 1H), 5.07 – 5.00 (m, 0.17H), 4.92 (dd, J = 10.8, 2.0 Hz, 1H), 3.83 (s, 0.5H), 3.80 (s, 3H), 3.77 (s, 3H), 3.73 (s, 0.5H), 3.67 (s, 3H), 3.63 – 3.52 (m, 1H), 3.31 (dd, J = 16.0, 3.8 Hz, 1H), 3.03 (dd, J = 15.6, 3.3 Hz, 0.17H), 2.56 – 2.47 (m, 1H), 2.13 (dd, J = 16.0, 9.7 Hz, 1H), 2.10 – 2.04 (m, 0.35H), 1.97 – 1.87 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 173.5, 172.9, 159.9, 159.6, 159.3, 158.6, 157.5, 156.1, 141.2, 128.6, 128.5, 128.0, 127.9, 126.2, 126.0, 106.2, 105.3, 94.0, 93.4, 92.4, 91.7, 77.6, 73.4, 55.5, 55.3, 51.6, 51.4, 39.5, 39.2, 38.0, 34.1, 28.5, 26.6 ppm; IR v_{max} (film): 2947, 1734, 1618, 1589, 1487, 1436, 1201, 1149, 1114, 1055, 821, 765, 700 cm⁻¹; HRMS (ESI) m/z calcd for C₂₀H₂₃O₅ [M+H]⁺: 343.1540; found: 343.1540.



Product 5n (45.8 mg, colorless oil) was obtained in 82% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.07 – 6.03 (m, 2H), 6.03 – 6.01 (m, 0.25H), 4.19 – 4.07 (m, 0.25H), 4.00 – 3.89 (m, 1H), 3.78 (s, 0.75H), 3.76 (s, 3H), 3.74 (s, 3H), 3.71 (s, 0.75H), 3.69 (s, 3H), 3.44 – 3.35 (m, 1H), 3.31 (dd, J = 15.7, 3.7 Hz, 1H), 2.90 (dd, J = 15.8, 2.3 Hz, 0.25H), 2.34 (d, J = 11.2 Hz, 0.25H), 2.32 – 2.25 (m, 1H), 2.14 (dd, J = 15.7, 9.5 Hz, 1H), 1.86 – 1.75 (m, 0.25H), 1.75 – 1.64 (m, 0.25H), 1.53 – 1.42 (m, 1H), 1.39 (d, J = 6.2 Hz, 0.75H), 1.36 (d, J = 6.2 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 173.6, 173.0, 159.8, 159.4, 159.3, 158.6, 157.6, 156.1, 106.2, 105.3, 93.8, 93.0, 92.1, 91.34, 72.0, 67.5, 55.3, 55.2, 55.2, 51.5, 51.4, 39.8, 39.2, 37.8, 33.3, 28.1, 26.1, 21.6, 21.2 ppm; IR v_{max} (film): 2949, 1735, 1616, 1587, 1492, 1438, 1348, 1209, 1149, 1122, 1056, 947, 813 cm⁻¹; HRMS (ESI) m/z calcd for C₁₅H₂₁O₅ [M+H]⁺: 281.1384; found: 281.1385.



Product 50 (47.7 mg, white solid) was obtained in 70% yield.

¹H NMR (400 MHz, CDCl₃) δ = 7.34 – 7.17 (m, 5H), 6.08 (dd, *J* = 5.0, 2.4 Hz, 2H), 4.33 (d, *J* = 3.2 Hz, 2H), 3.78 (s, 3H), 3.77 (s, 3H), 3.69 (s, 3H), 3.63 – 3.56 (m, 1H), 3.10 (dd, *J* = 5.9, 3.0 Hz, 1H), 3.00 (dd, *J* = 16.0, 3.2 Hz, 1H), 2.50 (dd, *J* = 16.0, 10.5 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 173.0, 159.7, 158.8, 155.6, 142.2, 128.4, 127.7, 126.6, 104.6, 93.2, 91.9, 66.1, 55.3, 55.2, 51.5, 41.5, 40.0, 32.1 ppm; IR ν_{max} (film): 2949, 2841, 1732, 1618, 1589, 1492, 1452, 1436, 1201, 1145, 1118, 916, 812, 750 cm⁻¹; HRMS (ESI) m/z calcd for C₂₀H₂₃O₅ [M+H]⁺: 343.1540; found: 343.1542.



