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Supporting Information

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Direct Oxidative Heck Cyclizations: Palladium-Catalyzed Intramolecular Fujiwara-Moritani Arylations for the Synthesis of Functionalized Benzofurans and Dihydrobenzofurans

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Materials and Methods. Unless stated otherwise, reactions were conducted in flame-dried glassware under an argon or nitrogen atmosphere with freshly distilled solvents. All commercially obtained reagents were used as received. Reaction temperatures were controlled by an IKAmag temperature modulator. Thin-layer chromatography was conducted with E. Merck silica gel 60 F254 precoated plates (0.25 mm) and visualized via UV, $KMnO_4$ and anisaldehyde staining. ICN silica gel (particle size 0.032 – 0.063 mm) was used for flash column chromatography. Preparative HPLC was performed on a Waters HPLC with an Agilent ZORBAX S1L 4.6 x 250 mm, 5 μm column utilizing a flow rate of 1.5 mL/min and a ramp of 0.11% B/min (A eluent = hexanes, B eluent = EtOAc) with visualization at 270 nm. ^1H and ^{13}C NMR spectra were recorded on a Varian Mercury 300 (at 300 MHz and 75 MHz respectively). Data for ^1H NMR spectra are reported as follows: chemical shift (δ ppm), multiplicity, coupling constant (Hz) and integration. Data for ^{13}C NMR are reported in terms of chemical shift. IR spectra were recorded on a Perkin Elmer Paragon 1000 spectrometer and are reported in frequency of absorption (cm^{-1}). High resolution mass were obtained from the California Institute of Technology Mass Spectral Facility.

Preparation of Starting Materials

3,5-Dimethoxy-4-methylphenol

To a solution of (3,5-dimethoxyphenoxy)triisopropylsilane[1] (1.36 g, 4.54 mmol) in THF (20.0 mL) was added *n*-BuLi (2.00 mL, 2.50 M in hexanes, 1.10 equiv) dropwise at 23 °C. The resulting mixture was stirred at 23 °C for 1 h and MeI (0.570 mL, 2.00 equiv) was added dropwise. After the addition was complete, the mixture was stirred for additional 30 min and quenched with saturated aq NH_4Cl. The mixture was extracted with Et_2O, dried ($MgSO_4$), evaporated and purified by flash chromatography using 50:1 hexanes/EtOAc to afford 1.33 g (93%) of (3,5-dimethoxy-4-methyl-phenoxy)triisopropylsilane as a colorless oil: ^1H NMR ($CDCl_3$) δ 1.12 (d, J = 6.6 Hz, 18H), 1.22 (m, 3H), 2.01 (s, 3H), 3.76 (s, 6H), 6.11 (s, 2H). To a solution of (3,5-dimethoxy-4-methylphenoxy)triisopropylsilane (1.32 g, 4.20 mmol) in 95% EtOH (20.0 mL) was added conc. HCl (1.70 mL). The mixture was stirred at 23 °C for 20 h, concentrated and extracted with EtOAc. The organic phase was dried ($MgSO_4$), concentrated and purified by flash chromatography using 2:1 hexanes/EtOAc to afford 0.706 g (100%) of 3,5-dimethoxy-4-methylphenol as a white solid: mp 149-150 °C; ^1H NMR ($CDCl_3$) δ 2.00 (s, 3H), 3.77 (s, 6H), 4.96 (br s, 1H), 6.06 (s, 2H).

7-Benzyloxy-1-hepten-3-ol

To a solution of 5-benzyloxy-1-pentanal[2] (1.65 g, 8.58 mmol) in THF (20.0 mL) at –78 °C was added vinyl magnesium bromide (9.50 mL, 1.00 M in THF, 1.10 equiv) dropwise. After the addition was complete, the reaction was stirred at –78 °C for additional 30 min. The reaction mixture was quenched with saturated aq NH_4Cl, extracted with Et_2O, dried ($MgSO_4$), concentrated and purified by flash chromatography using 3:1 hexanes/EtOAc to afford 1.17 g (62%) pale yellow oil: ^1H NMR ($CDCl_3$) δ 1.40-1.75 (m, 6H), 3.52 (t, J = 6.6 Hz, 2H), 4.14

[1]. J. J. Landi, Jr., K. Ramig, *Synth. Commun.* **1991**, *21*, 167-171.
[2]. Z. Xu, Y. Peng, T. Ye, *Org. Lett.* **2003**, *5*, 2821-2824.

(q, *J* = 6.0 Hz, 1H), 4.54 (s, 2H), 5.14 (dt, *J* = 10.2, 1.5 Hz, 1H), 5.26 (dt, *J* = 17.4, 1.5 Hz, 1H), 5.91 (m, 1H), 7.29-7.40 (m, 5H).

trans-(4-Benzyloxymethyl-3-methylcyclohex-1-enyl)methanol

To a flame-dry 25 mL round-bottom flask were sequentially charged with $Pd(PPh_3)_4$ (66.0 mg, 5 mol %), *trans*-4-benzyloxymethyl-3-methylcyclohex-1-enyl triflate[3] (400 mg, 1.15 mmol), DMF (10.0 mL), MeOH (2.50 mL) and Et_3N (320 μL, 2.00 equiv). The flask was sealed with a septum and flushed with CO. The mixture was stirred under CO (balloon) at 65 °C for 12 h. The reaction mixture was passed through a plug of celite (0.6 × 5 cm), diluted with ether and washed with saturated aq NH_4Cl. The organic phase was dried ($MgSO_4$), concentrated and purified by flash chromatography using 12:1 hexanes/EtOAc to afford 236 mg (75%) of *trans*-4-benzyloxymethyl-3-methyl-cyclohex-1-enecarboxylic acid methyl ester as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.13 (d, *J* = 7.2 Hz, 3H), 1.55 (m, 2H), 1.98 (m, 1H), 2.22 (m, 2H), 2.40 (m, 1H), 3.40 (dd, *J* = 9.0, 6.6 Hz, 1H), 3.55 (dd, *J* = 9.0, 4.2 Hz, 1H), 3.77 (s, 3H), 4.52 (d, *J* = 12.0 Hz, 1H), 4.58 (d, *J* = 12.0 Hz, 1H), 6.80 (br s 1H), 7.37 (m, 5H). To a solution of *trans*-4-benzyloxymethyl-3-methyl-cyclohex-1-enecarboxylic acid methyl ester (236 mg, 0.86 mmol) in CH_2Cl_2 (5.00 mL) under N_2 at –78 °C was added DIBAL (353 μL, 2.30 equiv) dropwise. The reaction mixture was stirred at –78 °C for 30 min, quenched with 10% aq NaOH (2.00 mL), and extracted with Et_2O. The combined organic layers were dried ($MgSO_4$), evaporated and purified by flash chromatography using 2:1 hexanes/EtOAc to afford 158 mg (75%) of *trans*-(4-benzyloxymethyl-3-methylcyclohex-1-enyl)methanol as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.06 (d, *J* = 7.2 Hz, 3H), 1.42 (br s, 1H), 1.46 (m, 2H), 1.95-2.15 (m, 4H), 3.39 (dd, *J* = 9.0, 6.6 Hz, 1H), 3.58 (dd, *J* = 9.0, 4.2 Hz, 1H), 4.03 (s, 2H), 4.52 (d, *J* = 12.0 Hz, 1H), 4.58 (d, *J* = 12.0 Hz, 1H), 5.50 (br s, 1H), 7.37 (m, 5H).

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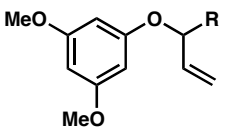
[3]. a) J. E. McMurry, W. J. Scott, *Tetrahedron Lett*. **1983**, *24*, 979-982; (b) E. M. Ferreira, B. M. Stoltz, *J. Am. Chem. Soc*. **2003**, *125*, 9578-9579.

