Remarkable Phosphine-Effect on the Intramolecular Aldol Reactions of Unsaturated 1,5-Diketones: Highly Regioselective Synthesis of Cross-Conjugated Dienones

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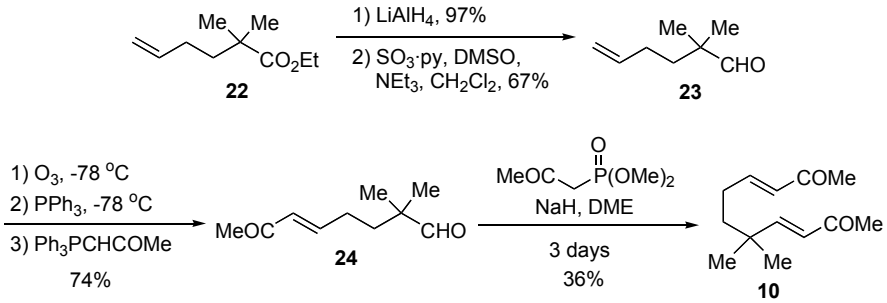
Supporting Information—Experimental Procedures

General Experimental

Unless otherwise noted, all reagents were obtained from commercial suppliers and were used without further purification. Et_2O, THF, toluene, and CH_2Cl_2 were purified by passage through a column composed of activated alumina (A-1). *tert*-Amyl alcohol and triethylamine were distilled from CaH_2 immediately prior to use. Methanol and 2-propanol were distilled from magnesium turnings. Tributylphosphine and trimethylphosphine were purchased from Strem Chemical Company. All reactions were carried out in flame-dried glassware under an inert N_2 atmosphere. Nitrogen was passed through a long drying column containing Drierite™. Extracts were dried over Na_2SO_4 and solvents were removed with a rotary evaporator using a water aspirator. Flash column chromatography was carried out according to the method of Still[1] using Kieselgel 60 230-400 mesh silica gel. Analytical thin-layer chromatography was performed on Merck 60 F254 250-μm silica gel plates. Visualization of the developed chromatogram was performed by fluorescence quenching, $KMnO_4$ stain, or Hanessian solution (a mixture of ceric sulfate and ammonium molybdate in aqueous sulfuric acid). HPLC purifications were performed using a system composed of two Rainin HPXL pumps connected to a Dynamax® axial compression column, packed with Rainin 60 Å irregular silica gel. Samples were loaded into the system with a 2-mL Rheodyne 7125 injector and detected using a Rainin Dynamax® UV-C detector. Melting points were determined on a Mel-Temp II hot stage apparatus and are uncorrected. ^1H and ^{13}C NMR spectra were recorded on a Varian Inova-500 or a Varian VXR-400, as noted. NMR spectra were obtained in $CDCl_3$ and are internally referenced to the residual protio solvent signal. Infrared (IR) spectra were recorded on a Perkin-Elmer Spectrum 1000 FTIR as thin films on NaCl plates and only partial data are listed. Mass spectra were recorded on a VG 70-250-S spectrometer manufactured by Micromass Corp. (Manchester UK) at the University of Michigan Mass Spectrometry facility.

Preparation of substrates:

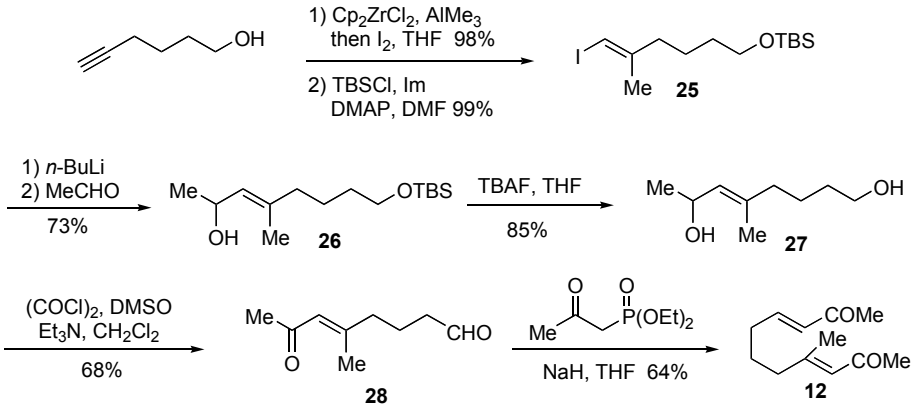


2,2-Dimethyl-hex-5-enal (23). To a suspension of $LiAlH_4$ (3.41 g, 89.8 mmol) in Et_2O (329 mL) at -78 °C was added ester **22**[2] (12.7 g, 74.8 mmol) in 45 mL of Et_2O over 20 min. The -78 °C bath was replaced with an ice bath, and the reaction mixture was stirred for 1 h. The reaction was quenched by careful addition of H_2O at 0 °C. The aqueous layer was extracted with Et_2O (2x) and the combined organics were dried, filtered, and concentrated to afford the alcohol[3] (9.27 g, 97% yield). To a solution of the crude alcohol (8.86 g, 69.1 mmol) in 346 mL of CH_2Cl_2 were added DMSO (38 mL), Et_3N (29.0 mL, 207 mmol), and SO_3·py (16.5 g, 104 mmol). The clear, light yellow solution was stirred for 0.5 h, after which time more SO_3·py (3.75 g, 23.6 mmol) was added. The reaction mixture was stirred for an additional 0.5 h, diluted with CH_2Cl_2, and washed twice with 1 N HCl (aq) and once with sat. $NaHCO_3$ (aq). The organic layer was dried, filtered, and concentrated to provide an oil that was purified by flash column chromatography (33% hexanes-Et_2O) to afford 5.87 g (67% yield) of aldehyde **23** as a colorless oil. Spectroscopic data are in agreement with those reported in the literature.[4]

2,2-Dimethyl-7-oxo-oct-5-enal (24). Ozone was bubbled through a cooled (-78 °C) solution of aldehyde **23** (1.00 g, 7.92 mmol) and CH_2Cl_2 (40 mL) until the color of the mixture turned from clear to blue. The excess ozone was removed by bubbling nitrogen through the solution until the blue color disappeared. Triphenylphosphine (2.29 g, 8.72 mmol) was added, and the mixture was stirred at -78 °C for 10 min. The stabilized ylide (Ph_3P=CHCOMe, 5.05 g, 15.8 mmol) was then added, and the solution was stirred at room temperature for 24 h. Concentration of the mixture, followed by chromatographic purification of the resulting oil (25% hexanes-Et_2O) afforded 984 mg (74% yield) of enone **24**. ^{1}H NMR ($CDCl_3$, 500 MHz): □ 9.47 (s, 1H), 6.77 (dt, *J* = 15.9, 6.8 Hz, 1H), 6.08 (dt, *J* = 15.9, 1.5 Hz, 1H), 2.24 (s, 3H), 2.19-2.14 (m, 2H), 1.67-1.63 (m, 2H), 1.10 (s, 6H). ^{13}C NMR ($CDCl_3$, 125 MHz): □ 205.4, 198.4, 147.2, 131.4, 45.6, 35.2, 27.4, 26.9, 21.4. IR (cm^{-1}): 2968, 2932, 1726, 1675, 1365, 1255, 984. CI-HRMS [M+H$^+$] Calcd. for $C_{10}H_{17}O_2$: 169.1229, Found: 169.1232.

5,5-Dimethyl-undeca-3,8-diene-2,10-dione (10). To a slurry of NaH (60% dispersion in oil, 214 mg, 5.35 mmol) in DME (40 mL), dimethyl-(2-oxo-propyl)-phosphonate (962 mg, 5.79 mmol) was added dropwise over 15 min. The solution was stirred for 2 h and then cooled with an ice bath.