Product **5p** (70.3 mg, colorless oil) was obtained in 86% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.26 (dd, *J* = 8.4, 2.3 Hz, 2H), 4.32 – 4.00 (m, 4H), 3.75 (d, *J* = 4.5 Hz, 6H), 3.66 (s, 3H), 3.65 – 3.54 (m, 1H), 3.28 – 3.04 (m, 2H), 2.95 (dd, *J* = 16.0, 3.6 Hz, 1H), 2.74 – 2.64 (m, 1H), 2.25 (dd, *J* = 16.0, 9.9 Hz, 1H), 2.03 (dd, *J* = 13.9, 6.8 Hz, 1H), 1.25 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 173.2, 171.9, 170.6, 158.9, 158.1, 136.1, 118.0, 104.4, 97.0, 61.6, 61.2, 55.2, 55.1, 53.5, 51.4, 39.6, 35.9, 34.1, 28.4, 13.9, 13.9 ppm; IR v_{max} (film): 2922, 1732, 1620, 1598, 1510, 1465, 1433, 1404, 1282, 1234, 1165, 1087, 1016, 812, 748 cm⁻¹; HRMS (ESI) m/z calcd for C₂₁H₂₉O₈ [M+H]⁺: 409.1857; found: 409.1856.



Product 6a (43.5 mg, white solid) was obtained in 78% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.05 (d, *J* = 2.3 Hz, 1H), 6.01 (d, *J* = 2.3 Hz, 1H), 4.27 – 4.12 (m, 3H), 4.11 – 4.00 (m, 1H), 3.79 (s, 3H), 3.75 (s, 3H), 3.47 – 3.34 (m, 1H), 2.89 (dd, *J* = 15.7, 2.6 Hz, 1H), 2.33 (dd, *J* = 15.7, 11.2 Hz, 1H), 2.11 – 1.94 (m, 1H), 1.90 – 1.78 (m, 1H), 1.28 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 172.6, 159.7, 158.7, 155.7, 105.8, 93.2, 91.3, 62.0, 60.3, 55.4, 55.2, 38.9, 26.1, 25.2, 14.3 ppm; IR *v*_{max} (film): 2937, 1730, 1618, 1589, 1492, 1425, 1286, 1207, 1150, 1129, 1080, 1051, 947, 813 cm⁻¹; HRMS (ESI) m/z calcd for C₁₅H₂₀NaO₅ [M+Na]⁺: 303.1203; found: 303.1202.



Product 6b (46.9 mg, white solid) was obtained in 76% yield.

¹H NMR (400 MHz, CDCl₃) $\delta = 6.04$ (s, 1H), 6.01 (s, 1H), 4.29 – 3.98 (m, 4H), 3.79 (s, 3H), 3.75 (s, 3H), 3.47 – 3.32 (m, 1H), 2.89 (dd, J = 15.7, 2.5 Hz, 1H), 2.34 (dd, J = 15.6, 11.2 Hz, 1H), 2.03 (t, J = 13.3 Hz, 1H), 1.84 (d, J = 13.0 Hz, 1H), 1.70 – 1.56 (m, 2H), 1.46 – 1.33 (m, 2H), 0.95 (t, J = 7.3 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 172.7$, 159.7, 158.7, 155.7, 105.8, 93.2, 91.3, 64.2, 62.0, 55.3, 55.2, 38.9, 30.7, 26.1, 25.2, 19.2, 13.7 ppm; IR v_{max} (film): 2956, 1730, 1618, 1589, 1492, 1410, 1425, 1286, 1207, 1147, 1124, 1080, 1051, 947, 812 cm⁻¹; HRMS (ESI) m/z calcd for C₁₇H₂₄NaO₅ [M+Na]⁺: 331.1516; found: 331.1515.