Substrates for Oxidative Heck Cyclizations



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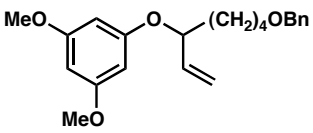
R = Et, ***S1***
R = *n*-C_5H_{11}, ***S2***



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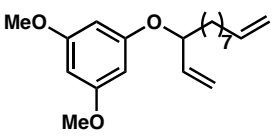

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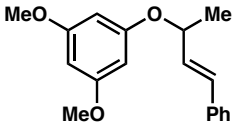

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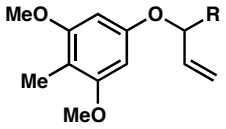

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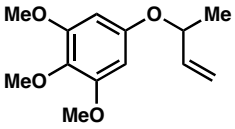

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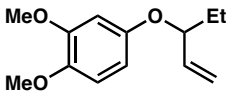

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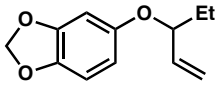

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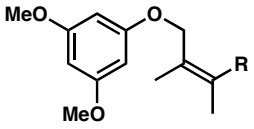

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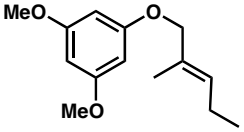
R = Me, ***S12***



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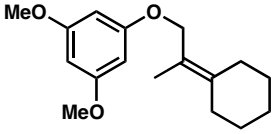

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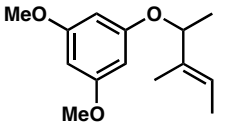

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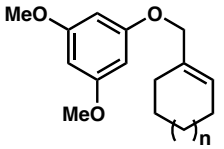

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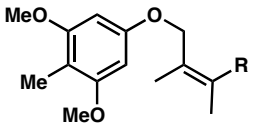

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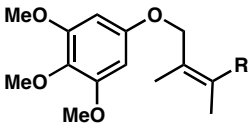

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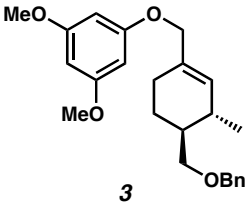

3

Representative Procedure for the Preparation of Starting Substrates
To a 25 mL flame-dried round bottom flask were added 3,5-dimethoxyphenol (308 mg, 2.00 mmol), triphenylphosphine (788 mg, 3.00 mmol), 3-buten-2-ol (216 mg, 3.00 mmol) and THF (10.0 mL). The mixture was stirred until all the solids disappeared, and diisopropyl azodicarboxylate (DIAD, 607 mg, 3.00 mmol) was added dropwise at 0 °C. The resulting yellow solution was heated at 60 °C. After the reaction was complete judged by TLC analysis, the reaction mixture was concentrated in vacuo, triturated with hexanes/EtOAc (20:1) and filtered. The filtrates were concentrated in vacuo and the residue was purified using hexanes/EtOAc (20:1) by flash chromatography on a silica gel column to afford 1,3-dimethoxy-5-(1-methylallyloxy)benzene (287 mg, 69%) as a colorless oil.

1,3-Dimethoxy-5-(1-methylallyloxy)benzene (*1*)
The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 69% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.46 (d, *J* = 6.3 Hz, 3H), 3.79 (s, 6H), 4.80 (m, 1H), 5.20 (m, 1H), 5.30 (m, 1H), 5.90 (m, 1H), 6.11 (t, *J* = 2.1 Hz, 1H), 6.14 (d, *J* = 2.1 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 21.5, 55.5, 74.8, 93.2, 95.0, 115.8, 139.3, 160.1, 161.6; IR (film, cm^{-1}) 2960, 2839, 1598, 1150; HRMS m/z Calcd for $C_{12}H_{16}O_3$ 208.1100; Found 208.1107.

1-(1-Ethylallyloxy)-3,5-dimethoxybenzene (*S1*)
The compound was prepared using 3,5-dimethoxyphenol and 1-penten-3-ol. The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 58% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.03 (t, *J* = 7.2 Hz, 3H), 1.79 (m, 2H), 3.79 (s, 6H), 4.52 (m, 1H), 5.26 (m, 2H), 5.87 (m, 1H), 6.10 (t, *J* = 2.1 Hz, 1H), 6.14 (d, *J* = 2.1 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 9.7, 28.5, 55.3, 80.3, 93.0, 94.8, 116.6, 137.8, 160.3, 161.4; IR (film, cm^{-1}) 2936, 1598, 1205, 1151; HRMS m/z Calcd for $C_{13}H_{18}O_3$ 222.1256; Found 222.1256.

1,3-Dimethoxy-5-(1-pentylallyloxy)benzene (*S2*)
The compound was prepared using 3,5-dimethoxyphenol and 1-octen-3-ol. The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 58% of the desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 0.87 (t, *J* = 6.9 Hz, 3H), 1.23-1.50 (m, 6H), 1.58-1.82 (m, 2H), 3.73 (s, 6H), 4.55 (q, *J* = 6.0 Hz, 1H), 5.19 (d, *J* = 10.5 Hz, 1H), 5.25 (d, *J* = 17.4 Hz, 1H), 5.82 (m, 1H), 6.05 (t, *J* = 2.1 Hz, 1H), 6.09 (d, *J* = 2.1 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 14.3, 22.8, 25.2, 31.9, 35.7, 55.5, 79.3, 93.2, 95.0, 116.5, 138.3, 160.5, 161.6; IR (film, cm^{-1}) 2932, 1596, 1465, 1152; HRMS m/z Calcd for $C_{16}H_{24}O_3$ 264.1726; Found 264.1731.

1,3-Dimethoxy-5-(1-vinyl-5-benzoxypentyloxy)benzene (*S3*)
The compound was prepared using 3,5-dimethoxyphenol and 7-benzyloxy-1-hepten-3-ol. The reaction mixture was chromatographed using 6:1 hexanes/EtOAc to afford 48% of the desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 1.44-1.82 (m, 6H), 3.48 (m, 2H), 3.75 (s, 6H), 4.50 (s, 2H), 4.56 (m, 1H), 5.21 (m, 2H), 5.82 (m, 1H), 6.05 (t, *J* = 1.8 Hz, 1H), 6.09 (d, *J* = 1.8 Hz, 2H), 7.30 (m, 5H); ^{13}C NMR ($CDCl_3$) δ 22.1, 29.6, 35.4, 55.3, 70.2, 72.9, 78.9, 93.0, 94.8, 116.5, 127.5, 127.7, 128.4, 138.0, 139.0, 160.2, 161.4; IR (film, cm^{-1}) 2932, 1595, 1205, 1152; HRMS m/z Calcd for $C_{22}H_{28}O_4$ 356.1988; Found 356.1995.

1,3-Dimethoxy-5-(1-vinyldec-9-enyloxy)benzene (*S4*)
The compound was prepared using 3,5-dimethoxyphenol and 1,11-dodecadien-3-ol.[4] The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 50% of the desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 1.20-1.50 (m, 10H), 1.54-1.82 (m, 2H), 2.00-2.10 (m, 2H), 3.75 (s, 6H), 4.55 (q, *J* = 6.6 Hz, 1H), 4.91-5.03 (m, 2H), 5.18-5.28 (m, 2H), 5.76-5.86 (m, 2H), 6.05-6.10 (m, 3H); ^{13}C NMR ($CDCl_3$) δ 25.5, 29.1, 29.3, 29.4, 29.6, 34.0, 35.8, 55.5, 79.3, 93.1, 95.0, 114.4, 116.5, 138.3, 139.4, 160.5, 161.6; IR (film, cm^{-1}) 2932, 2855, 1560, 1157; HRMS m/z Calcd for $C_{20}H_{30}O_3$ 318.2195; Found 318.2209.

1,3-Dimethoxy-5-(1-methylcinnamyloxy)benzene (*S5*)
The compound was prepared using 3,5-dimethoxyphenol and (*E*)-4-phenyl-3-buten-2-ol.[5] The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 58% of the desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 1.56 (d, *J* = 6.6 Hz, 3H), 3.79 (s, 6H), 4.98 (m, 1H), 6.10-6.23 (m, 3H), 6.30 (dd, *J* = 16.5, 6.3 Hz, 1H), 6.65 (d, *J* = 16.5 Hz, 1H), 7.25-7.43 (m, 5H); ^{13}C NMR ($CDCl_3$) δ 21.7, 55.3, 74.6, 93.2, 94.9, 126.5, 127.7, 128.5, 130.6, 130.7, 136.5, 159.9, 161.5; IR (film, cm^{-1}) 2980, 2836, 1595, 1190, 1148; HRMS m/z Calcd for $C_{18}H_{20}O_3$ 284.1413; Found 284.1424.

1,3-Dimethoxy-2-methyl-5-(1-methylallyloxy)benzene (*S6*)
The compound was prepared using 3,5-dimethoxy-4-methylphenol and 3-buten-2-ol. The reaction mixture was chromatographed using 25:1 hexanes/EtOAc to afford 41% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.44 (d, *J* = 6.3 Hz, 3H), 2.01 (s, 3H), 3.78 (s, 6H), 4.78 (quintet, *J* = 6.3 Hz, 1H), 5.18 (d, *J* = 10.5 Hz, 1H), 5.29 (d, *J* = 17.4 Hz, 1H), 5.93 (m, 1H), 6.16 (s, 2H); ^{13}C NMR ($CDCl_3$) δ 7.9, 21.6, 55.9, 75.2, 93.0, 115.7, 139.8, 148.9, 157.4, 158.9; IR (film, cm^{-1}) 2922, 1560, 1459, 1143; HRMS m/z Calcd for $C_{13}H_{18}O_3$ 222.1256; Found 222.1246.

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4. R. Dickinson, E. H. Smith, N. P. Franks, W. R. Lieb, *J. Med. Chem.* **1993**, *36*, 111-118.