Aldehyde **24** (679 mg, 4.04 mmol) in 1.5 mL DME was added dropwise over 15 min, and the resulting mixture was stirred at room temperature for 96 h. The solution was diluted with Et_2O and washed with brine. The aqueous layer was extracted with Et_2O and the organic layers were combined, dried (Na_2SO_4), filtered, and concentrated. Purification of the crude material by flash column chromatography (33% hexanes-Et_2O) yielded 303 mg (36%) of **10** as a colorless oil. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 6.77 (dt, *J* = 16.0, 6.7 Hz, 1H), 6.71 (d, *J* = 16.1 Hz, 1H), 6.06 (dt, *J* = 16.1, 1.4 Hz, 1H), 6.01 (d, *J* = 16.1 Hz, 1H), 2.27 (s, 3H), 2.23 (s, 3H), 2.16-2.11 (m, 2H), 1.57-1.53 (m, 2H), 1.10 (s, 6H). ^{13}C NMR ($CDCl_3$, 125 MHz): δ 199.0, 198.7, 156.1, 148.0, 131.5, 128.2, 40.6, 36.9, 28.0, 27.6, 27.2, 26.6. IR (cm^{-1}): 2964, 1698, 1674, 1624, 1362, 1256, 984. ES-HRMS [M+Na^+] Calcd. for $C_{13}H_{20}O_2Na$: 231.1361, Found: 231.1360.



***tert*-Butyl-(6-iodo-5-methyl-hex-5-enyloxy)-dimethyl-silane (25).** To an ice-cold suspension of Cp_2ZrCl_2 (29.8 g, 101.9 mmol) in CH_2Cl_2 (51 mL) was added $AlMe_3$ (153 mL of a 2.0 M solution in toluene, 306 mmol) dropwise over 30 min via a pressure-equalizing addition funnel. This mixture was allowed to warm to room temperature, stirred for 2 h, and then cooled to -20 °C. A solution of 5-hexyn-1-ol (10.0 g, 102 mmol) in CH_2Cl_2 (23 mL) was added dropwise over 15 min. The cold bath was removed, and the solution was stirred overnight at room temperature. The reaction mixture was cooled to -40 °C, and iodine (33.6 g, 132 mmol) in 74 mL of THF was added dropwise over 20 min. The resulting mixture was allowed to stir at room temperature for 2 h, and was then cooled to 0 °C and quenched by *very slow, dropwise* addition of H_2O (200 mL). Et_2O (200 mL) was added to this solution, which was then filtered through a Celite cake. The aqueous layer was diluted with 1 N HCl and extracted with Et_2O. The organic layers were combined, washed with sat. $NaHCO_3$ (aq), sat. Rochelle's salt (aq), and brine, and then dried, filtered, and concentrated. Purification of the crude product by flash column chromatography (4% *i*-PrOH/CH_2Cl_2) yielded 24.0 g (98% yield) of the vinyl iodide[5] as a yellow oil. To a solution of the iodide (23.0 g, 95.8 mmol) in DMF (168 mL) was added imidazole (7.82 g, 115 mmol), DMAP (468 mg, 3.83 mmol), and TBSCl (15.9 g, 105 mmol). After

0.5 h of stirring, TLC analysis of the mixture indicated that the reaction was complete. Distilled H_2O and Et_2O were added, and the aqueous layer was extracted with Et_2O. The organic layers were combined, dried, filtered, and concentrated to afford an oil that was purified by flash column chromatography (3% Et_2O-CH_2Cl_2). This procedure afforded 33.9 g (99% yield) of **25**. ^{1}H NMR ($CDCl_3$, 500 MHz): 5.88 (m, 1H), 3.62 (m, 2H), 2.23 (m, 2H), 1.84 (d, *J* = 1.0 Hz, 3H), 1.51-1.48 (m, 4H), 0.90 (s, 9H), 0.06 (s, 6H). ^{13}C NMR ($CDCl_3$, 125 MHz): 148.3, 74.8, 63.0, 39.5, 32.4, 26.2, 24.2, 24.0, 18.6, -5.0. IR (cm^{-1}): 2952, 2930, 2858, 1472, 1462, 1256, 1106, 836, 775. DCI-HRMS [M+H$^+$] Calcd. for $C_{13}H_{28}IOSi$: 355.0954, Found: 355.0959.