Product 6c (41.7 mg, colorless oil) was obtained in 68% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.05 (d, *J* = 2.4 Hz, 1H), 6.01 (d, *J* = 2.4 Hz, 1H), 5.87 – 5.73 (m, 1H), 5.17 – 5.05 (m, 2H), 4.29 – 4.13 (m, 3H), 4.11 – 4.00 (m, 1H), 3.79 (s, 3H), 3.75 (s, 3H), 3.45 – 3.34 (m, 1H), 2.96 – 2.81 (m, 1H), 2.50 – 2.27 (m, 3H), 2.08 – 1.95 (m, 1H), 1.90 – 1.78 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 172.6, 159.7, 158.6, 155.7, 134.1, 117.2, 105.8, 93.2, 91.4, 63.3, 62.0, 55.4, 55.2, 38.9, 33.1, 26.1, 25.2 ppm; IR *v*_{max} (film): 2953, 1732, 1618, 1589, 1492, 1438, 1286, 1207, 1151, 1118, 1082, 1043, 918, 810 cm⁻¹; HRMS (ESI) m/z calcd for C₁₇H₂₂NaO₅ [M+Na]⁺: 329.1359; found: 329.1360.



Product 6d (54.2 mg, white solid) was obtained in 70% yield.

¹H NMR (400 MHz, CDCl₃) δ = 7.16 (d, *J* = 8.6 Hz, 2H), 6.91 – 6.82 (m, 2H), 6.04 (dd, *J* = 13.9, 2.4 Hz, 2H), 4.36 – 4.26 (m, 2H), 4.22 – 4.13 (m, 1H), 4.05 – 3.97 (m, 1H), 3.79 (d, *J* = 5.6 Hz, 6H), 3.76 (s, 3H), 3.43 – 3.31 (m, 1H), 2.95 – 2.84 (m, 3H), 2.32 (dd, *J* = 15.7, 11.2 Hz, 1H), 2.05 – 1.91 (m, 1H), 1.77 – 1.68 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 172.5, 159.7, 158.6, 158.3, 155.7, 129.9, 113.9, 105.8, 93.2, 91.4, 65.0, 62.0, 55.4, 55.3, 55.2, 38.9, 34.3, 26.0, 25.2 ppm; IR ν_{max} (film): 2951, 1730, 1616, 1589,1492, 1463, 1286, 1246, 1209, 1151, 1118, 1035, 947, 815 cm⁻¹; HRMS (ESI) m/z calcd for C₂₂H₂₆NaO₆ [M+Na]⁺: 409.1622; found: 409.1620.



Product 6e (40.1 mg, white solid) was obtained in 68% yield.

¹H NMR (400 MHz, CDCl₃) $\delta = 6.05$ (d, J = 2.3 Hz, 1H), 6.01 (d, J = 2.3 Hz, 1H), 5.12 – 5.00 (m, 1H), 4.27 – 4.17 (m, 1H), 4.11 – 4.00 (m, 1H), 3.79 (s, 3H), 3.75 (s, 3H), 3.43 – 3.35 (m, 1H), 2.86 (ddd, J = 15.6, 3.2, 0.9 Hz, 1H), 2.30 (dd, J = 15.6, 11.2 Hz, 1H), 2.09 – 1.96 (m, 1H), 1.89 – 1.79 (m, 1H), 1.26 (d, J = 6.3 Hz, 6H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 172.2$, 159.7, 158.7, 155.7, 105.9, 93.2, 91.3, 67.5, 62.0, 55.4, 55.2, 39.2, 26.1, 25.3, 21.9, 21.8 ppm; IR v_{max} (film): 2976, 2937, 1726, 1618, 1589, 1492, 1458, 1371, 1286, 1205, 1147, 1123, 1049, 813 cm⁻¹; HRMS (ESI) m/z calcd for C₁₆H₂₂NaO₅ [M+Na]⁺: 317.1359; found: 317.1361.



Product 6f (44.1 mg, colorless oil) was obtained in 66% yield.