5. M. Schuster, W.–F. He, S. Blechert, *Tetrahedron Lett.* **2001**, *42*, 2289-2291.

5-(1-Ethylallyloxy)-1,3-dimethoxy-2-methylbenzene (*S7*)
The compound was prepared using 3,5-dimethoxy-4-methylphenol and 1-penten-3-ol. The reaction mixture was chromatographed using 25:1 hexanes/EtOAc to afford 34% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.05 (t, *J* = 7.2 Hz, 3H), 1.80 (m, 2H), 2.04 (s, 3H), 3.82 (s, 6H), 4.53 (m, 1H), 5.26 (d, *J* = 10.5 Hz, 1H), 5.32 (d, *J* = 18.9 Hz, 1H), 5.90 (m, 1H), 6.20 (s, 2H); ^{13}C NMR ($CDCl_3$) δ 7.7, 9.7, 28.6, 55.7, 80.6, 92.7, 106.8, 116.5, 138.3, 157.7, 158.6; IR (film, cm^{-1}) 2940, 1605, 1454, 1133; HRMS m/z Calcd for $C_{14}H_{20}O_3$ 236.1413; Found 236.1413.

1,2,3-Trimethoxy-5-(1-methylallyloxy)benzene (*S8*)
The compound was prepared using 3,4,5-trimethoxyphenol and 3-buten-2-ol. The reaction mixture was chromatographed using 8:1 hexanes/EtOAc to afford 51% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.40 (d, *J* = 6.3 Hz, 3H), 3.76 (s, 3H), 3.79 (s, 6H), 4.71 (quintet, *J* = 6.3 Hz, 1H), 5.16 (dt, *J* = 10.5, 1.2 Hz, 1H), 5.26 (dt, *J* = 17.1, 1.2 Hz, 1H), 5.89 (m, 1H), 6.15 (s, 2H); ^{13}C NMR ($CDCl_3$) δ 21.5, 56.2, 61.2, 75.5, 94.1, 115.8, 132.2, 139.6, 153.8, 154.8; IR (film, cm^{-1}) 2940, 1594, 1234, 1135; HRMS m/z Calcd for $C_{13}H_{18}O_4$ 238.1205; Found 238.1205.

4-(1-Ethylallyloxy)-1,2-dimethoxybenzene (*S9*)
The compound was prepared using 3,4-dimethoxyphenol and 1-penten-3-ol. The reaction mixture was chromatographed using 6:1 hexanes/EtOAc to afford 34% of the desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 1.06 (t, *J* = 7.2 Hz, 3H), 1.80 (m, 2H), 3.89 (s, 3H), 3.91 (s, 3H), 4.48 (q, *J* = 7.2 Hz, 1H), 5.25 (m, 2H), 5.90 (m, 1H), 6.48 (dd, *J* = 9.0, 3.0 Hz, 1H), 6.61 (d, *J* = 3.0 Hz, 1H), 6.80 (d, *J* = 9.0 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 9.7, 28.5, 55.8, 56.4, 81.2, 101.2, 102.3, 106.2, 111.7, 116.6, 138.2, 149.7, 153.0; IR (film, cm^{-1}) 2965, 1596, 1509, 1229; HRMS m/z Calcd for $C_{13}H_{18}O_3$ 222.1256; Found 222.1255.

5-(1-Ethylallyloxy)benzo[1,3]dioxole (*S10*)
The compound was prepared using 3,4-methylenedioxyphenol and 1-penten-3-ol. The reaction mixture was chromatographed using 25:1 hexanes/EtOAc to afford 56% of the desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 1.02 (t, *J* = 7.2 Hz, 3H), 1.77 (m, 2H), 4.40 (q, *J* = 7.2 Hz, 1H), 5.25 (m, 2H), 5.83 (m, 1H), 5.93 (s, 2H), 6.39 (dd, *J* = 8.4, 2.1 Hz, 1H), 6.54 (d, *J* = 2.1 Hz, 1H), 6.71 (d, *J* = 8.4 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 9.7, 28.5, 81.9, 99.6, 101.1, 107.9, 108.2, 116.6, 138.0, 141.6, 148.0, 153.9; IR (film, cm^{-1}) 2969, 2879, 1630, 1486, 1189; HRMS m/z Calcd for $C_{12}H_{14}O_3$ 206.0943; Found 206.0941.

1,3-Dimethoxy-5-(2-methylbut-2-enyloxy)benzene (*S11*)
The compound was prepared using 3,5-dimethoxyphenol and (*E*)-2-methyl-2-buten-1-ol.[6] The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 77% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.67 (d, *J* = 6.6 Hz, 3H), 1.73 (s, 3H), 2.17 (s, 3H), 3.76 (s, 6H), 4.34 (s, 2H), 5.63 (q, *J* = 6.6 Hz, 1H), 6.08 (t, *J* = 1.8 Hz, 1H), 6.11 (d, *J* = 1.8 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 13.3, 13.7, 55.3, 74.2, 93.0, 93.7, 123.6, 131.7, 160.9, 161.5; IR (film, cm^{-1}) 2924, 1594, 1207, 1153; HRMS m/z Calcd for $C_{13}H_{18}O_3$ 222.1256; Found 222.1248.

1-(2,3-Dimethylbut-2-enyloxy)-3,5-dimethoxybenzene (*S12*)
The compound was prepared using 3,5-dimethoxyphenol and 2,3-dimethyl-2-buten-1-ol.[7] The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 44% of the desired product as a colorless oil. Also the compound was prepared as follows: To a flame-dried vial were added 3,5-dimethoxyphenol (308 mg, 2.00 mmol), 1-bromo-2,3-dimethyl-2-butene[8] (489 mg, 3.00 mmol), Cs_2CO_3 (978 mg, 3.00 mmol) and acetone (6.00 mL). The mixture was sealed and heated at 75 °C for 10 h. The mixture was cooled, filtered, concentrated and chromatographed using 20:1 hexanes/EtOAc to afford 68% of the desired product as a colorless oil. ^{1}H NMR ($CDCl_3$) δ 1.78 (s, 3H), 1.82 (s, 6H), 3.80 (s, 6H), 4.49 (s, 2H), 6.12 (t, *J* = 2.4 Hz, 1H), 6.16 (d, *J* = 2.4 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 16.8, 20.3, 21.0,

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[7]. K. Okada, F. Kiyoka, E. Nakanishi, M. Hirano, I. Ono, N. Matsuo, M. Matsui, *Agric. Biol. Chem.* **1980**, *44*, 2595-2599.
[8]. E. L. Clennan, X. Chen, *J. Am. Chem. Soc.* **1989**, *111*, 5787-5792.

55.3, 69.3, 93.0, 93.5, 123.8, 131.3, 161.2, 161.5; IR (film, cm^{-1}) 2997, 2935, 1601, 1474, 1151; HRMS m/z Calcd for $C_{14}H_{20}O_3$ 236.1413; Found 236.1405.

1,3-Dimethoxy-5-(2-methylpent-2-enyloxy)benzene (*S13*)
The compound was prepared using 3,5-dimethoxyphenol and (*E*)-2-methyl-2-peten-1-ol.[9] The reaction mixture was chromatographed using 25:1 hexanes/EtOAc to afford 67% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.03 (d, *J* = 7.5 Hz, 3H), 1.77 (s, 3H), 2.13 (m, 2H), 3.80 (s, 6H), 4.38 (s, 2H), 5.59 (t, *J* = 6.6 Hz, 1H), 6.12 (t, *J* = 2.1 Hz, 1H), 6.15 (d, *J* = 2.1 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 13.8, 13.9, 21.0, 55.3, 74.3, 93.0, 93.7, 130.3, 131.1, 161.0, 161.5; IR (film, cm^{-1}) 2953, 1597, 1461, 1199, 1150; HRMS m/z Calcd for $C_{14}H_{20}O_3$ 236.1413; Found 236.1415.

1-(2-Cyclohexylidenepropoxy)-3,5-dimethoxybenzene (*S14*)
The compound was prepared using 3,5-dimethoxyphenol and 2-cyclohexylidene-1-propanol.[10] The reaction mixture was chromatographed using 25:1 hexanes/EtOAc to afford 66% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.60 (br s, 6H), 1.84 (s, 3H), 2.29 (m, 4H), 3.80 (s, 6H), 4.50 (s, 2H), 6.12 (t, *J* = 2.1 Hz, 1H), 6.16 (d, *J* = 2.1 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 16.4, 26.8, 27.8, 28.3, 30.5, 30.9, 55.3, 68.8, 93.0, 93.6, 120.4, 139.7, 161.2, 161.5; IR (film, cm^{-1}) 2917, 1592, 1199, 1150; HRMS m/z Calcd for $C_{17}H_{24}O_3$ 276.1726; Found 276.1717.

1-(1,2-Dimethylbut-2-enyloxy)-3,5-dimethoxybenzene (*S15*)
The compound was prepared using 3,5-dimethoxyphenol and (*E*)-3-methyl-3-penten-2-ol.[11] The reaction mixture was chromatographed using 25:1 hexanes/EtOAc to afford 43% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.43 (d, *J* = 6.6 Hz, 3H), 1.65 (m, 6H), 3.78 (s, 6H), 4.66 (q, *J* = 6.6 Hz, 1H), 5.59 (m, 1H), 6.09 (t, *J* = 2.1 Hz, 1H), 6.12 (d, *J* = 2.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 11.0, 13.1, 20.5, 55.3, 79.1, 92.8, 94.7, 121.0, 136.3, 160.1, 161.3; IR (film, cm^{-1}) 2935, 1599, 1205, 1153; HRMS m/z Calcd for $C_{14}H_{20}O_3$ 236.1413; Found 236.1418.