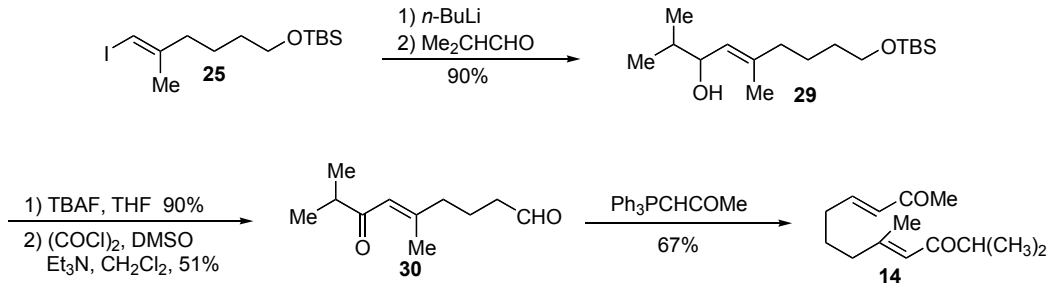
8-(*tert*-Butyl-dimethyl-silanyloxy)-4-methyl-oct-3-en-2-ol (26). To a cold (-78 °C) solution of vinyl iodide **25** (10.0 g, 28.2 mmol) in Et_2O (523 mL) was added *n*-BuLi (13.4 mL of a 2.11 M solution in hexanes, 28.2 mmol) dropwise over 15 min. Stirring was continued for 5 min, after which time acetaldehyde (2.39 mL, 42.3 mmol) was added. The cold bath was removed, and the reaction mixture was stirred at room temperature overnight. The reaction was quenched with sat. NH_4Cl (aq), and the aqueous layer was extracted with Et_2O (2x). The organic layers were combined, dried, filtered, and concentrated to afford an oil that was purified by flash column chromatography (20% EtOAc-hexanes). This procedure gave 5.64 g (73% yield) of **26** as a yellow oil. ^{1}H NMR ($CDCl_3$, 500 MHz): 5.22 (dp, *J* = 8.6, 1.2 Hz, 1H), 4.62-4.56 (m, 1H), 3.62 (t, *J* = 6.3 Hz, 2H), 2.00 (t, *J* = 7.3 Hz, 2H), 1.68 (d, *J* = 1.2 Hz, 3H), 1.52-1.44 (m, 4H), 1.24 (d, *J* = 6.3 Hz, 3H), 0.90 (s, 9H), 0.06 (s, 6H). ^{13}C NMR ($CDCl_3$, 125 MHz): 138.0, 129.3, 65.0, 63.3, 39.4, 32.6, 26.2, 24.1, 23.9, 18.6, 16.5, -5.0. IR (cm^{-1}): 3349, 2955, 2930, 2859, 1472, 1463, 1255, 1105, 836, 775. ES-HRMS [M+Na$^+$] Calcd. for $C_{15}H_{32}O_2SiNa$: 295.2069, Found: 295.2072.

5-Methyl-oct-5-ene-1,7-diol (27). TBAF (31.8 mL of a 1.0 M solution in THF, 31.8 mmol) was added dropwise over 15 min to an ice-cold solution of alcohol **26** (7.22 g, 26.5 mmol) in 294 mL of THF. The ice bath was removed, and stirring was continued for 5 h, after which time TLC analysis indicated that the reaction was complete. H_2O (200 mL) and EtOAc (200 mL) were added, and the mixture was agitated. The emulsion that formed was then broken up by the addition of a small amount of brine. The aqueous layer was separated and extracted with EtOAc (2x). The combined organic layers were dried, filtered, and concentrated to an oil that was purified using flash column chromatography (15% hexanes-EtOAc). This procedure afforded 4.27 g (82% yield) of diol **27**. ^{1}H NMR ($CDCl_3$, 500 MHz): 5.22 (dt, *J* = 8.5, 1.2 Hz, 1H), 4.57 (app p, *J* = 6.3 Hz, 1H), 3.64 (t, *J* = 6.2 Hz, 2H), 2.01 (t, *J* = 7.3 Hz, 2H), 1.68 (s, 3H), 1.60-1.47 (m, 4H), 1.23 (d, *J* = 6.1 Hz, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz): 137.6, 129.5, 65.0, 63.0, 39.3, 32.5, 24.0, 23.9, 16.5. IR (cm^{-1}): 3327, 2967,

2934, 2865, 1670, 1448, 1369, 1058. ES-HRMS [M+Na$^+$] Calcd. for $C_9H_{18}O_2Na$: 181.1204, Found: 181.1198.