¹H NMR (400 MHz, CDCl₃) $\delta = 6.05$ (d, J = 2.2 Hz, 1H), 6.01 (d, J = 2.2 Hz, 1H), 4.88 – 4.71 (m, 1H), 4.28 – 4.14 (m, 1H), 4.14 – 3.99 (m, 1H), 3.79 (s, 3H), 3.75 (s, 3H), 3.44 – 3.32 (m, 1H), 2.88 (dd, J =15.5, 2.7 Hz, 1H), 2.31 (dd, J = 15.5, 11.2 Hz, 1H), 2.10 – 1.95 (m, 1H), 1.91 – 1.80 (m, 3H), 1.78 – 1.67 (m, 2H), 1.61 – 1.51 (m, 1H), 1.50 – 1.34 (m, 4H), 1.34 – 1.27 (m, 1H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 172.1$, 159.6, 158.7, 155.7, 105.9, 93.2, 91.3, 72.5, 62.0, 55.4, 55.2, 39.3, 31.7, 31.6, 26.1, 25.4, 25.3, 23.7 ppm; IR v_{max} (film): 2935, 1726, 1616, 1589, 1492, 1452, 1286, 1207, 1149, 1121, 1075, 1040, 1016, 810 cm⁻¹; HRMS (ESI) m/z calcd for C₁₉H₂₆NaO₅ [M+Na]⁺: 357.1672; found: 357.1674.



Product 6g (24.7 mg, white solid) was obtained in 40% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.05 (d, *J* = 2.3 Hz, 1H), 6.01 (d, *J* = 2.3 Hz, 1H), 4.29 – 4.17 (m, 1H), 4.11 – 4.02 (m, 1H), 3.79 (s, 3H), 3.75 (s, 3H), 3.40 – 3.29 (m, 1H), 2.82 (dd, *J* = 15.5, 2.2 Hz, 1H), 2.24 (dd, *J* = 15.5, 11.3 Hz, 1H), 2.09 – 1.95 (m, 1H), 1.85 (dd, *J* = 14.3, 2.2 Hz, 1H), 1.48 (s, 9H); ¹³C NMR (100 MHz, CDCl₃) δ = 172.1, 159.6, 158.7, 155.7, 106.1, 93.2, 91.3, 80.3, 62.1, 55.4, 55.2, 40.0, 28.2, 26.0, 25.4 ppm; IR *v*_{max} (film): 2974, 2935, 1726, 1616, 1589, 1492, 1440, 1367, 1290, 1207, 1143, 1123, 1080, 1051, 813 cm⁻¹; HRMS (ESI) m/z calcd for C₁₇H₂₄NaO₅ [M+Na]⁺: 331.1516; found: 331.1517

OMe u		OMe 4
ОН	Pd catalyst, Oxidant	
MeO	Solvent, Additives CO balloon, 0°C to rt,12 h	MeO

Ontimi	zation of	conditions fo	r Pd-catal	vzed carbon	vlation of a	rvl alkenols ^{a,b}
Opunn	Lanon or v	containons io	i i u-catai	yzcu cai bun	ylation of a	I YI AIKCHUIS

Entry	Solvent	Catalyst (0.1 eq)	Oxidant (3.5 eq)	Additives	Yield
1	THF	Pd(OAc) ₂	CuCl ₂		0%
2	THF	Pd(OAc) ₂	CuCl ₂	TMTU(0.1 eq)	0%
				Propylene-oxide(5 eq)	
				NH ₄ OAc(1 eq)	
3	THF	PdCl ₂ (CH ₃ CN) ₂	CuCl ₂		0%
4	THF	PdCl ₂ (CH ₃ CN) ₂	CuCl ₂	NaOAc(3 eq)	0%
5	HOAc	PdCl ₂ (CH ₃ CN) ₂	CuCl ₂	NaOAc(3 eq)	25%
6	DCM	PdCl ₂ (CH ₃ CN) ₂	CuCl ₂		55%
7	DCE	PdCl ₂ (CH ₃ CN) ₂	CuCl ₂		62%
8	DCE	Pd(OAc) ₂	CuCl ₂		<10%
9	DCE	PdCl ₂ (CH ₃ CN) ₂	CuCl ₂	CsOAc(3 eq)	<10%
10	DCE	PdCl ₂ (CH ₃ CN) ₂	CuCl ₂	TMTU(0.1 eq)	23%
11	DCE	PdCl ₂ (CH ₃ CN) ₂	CuCl ₂	Propylene-oxide(5 eq)	0%
12	DCE	PdCl ₂ (CH ₃ CN) ₂	CuCl ₂	$AgSbF_6(3 eq)$	<10%
13 ^a	DCE	PdCl ₂ (CH ₃ CN) ₂	CuCl ₂		48%
14 ^b	DCE	PdCl ₂ (CH ₃ CN) ₂	CuCl ₂		35%
15	DCE	PdCl ₂ (CH ₃ CN) ₂	Cu(OAc) ₂		0%
16	DCE	PdCl ₂ (CH ₃ CN) ₂	Benzoquinone		0%