1-(Cyclohex-1-enylmethoxy)-3,5-dimethoxybenzene (*S16*)
The compound was prepared using 3,5-dimethoxyphenol and 1-cyclohexene-1-methanol.[12] The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 73% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.60-1.80 (m, 4H), 2.12 (m, 4H), 3.80 (s, 6H), 4.35 (s, 2H), 5.85 (br s, 1H), 6.12 (t, *J* = 2.1 Hz, 1H), 6.15 (d, *J* = 2.1 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 22.3, 22.5, 25.1, 25.9, 55.3, 72.9, 93.0, 93.7, 125.9, 133.8, 161.0, 161.5; IR (film, cm^{-1}) 2931, 2838, 1600, 1152; HRMS m/z Calcd for $C_{15}H_{20}O_3$ 248.1413; Found 248.1404.

1-(Cyclopent-1-enylmethoxy)-3,5-dimethoxybenzene (*S17*)
The compound was prepared using 3,5-dimethoxyphenol and 1-cyclopentene-1-methanol.[13] The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 67% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.98 (quintet, *J* = 7.2 Hz, 2H), 2.43 (m, 4H), 3.80 (s, 6H), 4.57 (s, 2H), 5.79 (br s, 1H), 6.12 (t, *J* = 2.1 Hz, 1H), 6.15 (d, *J* = 2.1 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 23.3, 32.5, 32.9, 55.3, 67.2, 93.0, 93.6, 128.4, 140.0, 160.9, 161.5; IR (film, cm^{-1}) 2952, 1599, 1205, 1152; HRMS m/z Calcd for $C_{14}H_{18}O_3$ 234.1256; Found 234.1246.

1,3-Dimethoxy-2-methyl-5-(2-methylbut-2-enyloxy)benzene (*S18*)
The compound was prepared using 3,5-dimethoxy-4-methylphenol and (*E*)-2-methyl-2-buten-1-ol.[6] The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 49% of the desired product as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 1.71 (d, *J* = 6.6 Hz, 3H), 1.79 (s, 3H), 2.05 (s, 3H), 3.83 (s, 6H), 4.41 (s, 2H), 5.70 (q, *J* = 6.6 Hz, 1H), 6.20 (s, 2H); ^{13}C

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NMR ($CDCl_3$) δ 7.7, 13.3, 13.7, 55.7, 74.4, 91.4, 106.7, 123.6, 132.0, 158.3, 158.7; IR (film, cm^{-1}) 2936, 1611, 1195, 1141; HRMS m/z Calcd for $C_{14}H_{20}O_3$ 236.1413; Found 236.1421.

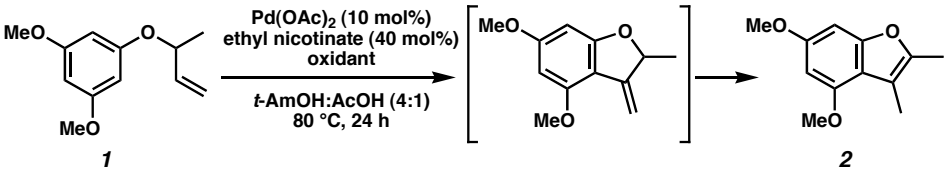
5-(2,3-Dimethylbut-2-enyloxy)-1,3-dimethoxy-2-methylbenzene (*S19*)
The compound was prepared using 3,5-dimethoxy-4-methylphenol and 2,3-dimethyl-2-buten-1-ol.[7] The reaction mixture was chromatographed using 25:1 hexanes/EtOAc to afford 52% of the desired product as a pale yellow oil: ^1H NMR ($CDCl_3$) δ 1.79 (s, 3H), 1.84 (s, 6H), 2.06 (s, 3H), 3.84 (s, 6H), 4.53 (s, 2H), 6.22 (s, 2H); ^{13}C NMR ($CDCl_3$) δ 7.7, 16.8, 20.3, 21.0, 55.7, 69.3, 91.3, 106.6, 124.0, 131.1, 158.6, 158.7; IR (film, cm^{-1}) 2935, 1611, 1459, 1195, 1142; HRMS m/z Calcd for $C_{15}H_{22}O_3$ 250.1569; Found 250.1571.

1,2,3-Trimethoxy-5-(2-methyl-but-2-enyloxy)benzene (*S20*)
The compound was prepared using 3,4,5-trimethoxyphenol and (*E*)-2-methyl-2-buten-1-ol.[6] The reaction mixture was chromatographed using 7:1 hexanes/EtOAc to afford 57% of the desired product as a colorless oil: ^1H NMR ($CDCl_3$) δ 1.67 (d, J = 6.6 Hz, 3H), 1.74 (s, 3H), 2.16 (s, 3H), 3.78 (s, 3H), 3.83 (s, 6H), 4.34 (s, 2H), 5.64 (q, J = 6.6 Hz, 1H), 6.17 (s, 2H); ^{13}C NMR ($CDCl_3$) δ 13.3, 13.7, 56.1, 61.0, 74.6, 92.5, 123.8, 131.8, 132.3, 153.6, 155.7; IR (film, cm^{-1}) 2938, 1593, 1506, 1225, 1130; HRMS m/z Calcd for $C_{14}H_{20}O_4$ 252.1362; Found 252.1352.

5-(2,3-Dimethyl-but-2-enyloxy)-1,2,3-trimethoxybenzene (*S21*)
To a flame-dried vial were added 3,4,5-trimethoxyphenol (368 mg, 2.00 mmol), 1-bromo-2,3-dimethyl-2-butene (489 mg, 3.00 mmol), Cs_2CO_3 (978 mg, 3.00 mmol) and acetone (6.00 mL). The mixture was sealed and heated at 75 °C for 10 h. The mixture was cooled, filtered, concentrated and chromatographed using 5:1 hexanes/EtOAc to afford 65% of the desired product as a white solid: mp 60-61 °C; ^1H NMR ($CDCl_3$) δ 1.79 (s, 3H), 1.83 (s, 6H), 3.82 (s, 3H), 3.87 (s, 6H), 4.50 (s, 2H), 6.22 (s, 2H); ^{13}C NMR ($CDCl_3$) δ 16.8, 20.3, 21.0, 56.1, 61.1, 69.5, 92.4, 123.8, 131.3, 132.2, 153.7, 155.9; IR (film, cm^{-1}) 2936, 1593, 1505, 1226, 1129; HRMS m/z Calcd for $C_{15}H_{22}O_4$ 266.1518; Found 266.1518.

1,3-Dimethoxy-5-(4-benzyloxymethyl-3-methylcyclohex-1-enylmethoxy)benzene (*3*)
The compound was prepared using 3,5-dimethoxyphenol and *trans*-(4-benzyloxymethyl-3-methylcyclohex-1-enyl)methanol. The reaction mixture was chromatographed using 12:1 hexanes/EtOAc to afford 63% of the desired product as a colorless oil: ^1H NMR ($CDCl_3$) δ 1.07 (d, J = 6.9 Hz, 3H), 1.56 (m, 2H), 1.95-2.15 (m, 4H), 3.40 (m, 1H), 3.58 (m, 1H), 3.80 (s, 6H), 4.37 (s, 2H), 4.55 (m, 2H), 5.63 (br s, 1H), 6.12 (t, J = 2.1 Hz, 1H), 6.14 (d, J = 2.1 Hz, 2H), 7.37 (m, 5H); ^{13}C NMR ($CDCl_3$) δ 15.3, 20.3, 24.9, 32.2, 40.9, 55.3, 72.5, 73.1, 73.3, 93.1, 93.7, 127.49, 127.53, 128.4, 131.2, 132.8, 138.8, 161.0, 161.4; IR (film, cm^{-1}) 2927, 2870, 1600, 1153; HRMS m/z Calcd for $C_{24}H_{30}O_4$ 382.2144; Found 382.2146.

Table 1. Oxidant Screen.[a]

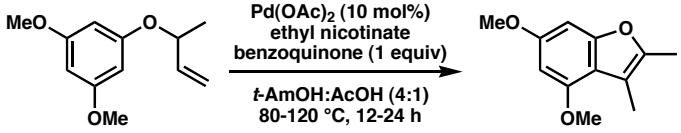


1 *2*

entry	oxidant (1 equiv)	% yield[b]	entry	oxidant (1 equiv)	% yield[b]
1	O_2 (1 atm)	56	5	$Tl(O_2CCF_3)_3$	<10
2	benzoquinone	62	6	$K_2S_2O_8$	30
3	$Cu(OAc)_2$	31	7	$H_2NC(S)NH_2$	<10
4	$Ag(OAc)_2$	29	8	$PhCO_3$-*t*-Bu	42

[a] All reactions were carried out using 0.10 mmol of **1**, 10 mol% $Pd(OAc)_2$ (0.01 mmol), 40 mol% ethyl nicotinate (0.04 mmol), 0.10 mmol or 1 atm oxidant, in 1.0 mL 4:1 *t*-AmOH:AcOH (0.1 M in substrate). [b] GC yield.