5-Methyl-7-oxo-oct-5-enal (28). Oxalyl chloride (6.99 g, 55.0 mmol) was dissolved in CH_2Cl_2 (120 mL) and cooled to -78 °C. DMSO (9.14 mL, 117 mmol) was added over 10 min, and the resulting solution was stirred for 15 min. A solution of diol **27** (3.40 g, 21.5 mmol) in CH_2Cl_2 (60 mL) was added dropwise over 10 min. Stirring was continued for 30 min at -78 °C. Et_3N (33.5 mL, 239 mmol) was added dropwise over 10 min, the cold bath was removed, and the mixture was allowed to warm to room temperature. The volatile components were removed *in vacuo,* and the resulting residue was diluted with Et_2O and filtered through a Celite cake. The filtrate was concentrated, and the resulting oil was purified by flash column chromatography (40% hexanes-Et_2O) to afford 2.24 g (68% yield) of aldehyde **28**. ^{1}H NMR ($CDCl_3$, 500 MHz): 9.79 (m, 1H), 6.07 (s, 1H), 2.47 (tt, *J* = 7.2, 1.5 Hz, 2H), 2.18 (d, *J* = 1.7 Hz, 3H), 2.16 (t, *J* = 7.7 Hz, 2H), 2.13 (s, 3H), 1.83 (m, 2H). ^{13}C NMR ($CDCl_3$, 125 MHz): 201.9, 199.0, 157.1, 124.4, 43.3, 40.3, 32.1, 19.9, 19.3. IR (cm^{-1}): 2942, 1724, 1686, 1617, 1357, 1216. EI-HRMS [M$^+$] Calcd. for $C_9H_{14}O_2$: 154.0994, Found: 154.0997.

4-Methyl-undeca-3,8-diene-2,10-dione (12). To a slurry of NaH (60% dispersion in oil, 311 mg, 7.78 mmol) in THF (9 mL) was added diethyl-(2-oxo-propyl)-phosphonate (1.62 g, 8.43 mmol) dropwise over 10 min. The solution turned from cloudy to clear over the addition period. This mixture was added dropwise (10 min) to an ice-cold solution of aldehyde **28** (1.00 g, 6.49 mmol) in 50 mL of THF. The mixture was stirred for 5 min, then Et_2O and brine were added, and the aqueous layer was extracted twice with Et_2O. The combined organics were dried, filtered, and concentrated to an oil that was purified by flash column chromatography (25% EtOAc-hexanes). This procedure afforded 803 mg (64% yield) of bisenone **12**. ^{1}H NMR ($CDCl_3$, 400 MHz): 6.79 (dt, *J* = 15.9, 6.8 Hz, 1H), 6.10 (d, *J* = 15.9 Hz, 1H), 6.08 (s, 1H), 2.26 (s, 3H), 2.24 (app q, *J* = 7.4 Hz, 2H), 2.19 (s, 3H), 2.16 (t, *J* = 7.6 Hz, 2H), 2.13 (s, 3H), 1.68 (app p, *J* = 7.6 Hz, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): 199.0, 198.7, 157.5, 147.4, 132.0, 124.2, 77.0, 40.7, 32.1, 27.2, 26.0, 19.4. IR (cm^{-1}): 2938, 1676, 1618, 1426, 1361, 1252, 977. ES-HRMS [M+Na$^+$] Calcd. for $C_{12}H_{18}O_2Na$: 217.1204, Found: 217.1199.