17 DCE $PdCl_2(CH_3CN)_2$ Ag ₂ O	0%
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Reaction conditions: aryl alkenol (0.3 mmol, 1.0 equiv), Pd catalyst (0.03 mmol, 0.1 equiv), Oxidant (10.5 mmol, 3.5 equiv), DCE (10 ml, 0.03 M for substrate) in a Schlenk tube with a CO balloon, $0 \degree C$ for 1 h then room temperature for another 11 h. [a] the temperature is $0 \degree C$. [b] the temperature is $50 \degree C$.

Part 5: General procedure and characteristic data for products 8a-8i

General Procedure for the intramolecular palladium-catalyzed domino reactions of aryl alkenols



To a flame dried 25 mL Schlenk tube was added $PdCl_2(CH_3CN)_2$ (7.8 mg, 0.03 mmol, 0.1 equiv), $CuCl_2$ (141.2 mg, 10.5 mmol, 3.5 equiv). Degassed by CO for 2 times then dried DCE (6 mL) was added and the solution was cooled down to 0 °C. Substrate (0.3 mmol, 1.0 equiv) in DCE (4 mL) was added and the reaction mixture was stirred for 1 h at 0 °C, then warm up to ambient temperature and stirred for another 11 h. Filtration and the residue was washed with DCM. Concentrated *in vacuo*, purification by flash column chromatography (SiO₂, hexane/AcOEt = 3/1 for **8a**, **8e**, **8f**, **8h**; hexane/AcOEt = 2/1 for **8b-8d**, **8g**; hexane/AcOEt = 4/1 for **8i**) afforded the desired product.



Product 8a (11.9 mg, colorless oil) was obtained in 18% yield.

¹H NMR (400 MHz, CDCl₃) $\delta = 6.99$ (d, J = 8.5 Hz, 1H), 6.59 (dd, J = 8.5, 2.4 Hz, 1H), 6.45 (d, J = 2.3 Hz, 1H), 4.96 – 4.85 (m, 1H), 4.38 (dd, J = 12.4, 3.9 Hz, 1H), 4.05 (dd, J = 12.4, 1.9 Hz, 1H), 3.83 – 3.71 (m, 4H), 3.11 (dd, J = 17.5, 8.9 Hz, 1H), 2.58 (dd, J = 17.5, 3.4 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 175.6$, 159.7, 154.9, 129.9, 114.1, 110.0, 102.0, 76.0, 65.0, 55.4, 38.1, 33.2 ppm; IR v_{max} (film): 2918, 2848, 1770, 1618, 1583, 1506, 1425, 1344, 1278, 1197, 1170, 1149, 1118, 1072 1028, 1002, 941, 889, 854 cm⁻¹; HRMS (ESI) m/z calcd for C₁₂H₁₂NaO₄ [M+Na]⁺: 243.0628; found: 243.0633.



Product 8b (46.4 mg, white solid) was obtained in 62% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.12 (d, *J* = 2.3 Hz, 1H), 6.09 (d, *J* = 2.3 Hz, 1H), 4.93 – 4.81 (m, 1H), 4.25 (dd, *J* = 12.1, 4.8 Hz, 1H), 4.03 (dd, *J* = 12.1, 2.4 Hz, 1H), 3.80 (s, 3H), 3.76 (s, 3H), 3.75 – 3.69 (m, 1H), 3.09 (dd, *J* = 18.1, 9.0 Hz, 1H), 2.52 (dd, *J* = 18.1, 4.4 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 176.5, 160.3, 158.9, 155.5, 103.7, 93.7, 92.9, 75.3, 65.0, 55.5, 55.4, 36.3, 29.9 ppm; IR *v*_{max} (film): 2943, 1768, 1618, 1597, 1496, 1425, 1342, 1311, 1203, 1182, 1159, 1139, 1120, 1064, 935, 827, 812 cm⁻¹; HRMS (ESI) m/z calcd for C₁₃H₁₅O₅ [M+H]⁺: 251.0914; found: 251.0912