Table 2. Optimization Studies.[a]



1 *2*

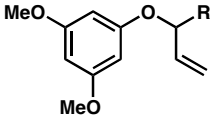
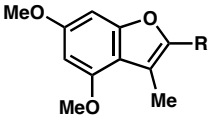
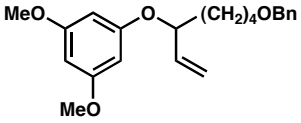
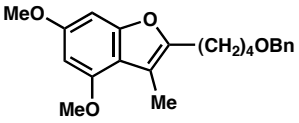
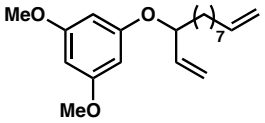
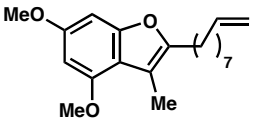
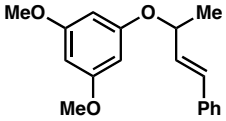
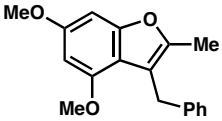
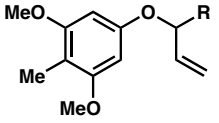
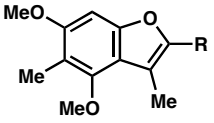
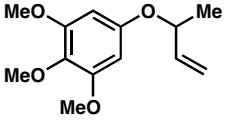
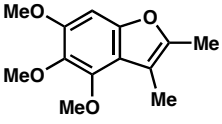
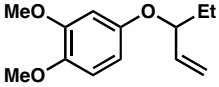
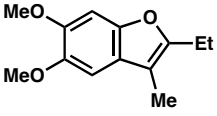
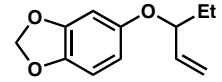
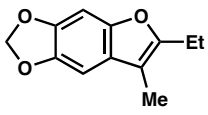
entry	ethyl nicotinate	additive	temp (°C)	time (h)	% yield[b]
1	40 mol%	–	80	24	62
2	20 mol%	–	80	24	66
3	10 mol%	–	80	24	59
4	0 mol%	–	80	24	55
5	20 mol%	NaOAc (1 equiv)	80	24	70
6	20 mol%	NaOAc (20 mol %)	80	24	74
7	20 mol%	NaOAc (20 mol %)	100	12	80 (77)[c]
8	20 mol%	NaOAc (20 mol %)	120	12	67

[a] All reactions were carried out using 0.10 mmol of **1**, 10 mol% $Pd(OAc)_2$ (0.01 mmol), 0-40 mol% ethyl nicotinate (0-0.04 mmol), 0-0.10 mmol NaOAc, 0.10 mmol benzoquinone, in 1.0 mL 4:1 *t*-AmOH:AcOH (0.1 M in substrate). [b] GC yield. [c] Isolated yield in parentheses.

Representative procedure for the optimization (Tables 1 and 2): A flame-dried 1-dram vial equipped with a magnetic stir bar was charged with $Pd(OAc)_2$ (2.3 mg, 10 mol %), followed by ethyl nicotinate (2.8 μL, 20 mol %), tridecane (12.0 μL, 0.049 mmol, internal standard), 1,3-dimethoxy-5-(1-methylallyloxy)benzene (20.8 mg, 0.10 mmol), NaOAc (1.7 mg, 20 mol %) and a mixture of *t*-amyl alcohol and acetic acid (1.0 mL, 4:1 v/v). The resulting mixture was stirred at 23 °C for 2 min and benzoquinone (10.8 mg, 0.10 mmol) was added. The

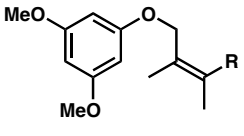
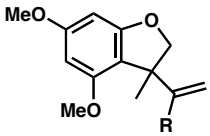
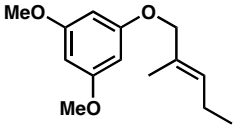
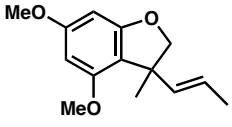
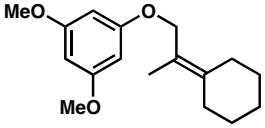
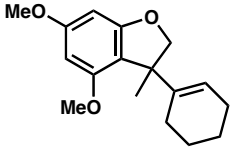
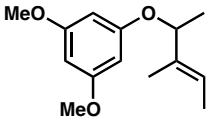
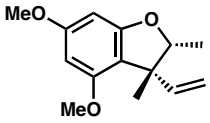
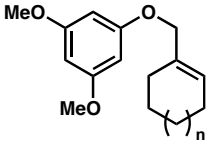
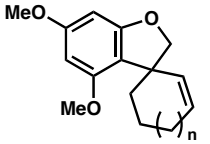
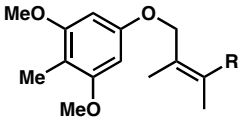
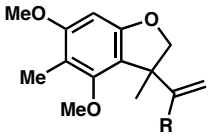
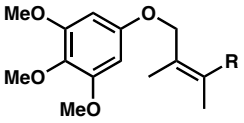
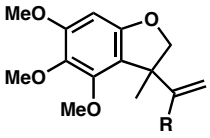
reaction mixture was heated at 100 °C for 12 h. The reaction mixture was then cooled, filtered through a short plug of silica gel (Et_2O as eluent) and analyzed by GC.

Table 3. Oxidative benzofuran synthesis.[a]

entry	substrate	product		time (h)	% yield[b]
1			R = Me	12	77
2			R = Et	12	74
3			R = *n*-C_5H_{11}	13	72
4				12	62
5				14	54
6				12	61
7			R = Me	14	75
8			R = Et	12	79
9				12	61
10				16	56
11				16	52

[a] All reactions were carried out using 0.50 mmol of substrate, 10 mol% $Pd(OAc)_2$ (0.05 mmol), 20 mol% ethyl nicotinate (0.10 mmol), 0.10 mmol NaOAc, 0.50 mmol benzoquinone, in 5.0 mL 4:1 *t*-AmOH:AcOH (0.1 M in substrate) at 100 °C. [b] Isolated yield.

Table 4. Oxidative dihydrobenzofuran synthesis.[a]

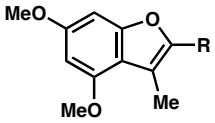
entry	substrate	product		time (h)	% yield
1			R = H	16	74
2			R = Me	12	71
3				30	58[b]
4				28	55
5				15	74[c]
6			n = 1	24	80
7			n = 0	18	78
8			R = H	15	50
9			R = Me	15	63
10			R = H	15	60
11			R = Me	15	66

[a] All reactions were carried out using 0.50 mmol of substrate, 10 mol% $Pd(OAc)_2$ (0.05 mmol), 20 mol% ethyl nicotinate (0.10 mmol), 0.10 mmol NaOAc, 0.50 mmol benzoquinone, in 5.0 mL 4:1 *t*-AmOH:AcOH (0.1 M in substrate) at 100 °C. [b] An inseperable mixture of ca. 66% product (*E*/*Z* = 3:1) and 10% starting material was isolated after 18 h. This mixture was subjected to another reaction with 5 mol% $Pd(OAc)_2$, 10 mol% ethyl nicotinate, 20 mol% NaOAc and 50 mol% benzoquinone in 4:1 *t*-AmOH:AcOH (0.1 M) for 12 h after which only *E*-isomer was observed. The yield presented is the overall isolated yield. [c] A 2.3:1 diastereomeric mixture was isolated with the major isomer shown.

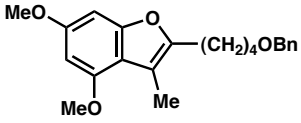
Representative procedure for the Pd-catalyzed synthesis of benzofurans and dihydrobenzofurans (Tables 3 and 4): A flame-dried 2-dram vial equipped with a magnetic stir bar was charged with $Pd(OAc)_2$ (11.3 mg, 10 mol %), followed by ethyl nicotinate (13.8 μL, 20 mol %), 1,3-dimethoxy-5-(1-methylallyloxy)benzene (104.1 mg, 0.500 mmol), NaOAc (8.2 mg, 20 mol %) and a mixture of *t*-amyl alcohol and acetic acid (5.00 mL, 4:1 v/v). The resulting mixture was stirred at 23 °C for 2 min and benzoquinone (54.1 mg, 0.500 mmol) was added. The reaction mixture was heated at 100 °C for 12 h. The reaction mixture

was then cooled, filtered through a short plug of silica gel (0.6 × 5 cm, Et_2O as eluent), evaporated and purified by flash chromatography on a silica gel column.