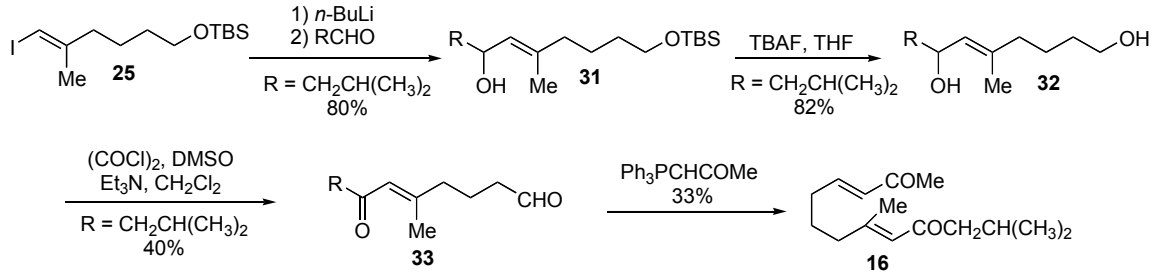
9-(*tert*-Butyl-dimethyl-silanyloxy)-2,5-dimethyl-non-4-en-3-ol (29). To a cold (-78 °C) solution of vinyl iodide **25** (11.4 g, 32.2 mmol) in Et_2O (596 mL) was added *n*-BuLi (14.1 mL of a 2.28 M solution in hexanes, 32.2 mmol) dropwise over 15 min. The mixture was stirred 5 min, at which point isobutyraldehyde (3.48 g, 48.3 mmol) was added. The cold bath was removed, and the reaction mixture was stirred at room temperature for 2.5 h. The reaction was quenched with sat. NH_4Cl (aq), and the aqueous layer was extracted with Et_2O. The organic layers were combined, dried, filtered, and concentrated. The resulting oil was purified by flash column chromatography (15% EtOAc-hexanes) to provide 8.66 g (90% yield) of **29** as a light yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz): □ 5.14 (dd, *J* = 8.8, 1.1 Hz, 1H), 4.05-4.00 (m, 1H), 3.57 (t, *J* = 5.9 Hz, 2H), 2.00-1.97 (m, 2H), 1.65-1.62 (m, 1H), 1.63 (d, *J* = 1.1 Hz, 3H), 1.47-1.41 (m, 4H), 0.91 (d, *J* = 6.6 Hz, 3H), 0.85 (s, 9H), 0.81 (d, *J* = 6.6 Hz, 3H), 0.00 (s, 6H). ^{13}C NMR ($CDCl_3$, 100 MHz): □ 139.5, 126.4, 73.8, 63.2, 39.6, 34.6, 32.6, 26.2, 24.1, 23.0, 18.6, 18.3, 16.8, -5.1. IR (cm^{-1}): 3368, 2955, 2931, 2859, 1472, 1255, 1102, 836, 775. EI-HRMS [M+Na^+] Calcd. for $C_{17}H_{36}O_2SiNa$: 323.2382, Found: 323.2378.

5,8-Dimethyl-7-oxo-non-5-enal (30). TBAF (31.8 mL of a 1.0 M solution in THF, 31.8 mmol) was added dropwise over 15 min to an ice-cold solution of alcohol **29** (8.17 g, 26.0 mmol) in 289 mL of THF. The ice bath was removed, and stirring was continued for 5 h, after which time TLC analysis of the mixture indicated that the reaction was complete. H_2O (200 mL) and EtOAc (200 mL) were added, and the mixture was agitated. The emulsion that formed was broken up by the addition of a small amount of brine. The aqueous layer was separated and extracted with EtOAc (2x). The combined organic layers were dried, filtered, and concentrated to an oil that was purified using flash column chromatography (15% hexanes/ EtOAc). This procedure afforded 4.42 g (90% yield) of the diol. ^{1}H NMR ($CDCl_3$, 500 MHz): □ 5.21 (dq, *J* = 9.0, 1.2 Hz, 1H), 4.08 (app t, *J* = 7.8 Hz, 1H), 3.66 (br s, 2H), 2.06 (t, *J* = 7.1 Hz, 2H), 1.71-1.66 (m, 1H), 1.68 (d, *J* = 1.2 Hz, 3H), 1.60-1.49 (m, 4H), 1.36 (br s, 2H), 0.96 (d, *J* = 6.6 Hz, 3H), 0.86 (d, *J* = 6.8 Hz, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz): □ 139.3, 126.6, 73.9, 63.1, 39.7, 34.7, 32.6, 24.1, 18.6, 18.4, 16.9.