Product 8c (52.2 mg, white solid) was obtained in 66% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.25 (s, 1H), 4.94 – 4.85 (m, 1H), 4.22 (dd, *J* = 12.0, 5.0 Hz, 1H), 4.03 (dd, *J* = 12.0, 2.7 Hz, 1H), 3.83 – 3.78 (m, 1H), 3.77 (s, 3H), 3.73 (s, 3H), 3.14 (dd, *J* = 18.1, 9.2 Hz, 1H), 2.57 (dd, *J* = 18.1, 4.9 Hz, 1H), 2.07 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 176.3, 158.4, 157.7, 153.0, 113.4, 108.1, 95.8, 75.5, 65.1, 60.4, 55.6, 36.9, 30.2, 8.8 ppm; IR *v*_{max} (film): 2941, 1778, 1614, 1598, 1483, 1456, 1409, 1309, 1203, 1163, 1132, 1109, 1062, 1000, 960, 925, 823 cm⁻¹; HRMS (ESI) m/z calcd for C₁₄H₁₇O₅ [M+H]⁺: 265.1071; found: 265.1071.



Product 8d (40.2 mg, colorless oil) was obtained in 48% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.23 (s, 1H), 4.93 – 4.78 (m, 1H), 4.20 (dd, *J* = 12.0, 4.9 Hz, 1H), 3.99 (dd, *J* = 12.0, 2.6 Hz, 1H), 3.95 (s, 3H), 3.79 (s, 3H), 3.77 (s, 3H), 3.77 – 3.72 (m, 1H), 3.12 (dd, *J* = 18.1, 9.2 Hz, 1H), 2.50 (dd, *J* = 18.1, 4.7 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 176.2, 153.5, 151.6, 150.2, 136.6, 108.0, 96.3, 75.3, 65.1, 60.9, 60.6, 55.9, 36.8, 30.2 ppm; IR *v*_{max} (film): 2943, 1776, 1610, 1585, 1490, 1460, 1413, 1350, 1309, 1207, 1184, 1159, 1134, 1105, 1066, 1031, 1002, 966, 925, 898, 800 cm⁻¹; HRMS (ESI) m/z calcd for C₁₄H₁₇O₆ [M+H]⁺: 281.1020; found: 281.1021.



Product 8e (39.1 mg, colorless oil) was obtained in 52% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.51 (s, 1H), 6.43 (s, 1H), 4.93 – 4.84 (m, 1H), 4.34 (dd, *J* = 12.3, 3.8 Hz, 1H), 3.98 (dd, *J* = 12.3, 2.0 Hz, 1H), 3.81 (s, 6H), 3.78 – 3.68 (m, 1H), 3.10 (dd, *J* = 17.5, 9.0 Hz, 1H), 2.57 (dd, *J* = 17.5, 3.4 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ = 175.5, 149.2, 148.0, 144.9, 112.6, 111.2, 101.3, 76.1, 65.0, 56.5, 55.9, 37.9, 33.4 ppm; IR ν_{max} (film): 2954, 1761, 1519, 1454,

1442, 1271, 1228, 1197, 1159, 1132, 1068, 1014, 933, 873 cm⁻¹; HRMS (ESI) m/z calcd for $C_{13}H_{14}NaO_5 [M+Na]^+$: 273.0733; found: 273.0731.



Product 8f (53.2 mg, colorless oil) was obtained in 67% yield.

¹H NMR (400 MHz, CDCl₃) $\delta = 6.12$ (d, J = 2.3 Hz, 1H), 6.10 (d, J = 2.3 Hz, 1H), 3.99 – 3.75(m, 2H), 3.79 (s, 3H), 3.76 (s, 3H), 3.35 (dd, J = 8.8, 7.0 Hz, 1H), 3.20 (dd, J = 18.1, 9.0 Hz, 1H), 2.46 (dd, J = 18.2, 6.8 Hz, 1H), 1.51 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 175.9$, 160.3, 158.9, 154.7, 104.1, 93.5, 92.8, 80.7, 69.1, 55.5, 55.4, 37.1, 36.5, 22.9 ppm; IR v_{max} (film): 2920, 2845, 1774, 1618, 1591, 1496, 1458, 1425, 1317, 1201, 1151, 1112, 1093, 1060, 943, 817 cm⁻¹; HRMS (ESI) m/z calcd for C₁₄H₁₇O₅ [M+H]⁺: 265.1071; found: 265.1073.