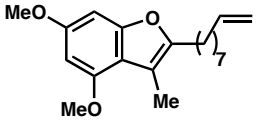
Benzofurans and Dihydrobenzourans Prepared



R = Me, *2*
R = Et, *P1*
R = *n*-C_5H_{11}, *P2*



P3



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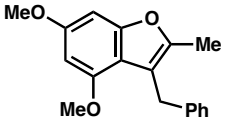
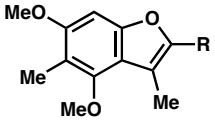
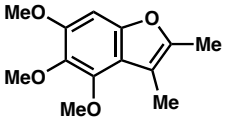


P5



R = Me, *P6*
R = Et, *P7*



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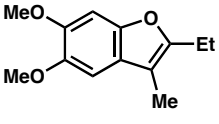

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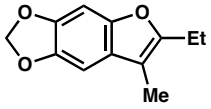
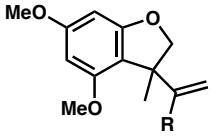


P10



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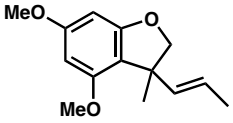

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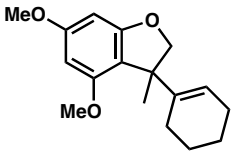
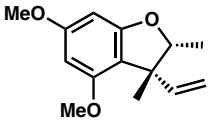
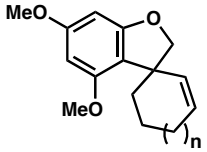


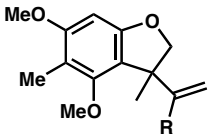
P14



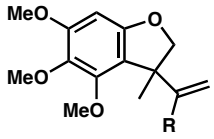
P15



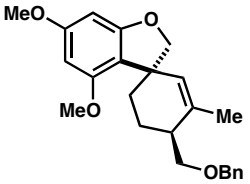
n = 1, *P16*
n = 0, *P17*



R = H, *P18*
R = Me, *P19*



R = H, *P20*
R = Me, *P21*



5

(Table 3, entry 1) 4,6-Dimethoxy-2,3-dimethylbenzofuran (*2*)
The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 79 mg (77%) desired product as a white sold: mp 53-54 °C; ^{1}H NMR ($CDCl_3$) δ 2.27 (s, 3H), 2.33 (s, 3H), 3.86 (s, 3H), 3.89 (s, 3H), 6.29 (d, *J* = 2.1 Hz, 1H), 6.57 (d, *J* = 2.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 9.8, 11.4, 55.4, 55.7, 88.0, 93.5, 109.5, 113.2, 147.6, 154.4, 155.5, 158.0; IR (film, cm^{-1}) 2917, 1602, 1427, 1108; HRMS m/z Calcd for $C_{12}H_{14}O_3$ 206.0943; Found 206.0939.

(Table 3, entry 2) 4,6-Dimethoxy-2-ethyl-3-methylbenzofuran (*P1*)
The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 81 mg (74%) desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 1.29 (t, *J* = 7.5 Hz, 3H), 2.29 (s, 3H), 2.71 (q, *J* = 7.5 Hz, 2H), 3.86 (s, 3H), 3.89 (s, 3H), 6.30 (d, *J* = 2.1 Hz, 1H), 6.60 (d, *J* = 2.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 9.6, 13.0, 19.3, 55.4, 55.7, 88.0, 93.5, 108.6, 113.2, 152.8, 154.5, 155.5, 158.1; IR (film, cm^{-1}) 2969, 1603, 1501, 1208, 1149; HRMS m/z Calcd for $C_{13}H_{16}O_3$ 220.1100; Found 220.1110.

(Table 3, entry 3) 4,6-Dimethoxy-2-*n*-pentyl-3-methylbenzofuran (*P2*)
The reaction mixture was chromatographed using 25:1 hexanes/EtOAc to afford 95 mg (72%) desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 0.90 (t, *J* = 7.2 Hz, 3H), 1.31 (m, 4H), 1.66 (quintet, *J* = 7.2 Hz, 2H), 2.25 (s, 3H), 2.63 (t, *J* = 7.2 Hz, 2H), 3.82 (s, 3H), 3.85 (s, 3H), 6.26 (d, *J* = 2.1 Hz, 1H), 6.55 (d, *J* = 2.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 9.9, 14.2,

22.7, 26.0, 28.4, 31.5, 55.6, 55.9, 88.2, 93.7, 109.5, 113.4, 152.0, 154.7, 155.8, 158.2; IR (film, cm^{-1}) 2930, 1603, 1501, 1148, 1113; HRMS m/z Calcd for $C_{16}H_{22}O_3$ 262.1569; Found 262.1570.

(Table 3, entry 4) 2-(4-Benzyloxybutyl)-4,6-dimethoxy-3-methylbenzofuran (*P3*)
The reaction was carried out in 0.40 mmol scale and chromatographed using 10:1 hexanes/EtOAc to afford 88 mg (62%) desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 1.64-1.84 (m, 4H), 2.30 (s, 3H), 2.73 (t, *J* = 6.6 Hz, 2H), 3.54 (t, *J* = 6.6 Hz, 3H), 3.87 (s, 3H), 3.90 (s, 3H), 4.55 (s, 2H), 6.32 (d, *J* = 1.8 Hz, 1H), 6.60 (d, *J* = 1.8 Hz, 1H), 7.39 (m, 5H); ^{13}C NMR ($CDCl_3$) δ 9.8, 25.2, 25.6, 29.2, 55.4, 55.7, 70.1, 73.0, 88.0, 93.6, 109.6, 113.2, 127.5, 127.7, 128.4, 138.7, 151.3, 154.5, 155.6, 158.1; IR (film, cm^{-1}) 2939, 2860, 1602, 1500, 1202; HRMS m/z Calcd for $C_{22}H_{26}O_4$ 354.1831; Found 354.1824.

(Table 3, entry 5) 4,6-Dimethoxy-3-methyl-2-non-8-enylbenzofuran (*P4*)
The reaction mixture was chromatographed using 2:1 hexanes/$CHCl_3$ to afford 86 mg (54%) desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 1.32 (m, 8H), 1.65 (m, 2H), 2.04 (m, 2H), 2.24 (s, 3H), 2.63 (t, *J* = 7.2 Hz, 2H), 3.82 (s, 3H), 3.85 (s, 3H), 4.91-5.02 (m, 2H), 5.81 (m, 1H), 6.26 (d, *J* = 2.1 Hz, 1H), 6.55 (d, *J* = 2.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 10.0, 26.1, 28.6, 29.1, 29.3, 29.5, 34.0, 55.6, 55.9, 88.2, 93.7, 109.5, 113.4, 114.4, 139.4, 151.9, 154.7, 155.8, 158.2; IR (film, cm^{-1}) 2927, 2854, 1602, 1148; HRMS m/z Calcd for $C_{20}H_{28}O_3$ 316.2039; Found 316.2040.

(Table 3, entry 6) 3-Benzyl-4,6-dimethoxy-2-methylbenzofuran (*P5*)
The reaction mixture was chromatographed using 3:1 hexanes/$CHCl_3$ to afford 86 mg (61%) desired product as a white solid: mp 72-73 °C; ^{1}H NMR ($CDCl_3$) δ 2.38 (s, 3H), 3.79 (s, 3H), 3.85 (s, 3H), 4.09 (s, 2H), 6.28 (d, *J* = 2.1 Hz, 1H), 6.60 (d, *J* = 2.1 Hz, 1H), 7.15-7.30 (m, 5H); ^{13}C NMR ($CDCl_3$) δ 11.9, 30.2, 55.2, 55.7, 88.0, 93.8, 112.6, 113.0, 125.7, 128.2, 128.3, 141.6, 148.9, 154.1, 155.7, 158.2; IR (film, cm^{-1}) 2917, 1603, 1501, 1217, 1148; HRMS m/z Calcd for $C_{18}H_{18}O_3$ 282.1256; Found 282.1252.

(Table 3, entry 7) 4,6-Dimethoxy-2,3,5-trimethylbenzofuran (*P6*)
The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 83 mg (75%) desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 2.25 (s, 3H), 2.32 (s, 3H), 2.36 (s, 3H), 3.85 (s, 3H), 3.88 (s, 3H), 6.77 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 8.6, 9.3, 11.5, 55.9, 62.0, 90.4, 108.4, 113.9, 116.2, 148.3, 151.7, 153.7, 155.9; IR (film, cm^{-1}) 2942, 1593, 1223, 1149; HRMS m/z Calcd for $C_{13}H_{16}O_3$ 220.1100; Found 220.1107.

(Table 3, entry 8) 2-Ethyl-4,6-dimethoxy-3,5-dimethylbenzofuran (*P7*)
The reaction mixture was chromatographed using 4:1 hexanes/$CHCl_3$ to afford 93 mg (79%) desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 1.30 (t, *J* = 7.5 Hz, 3H), 2.24 (s, 3H), 2.32 (s, 3H), 2.72 (q, *J* = 7.5 Hz, 2H), 3.84 (s, 3H), 3.88 (s, 3H), 6.78 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 8.6, 9.2, 12.9, 19.4, 55.9, 62.0, 90.5, 107.5, 113.9, 116.3, 151.9, 153.5, 153.7, 155.9; IR (film, cm^{-1}) 2938, 1594, 1461, 1149; HRMS m/z Calcd for $C_{14}H_{18}O_3$ 234.1256; Found 234.1248.