A solution of oxalyl chloride (7.54 g, 59.4 mmol) in CH_2Cl_2 (129 mL) was cooled to -78 °C. DMSO (8.95 mL, 126 mmol) was added over 10 min, and the resulting solution was stirred for 15 min. A mixture of the diol (4.32 g, 23.2 mmol) in CH_2Cl_2 (64 mL) was added dropwise over 10 min. The mixture was stirred for 30 min at -78 °C, then Et_3N (36.2 mL, 257 mmol) was added dropwise over 10 min, the cold bath was removed, and the mixture was allowed to warm to room temperature. The volatile components were removed *in vacuo,* and the resulting residue was diluted with Et_2O and filtered through a Celite cake. The filtrate was concentrated, and the residue was purified by flash

column chromatography (20% EtOAc-hexanes) to afford 2.16 g (51% yield) of aldehyde **30**. ^{1}H NMR ($CDCl_3$, 500 MHz): 9.75 (t, *J* = 1.3 Hz, 1H), 6.05 (s, 1H), 2.55 (sept, *J* = 7.0 Hz, 1H), 2.42 (td, *J* = 7.3, 1.3 Hz, 2H), 2.13 (t, *J* = 7.5 Hz, 2H), 2.08 (d, *J* = 1.1 Hz, 3H), 1.79 (p, *J* = 7.3 Hz, 2H), 1.04 (d, *J* = 7.0 Hz, 6H). ^{13}C NMR ($CDCl_3$, 125 MHz): 205.0, 201.9, 157.5, 122.8, 43.2, 41.8, 40.4, 19.9, 19.3, 18.5. IR (cm^{-1}): 2968, 1725, 1685, 1618, 1458. EI-HRMS [M^+] Calcd. for $C_{11}H_{18}O_2$: 182.1307, Found: 182.1301.

8,11-Dimethyl-dodeca-3,8-diene-2,10-dione (14). A flame-dried flask was charged with aldehyde **30** (1.20 g, 6.58 mmol), CH_2Cl_2 (33 mL), and Ph_3P=CHCOMe (3.14 g, 9.88 mmol). The resulting mixture was stirred for 2 days, after which time it was concentrated to an oil. Chromatographic purification (15% EtOAc-hexanes) of this oil provided 981 mg (67%) of bisenone **14**. ^{1}H NMR ($CDCl_3$, 500 MHz): 6.79 (dt, *J* = 15.9, 6.8 Hz, 1H), 6.10 (dt, *J* = 15.9, 1.5 Hz, 1H), 6.10 (q, *J* = 1.2 Hz, 1H), 2.60 (septet, *J* = 6.9 Hz, 1H), 2.27-2.23 (m, 2H), 2.26 (s, 3H), 2.18 (t, *J* = 7.5 Hz, 2H), 2.14 (s, 3H), 1.69 (app p, *J* = 7.6 Hz, 2H), 1.10 (d, *J* = 6.8 Hz, 6H). ^{13}C NMR ($CDCl_3$, 125 MHz): 205.0, 198.7, 157.9, 147.4, 131.9, 122.6, 41.8, 40.8, 32.0, 27.2, 26.1, 19.4, 18.5. IR (cm^{-1}): 2968, 2934, 2872, 1678, 1619, 1363, 1254, 978. ES-HRMS [M+Na^+] Calcd. for $C_{14}H_{22}O_2Na$: 245.1517, Found: 245.1525.