Product 8g (36.9 mg, white solid) was obtained in 42% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.24 (s, 1H), 3.96 (s, 3H), 3.94 – 3.83 (m, 2H), 3.81 (s, 3H), 3.79 (s, 3H), 3.36 (dd, *J* = 8.9, 7.1 Hz, 1H), 3.22 (dd, *J* = 18.0, 9.1 Hz, 1H), 2.49 (dd, *J* = 18.0, 6.9 Hz, 1H), 1.51 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 175.6, 153.5, 151.6, 149.4, 136.6, 108.3, 96.0, 80.7, 69.1, 60.9, 60.6, 55.9, 37.6, 36.9, 22.9 ppm; IR v_{max} (film): 2937, 1778, 1612, 1589, 1490, 1460, 1409, 1315, 1240, 1201, 1109, 1049, 943, 817 cm⁻¹; HRMS (ESI) m/z calcd for C₁₅H₁₉O₆ [M+H]⁺: 295.1176; found: 295.1172.



Product 8h (46.3 mg, white solid) was obtained in 56% yield.

¹H NMR (400 MHz, CDCl₃) δ = 6.32 (d, J = 2.3 Hz, 1H), 6.20 (d, J = 2.2 Hz, 1H), 4.40 (dd, J = 6.1, 1.1 Hz, 1H), 3.79 (d, J = 5.7 Hz, 6H), 3.64 (t, J = 6.9 Hz, 1H), 3.03 (dd, J = 18.0, 9.0 Hz, 1H), 2.88 (d, J = 16.1 Hz, 1H), 2.60 (dd, J = 18.0, 2.2 Hz, 1H), 2.29 (d, J = 15.9 Hz, 1H), 1.19 (s, 3H), 0.88 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ = 177.7, 159.4, 158.3, 137.0, 115.1, 104.6, 96.7, 86.1, 55.2, 55.2, 37.8, 37.2, 33.2, 33.0, 26.3, 23.1 ppm; IR ν_{max} (film): 2926, 1776, 1606, 1591, 1490, 1467, 1340, 1319, 1200, 1174, 1136, 1099, 1051, 950, 823 cm⁻¹; HRMS (ESI) m/z calcd for C₁₆H₂₁O₄ [M+H]⁺: 277.1434; found: 277.1431.



Product 8i (46.3 mg, colorless oil) was obtained in 42% yield.

¹H NMR (400 MHz, CDCl₃) $\delta = 6.31$ (d, J = 2.2 Hz, 1H), 6.23 (d, J = 2.1 Hz, 1H), 4.55 (d, J = 5.8 Hz, 1H), 3.78 (d, J = 2.2 Hz, 6H), 3.68 – 3.57 (m, 1H), 3.01 (dd, J = 17.9, 8.9 Hz, 1H), 2.79 (d, J = 16.2 Hz, 1H), 2.65 – 2.49 (m, 2H), 1.76 – 1.46 (m, 5H), 1.45 – 1.31 (m, 3H), 1.30 – 1.14 (m, 2H); ¹³C NMR (100 MHz, CDCl₃) $\delta = 177.8$, 159.4, 158.3, 136.6, 115.4, 104.8, 96.7, 85.3, 55.2, 55.2, 37.1, 35.5, 34.7, 34.0, 32.8, 30.3, 26.2, 21.2, 21.1 ppm; IR v_{max} (film): 2958, 1778, 1610, 1593, 1492, 1458, 1336, 1316, 121, 1174, 1143, 1093, 1049, 991, 950, 825 cm⁻¹; HRMS (ESI) m/z calcd for C₁₉H₂₄NaO₄ [M+Na]⁺: 339.1567; found: 339.1565.

Part 6: References

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Part 7: NMR spectra









S33


















S42



















S51









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S56





















S66




































S84













S90





S92



S93



S94



S95