(Table 3, entry 9) 4,5,6-Trimethoxy-2,3-dimethylbenzofuran (*P8*)
The reaction mixture was chromatographed using 10:1 hexanes/EtOAc to afford 72 mg (61%) desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 2.23 (s, 3H), 2.29 (s, 3H), 3.86 (s, 6H), 3.96 (s, 3H), 6.72 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 9.3, 11.5, 56.3, 61.3, 61.8, 91.1, 109.3, 116.5, 138.2, 146.5, 148.8, 150.5, 151.1; IR (film, cm^{-1}) 2937, 1620, 1468, 1199; HRMS m/z Calcd for $C_{13}H_{16}O_4$ 236.1049; Found 236.1051.

(Table 3, entry 10) 2-Ethyl-5,6-dimethoxy-3-methylbenzofuran (*P9*)
The reaction mixture was chromatographed using 2:3 hexanes/$CHCl_3$ to afford 62 mg (56%) desired product as a pale yellow oil: ^{1}H NMR ($CDCl_3$) δ 1.30 (t, *J* = 7.5 Hz, 3H), 2.16 (s, 3H), 2.74 (q, *J* = 7.5 Hz, 2H), 3.94 (s, 6H), 3.96 (s, 3H), 6.89 (s, 1H), 7.02 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 7.9, 12.9, 19.8, 56.3, 56.5, 95.3, 100.7, 108.7, 122.3, 146.0, 147.0, 148.1, 154.6;

IR (film, cm^{-1}) 2938, 1621, 1489, 1212, 1146; HRMS m/z Calcd for $C_{13}H_{16}O_3$ 220.1100; Found 220.1103.

(Table 3, entry 11) 6-Ethyl-7-methyl-1,3,5-trioxa-s-indacene (*P10*)
The reaction mixture was chromatographed using 5:1 hexanes/$CHCl_3$ to afford 53 mg (52%) desired product as a pale yellow oil: ^1H NMR ($CDCl_3$) δ 1.30 (t, *J* = 7.5 Hz, 3H), 2.13 (s, 3H), 2.73 (q, *J* = 7.5 Hz, 2H), 5.98 (s, 3H), 6.83 (s, 1H), 6.94 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 7.9, 12.9, 19.8, 93.2, 97.6, 101.0, 109.0, 123.8, 143.8, 145.0, 148.6, 155.0; IR (film, cm^{-1}) 2973, 1463, 1292, 1170; HRMS m/z Calcd for $C_{12}H_{12}O_3$ 204.0787; Found 204.0795.

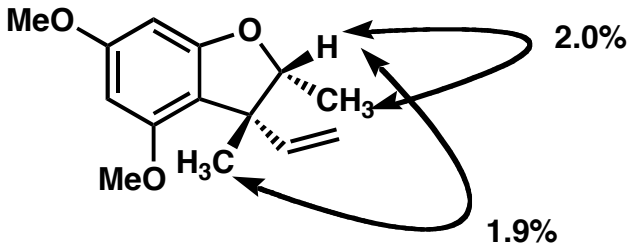
(Table 4, entry 1) 4,6-Dimethoxy-3-methyl-3-vinyl-2,3-dihydrobenzofuran (*P11*)
The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 81 mg (74%) desired product as a colorless oil: ^1H NMR ($CDCl_3$) δ 1.53 (s, 3H), 3.80 (s, 6H), 4.22 (d, *J* = 9.0 Hz, 1H), 4.44 (d, *J* = 9.0 Hz, 1H), 4.98-5.09 (m, 2H), 6.05-6.17 (m, 3H); ^{13}C NMR ($CDCl_3$) δ 23.2, 48.1, 55.3, 55.5, 83.6, 88.6, 91.7, 112.1, 142.9, 157.4, 161.6, 161.9 (one sp^2 carbon is missing); IR (film, cm^{-1}) 2961, 1601, 1500, 1151, 1098; HRMS m/z Calcd for $C_{13}H_{16}O_3$ 220.1100; Found 220.1098.

(Table 4, entry 2) 3-Isopropenyl-4,6-dimethoxy-3-methyl-2,3-dihydrobenzofuran (*P12*)
The reaction mixture was chromatographed using 20:1 hexanes/EtOAc and further purified by preparative HPLC to afford 83 mg (71%) desired product as a colorless oil: ^1H NMR ($CDCl_3$) δ 1.58 (s, 3H), 1.74 (s, 3H), 3.78 (s, 3H), 3.80 (s, 3H), 4.18 (d, *J* = 8.7 Hz, 1H), 4.43 (d, *J* = 8.7 Hz, 1H), 4.81 (s, 1H), 4.88 (s, 1H), 6.04 (d, *J* = 2.1 Hz, 1H), 6.08 (d, *J* = 2.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 20.2, 23.4, 50.6, 55.3, 55.5, 83.6, 88.4, 91.5, 110.3, 112.5, 148.2, 157.3, 161.8, 161.9; IR (film, cm^{-1}) 2964, 1601, 1500, 1201, 1151; HRMS m/z Calcd for $C_{14}H_{18}O_3$ 234.1256; Found 234.1267.

(Table 4, entry 3) 4,6-Dimethoxy-3-methyl-3-propenyl-2,3-dihydrobenzofuran (*P13*)
The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 68 mg (58%) desired product as a pale yellow oil: ^1H NMR ($CDCl_3$) δ 1.47 (s, 3H), 1.67 (dd, *J* = 6.3, 1.5 Hz, 3H), 3.76 (s, 6H), 4.16 (d, *J* = 8.4 Hz, 1H), 4.37 (d, *J* = 8.4 Hz, 1H), 5.36 (dq, *J* = 15.3, 6.3 Hz, 1H), 5.69 (dq, *J* = 15.3, 1.8 Hz, 1H), 6.02 (d, *J* = 2.1 Hz, 1H), 6.05 (d, *J* = 2.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 18.2, 24.1, 47.6, 55.5, 55.7, 84.4, 88.8, 91.9, 113.0, 123.0, 136.1, 157.6, 161.7, 161.9; IR (film, cm^{-1}) 2960, 1604, 1499, 1150, 1095; HRMS m/z Calcd for $C_{14}H_{18}O_3$ 234.1256; Found 234.1245.

(Table 4, entry 4) 3-Cyclohex-1-enyl-4,6-dimethoxy-3-methyl-2,3-dihydrobenzofuran (*P14*)
The reaction mixture was chromatographed using 30:1 hexanes/EtOAc and further purified by preparative HPLC to afford 60 mg (55%) desired product as a colorless oil. ^1H NMR ($CDCl_3$) δ 1.52 (s, 3H), 1.55-2.08 (m, 8H), 3.78 (s, 3H), 3.80 (s, 3H), 4.14 (d, *J* = 8.7 Hz, 1H), 4.38 (d, *J* = 8.7 Hz, 1H), 5.48 (m, 1H), 6.04 (d, *J* = 2.1 Hz, 1H), 6.08 (d, *J* = 2.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 22.4, 23.1, 23.3, 25.5, 25.6, 50.6, 55.3, 55.5, 83.8, 88.4, 91.5, 112.9, 120.6, 139.8, 157.3, 161.6, 161.9; IR (film, cm^{-1}) 2931, 1622, 1150, 1097; HRMS m/z Calcd for $C_{17}H_{22}O_3$ 274.1569; Found 274.1580.

(Table 4, entry 5) 4,6-Dimethoxy-2,3-dimethyl-3-vinyl-2,3-dihydrobenzofuran (*P15*)
The reaction mixture was chromatographed using 20:1 hexanes/EtOAc to afford 81 mg (74%) desired products in a 2.3 :1 ratio as a pale yellow oil. ^1H NMR ($CDCl_3$) δ major isomer 1.34 (d, *J* = 6.6 Hz, 3H), 1.52 (s, 3H), 3.78 (s, 3H), 3.80 (s, 3H), 4.42 (q, *J* = 6.6 Hz, 1H), 5.12 (m, 2H), 5.80 (dd, *J* = 17.4, 10.5 Hz, 1H), 6.07 (m, 3H); minor isomer 1.27 (s, 3H), 1.36 (d, *J* = 6.6 Hz, 3H), 4.55 (q, *J* = 6.6 Hz, 1H), 4.80 (dd, *J* = 17.4, 1.5 Hz, 2H) other peaks are overlapped with those of the major isomer; ^{13}C NMR ($CDCl_3$) δ 14.0, 14.9, 17.5, 22.1, 49.9, 50.2, 55.30, 55.33, 55.5, 87.6, 88.50, 88.53, 88.6, 90.1, 91.66, 91.73, 112.3, 112.7, 114.2, 139.5, 143.2, 157.0, 157.7, 160.5, 161.0, 161.6, 161.7 (one carbon missing due to overlap); IR (film, cm^{-1}) 2970, 1606, 1500, 1148; HRMS m/z Calcd for $C_{14}H_{18}O_3$ 234.1256; Found 234.1258. The structure of the major isomer was determined by nOe experiment.



(Table 4, entry 6) 4,6-Dimethoxy spiro[3,1']-2,3-dihydrobenzofuran-2'-cyclohexene (*P16*)
The reaction mixture was chromatographed using 20:1 hexanes/EtOAc and recrystallized from hexanes to afford 99 mg (80%) desired product as a white solid: mp 80-81 °C; ^{1}H NMR ($CDCl_3$) δ 1.59 (m, 1H), 1.83 (m, 2H), 2.00-2.20 (m, 3H), 3.79 (s, 3H), 3.80 (s, 3H), 4.21 (d, *J* = 8.7 Hz, 1H), 4.36 (d, *J* = 8.7 Hz, 1H), 5.70 (m, 1H), 5.85 (m, 1H), 6.05 (d, *J* = 2.1 Hz, 1H), 6.08 (d, *J* = 2.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 20.1, 24.4, 32.5, 46.5, 55.4, 55.5, 82.6, 88.5, 91.7, 113.5, 127.7, 131.2, 157.4, 161.7, 161.9; IR (film, cm^{-1}) 2934, 1603, 1200, 1146; HRMS m/z Calcd for $C_{15}H_{18}O_3$ 246.1256; Found 246.1252.

(Table 4, entry 7) 4,6-Dimethoxy spiro[3,1']-2,3-dihydrobenzofuran-2'-cyclopentene (*P17*)
The reaction mixture was chromatographed using 20:1 hexanes/EtOAc and recrystallized from hexanes to afford 91 mg (78%) desired product as a white solid: mp 49-50 °C; ^{1}H NMR ($CDCl_3$) δ 1.96 (m, 1H), 2.35-2.50 (m, 2H), 2.55-2.65 (m, 1H), 3.78 (s, 3H), 3.80 (s, 3H), 4.35 (s, 2H), 5.67 (m, 1H), 5.83 (m, 1H), 6.07 (d, *J* = 2.1 Hz, 1H), 6. 09 (d, *J* = 2.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 32.0, 36.0, 45.0, 55.4, 55.6, 83.2, 88.4, 91.7, 112.3, 130.9, 134.4, 157.4, 161.7, 161.8; IR (film, cm^{-1}) 2938, 1602, 1145, 1095; HRMS m/z Calcd for $C_{14}H_{16}O_3$ 232.1100; Found 232.1091.

(Table 4, entry 8) 4,6-Dimethoxy-3,5-dimethyl-3-vinyl-2,3-dihydrobenzofuran (*P18*)
The reaction mixture was chromatographed using 40:1 hexanes/EtOAc to afford 59 mg (50%) desired product as a pale yellow oil. ^{1}H NMR ($CDCl_3$) δ 1.58 (s, 3H), 2.09 (s, 3H), 3.75 (s, 3H), 3.82 (s, 3H), 4.19 (d, *J* = 8.4 Hz, 1H), 4.38 (d, *J* = 8.4 Hz, 1H), 5.09 (d, *J* = 16.8 Hz, 1H), 5.13 (d, *J* = 10.5 Hz, 1H), 6.15 (dd, *J* = 16.8, 10.5 Hz, 1H), 6.27 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 8.8, 23.0, 48.4, 55.8, 61.3, 83.5, 90.3, 111.7, 112.4, 117.2, 143.5, 156.1, 159.1, 159.4; IR (film, cm^{-1}) 2939, 1614, 1471, 1134, 1072; HRMS m/z Calcd for $C_{14}H_{18}O_3$ 234.1256; Found 234.1250.

(Table 4, entry 9) 3-Isopropenyl-4,6-dimethoxy-3,5-dimethyl-2,3-dihydrobenzofuran (*P19*)
The reaction mixture was chromatographed using 1:1 hexanes/$CHCl_3$ to afford 78 mg (63%) desired product as a pale yellow oil. ^{1}H NMR ($CDCl_3$) δ 1.65 (s, 3H), 1.75 (s, 3H), 2.09 (s, 3H), 3.72 (s, 3H), 3.82 (s, 3H), 4.16 (d, *J* = 8.4 Hz, 1H), 4.43 (d, *J* = 8.4 Hz, 1H), 4.88 (s, 1H), 4.92 (s, 1H), 6.25 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 8.8, 20.0, 23.8, 50.8, 55.7, 60.7, 83.3, 90.0, 110.5, 111.5, 117.2, 148.9, 155.9, 159.4 (one sp^2 carbon missing due to overlap); IR (film, cm^{-1}) 2940, 1614, 1471, 1130; HRMS m/z Calcd for $C_{15}H_{20}O_3$ 248.1413; Found 248.1416.

(Table 4, entry 10) 4,5,6-Trimethoxy-3-methyl-3-vinyl-2,3-dihydrobenzofuran (*P20*)
The reaction mixture was chromatographed using 8:1 hexanes/EtOAc to afford 72 mg (60%) desired product as a pale yellow oil. ^{1}H NMR ($CDCl_3$) δ 1.56 (s, 3H), 3.82 (s, 3H), 3.85 (s, 3H), 3.93 (s, 3H), 4.19 (d, *J* = 8.4 Hz, 1H), 4.39 (d, *J* = 8.4 Hz, 1H), 5.05 (dd, *J* = 17.4, 0.9 Hz, 1H), 5.12 (dd, *J* = 10.5, 0.9 Hz, 1H), 6.13 (dd, *J* = 17.4, 10.5 Hz, 1H), 6.25 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 23.4, 48.8, 56.1, 60.9, 61.0, 83.5, 90.6, 112.4, 116.9, 136.2, 143.1, 150.7, 154.3, 155.9; IR (film, cm^{-1}) 2937, 1614, 1472, 1197, 1105; HRMS m/z Calcd for $C_{14}H_{18}O_4$ 250.1205; Found 250.1207.

(Table 4, entry 11) 3-Isopropenyl-4,5,6-trimethoxy-3-methyl-2,3-dihydrobenzofuran (*P21*)

The reaction mixture was chromatographed using 8:1 hexanes/EtOAc to afford 87 mg (66%) desired product as a pale yellow oil. ^{1}H NMR ($CDCl_3$) δ 1.57 (s, 3H), 1.70 (s, 3H), 3.76 (s, 3H), 3.81 (s, 3H), 3.86 (s, 3H), 4.11 (d, *J* = 8.4 Hz, 1H), 4.37 (d, *J* = 8.4 Hz, 1H), 4.78 (s, 1H), 4.86 (s, 1H), 6.19 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 20.4, 24.1, 51.6, 56.4, 60.9, 61.2, 83.5, 90.5, 110.7, 117.1, 136.1, 148.5, 150.6, 154.3, 156.2; IR (film, cm^{-1}) 2939, 1614, 1472, 1199, 1103; HRMS m/z Calcd for $C_{15}H_{20}O_4$ 264.1362; Found 264.1364.

4,6-Dimethoxy-4'-benzyloxymethyl-3'-methyl spiro[3,1']-2,3-dihydrobenzofuran-2'-cyclohexene (*5*)

The reaction was carried out in a 0.34 mmol scale and chromatographed using 12:1 hexanes/EtOAc and recrystallized from hexanes/EtOAc (to remove small amount of starting material) to afford 78 mg (60%) desired product as a white solid: mp 99-100 °C; ^{1}H NMR ($CDCl_3$) δ 1.60 (m, 2H), 1.78 (s, 3H), 2.09 (m, 2H), 2.35 (m, 1H), 3.58 (m, 2H), 3.64 (s, 3H), 3.79 (s, 3H), 4.17 (d, *J* = 8.4 Hz, 1H), 4.32 (d, *J* = 8.4 Hz, 1H), 4.54 (d, *J* = 12.0 Hz, 1H), 4.65 (d, *J* = 12.0 Hz, 1H), 5.43 (s, 1H), 5.99 (d, *J* = 2.1 Hz, 1H), 6.06 (d, *J* = 2.1 Hz, 1H), 7.38 (m, 5H); ^{1}H NMR (C_6D_6) δ 1.45 (m, 1H), 1.60-1.68 (m, 4H), 2.06-2.16 (m, 1H), 2.22-2.34 (m, 2H), 3.19 (s, 3H), 3.31 (s, 3H), 3.60 (m, 2H), 4.14 (dd, *J* = 9.0, 1.2, 1H), 4.23 (d, *J* = 9.0 Hz, 1H), 4.36 (d, *J* = 12.0 Hz, 1H), 4.45 (d, *J* = 12.0 Hz, 1H), 5.45 (q, *J* = 1.2 Hz, 1H), 6.60 (d, *J* = 2.1 Hz, 1H), 6.26 (d, *J* = 2.1 Hz, 1H), 7.04-7.20 (m, 3H), 7.30-7.34 (m, 2H); ^{13}C NMR ($CDCl_3$) δ 22.5, 23.0, 27.7, 38.6, 46.8, 55.2, 55.5, 70.4, 73.0, 83.1, 88.5, 91.7, 113.5, 127.5, 127.6, 128.1, 128.4, 134.4, 138.7, 157.2, 161.7, 161.8; IR (film, cm^{-1}) 2937, 1605, 1499, 1147, 1098; HRMS m/z Calcd for $C_{24}H_{28}O_4$ 380.1988; Found 380.1981. The structure was determined by nOe experiment in C_6D_6.