10-(*tert*-Butyl-dimethyl-silanyloxy)-2,6-dimethyl-dec-5-en-4-ol (31). *n*-BuLi (14.9 mL of a 2.28 M solution in hexanes, 33.9 mmol) was added dropwise over 15 min to a cold (-78 °C) solution of vinyl iodide **25** (12.0 g, 33.9 mmol) in Et_2O (627 mL). This mixture was stirred for 5 min, after which point 3-methylbutyraldehyde (4.38 g, 50.8 mmol) was added. The cold bath was removed, and the reaction mixture was stirred at room temperature for 3 h. The reaction was quenched with sat. NH_4Cl (aq), and the aqueous layer was extracted with Et_2O. The organic layers were combined, dried, filtered, and concentrated to afford a yellow oil. Purification of this oil by flash column chromatography (15% EtOAc-hexanes) gave 8.50 g (80% yield) of **31** as a light yellow oil. ^{1}H NMR ($CDCl_3$, 500 MHz): 5.17 (dd, *J* = 8.8, 1.2 Hz, 1H), 4.44 (app q, *J* = 7.5 Hz, 1H), 3.61 (t, *J* = 6.1 Hz, 2H), 2.01 (t, *J* = 7.0 Hz, 2H), 1.68 (d, *J* = 1.2 Hz, 3H), 1.68-1.63 (m, 1H), 1.52-1.43 (m, 6H), 1.27 (p, *J* = 6.8 Hz, 1H), 0.93 (d, *J* = 6.6 Hz, 3H), 0.90 (d, *J* = 7.6 Hz, 3H), 0.90 (s, 9H), 0.05 (s, 6H). ^{13}C NMR

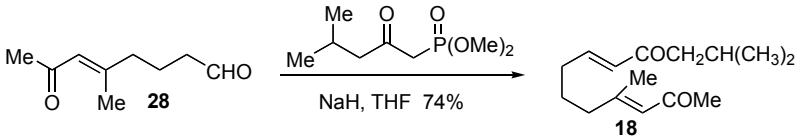
($CDCl_3$, 125 MHz): 138.5, 128.6, 67.0, 63.2, 47.1, 39.5, 32.6, 26.2, 24.9, 24.1, 23.2, 22.9, 18.6, 16.6, -5.1. IR (cm^{-1}): 3349, 2955, 2930, 2860, 1471, 1255, 1102, 836, 775. ES-HRMS [M+Na^+] Calcd. for $C_{18}H_{38}O_2SiNa$: 337.2539, Found: 337.2534.

5,9-Dimethyl-dec-5-ene-1,7-diol (32). TBAF (31.2 mL of a 1.0 M solution in THF, 31.2 mmol) was added dropwise over 15 min to a 0 °C solution of alcohol **31** (8.17 g, 26.0 mmol) in 289 mL of THF. The ice bath was removed, and stirring was continued for 7 h at room temperature. H_2O and EtOAc were added, and the mixture was agitated. The emulsion that formed was broken up by the addition of a small amount of brine. The aqueous layer was separated and extracted with EtOAc. The combined organic layers were dried, filtered, and concentrated to an oil that was purified using flash column chromatography (15% hexanes/EtOAc). This procedure afforded 4.27 g (82% yield) of diol **32**. ^{1}H NMR ($CDCl_3$, 500 MHz): 5.16 (dq, *J* = 8.5, 1.2 Hz, 1H), 4.44 (q, *J* = Hz, 1H), 3.65 (t, *J* = 6.2 Hz, 2H), 2.03 (t, *J* = 7.0 Hz, 2H), 1.69 (d, *J* = 1.2 Hz, 3H), 1.65 (m, 1H), 1.57-1.46 (m, 5H), 1.29-1.24 (m, 1H), 0.93 (d, *J* = 6.6 Hz, 3H), 0.90 (d, *J* = 6.6 Hz, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz): 138.3, 128.7, 67.1, 63.0, 47.1, 39.5, 32.5, 24.9, 24.0, 23.2, 22.9, 16.7. IR (cm^{-1}): 3328, 2953, 2934, 2868, 1467, 1384, 1056. ES-HRMS [M+Na^+] Calcd. for $C_{12}H_{24}O_2Na$: 223.1674, Found: 223.1670.

7-Hydroxy-5,9-dimethyl-dec-5-enal (33). DMSO (8.19 mL, 115 mmol) was added over 10 min to a –78 °C solution of oxalyl chloride (6.89 g, 54.3 mmol) in CH_2Cl_2 (118 mL). The resulting solution was stirred for 15 min, then a solution of diol **32** (4.25 g, 21.2 mmol) in CH_2Cl_2 (59 mL) was added dropwise over 10 min. This mixture was stirred for 30 min at -78 °C. Et_3N (33.1 mL, 236 mmol) was added dropwise over 10 min, the cold bath was removed, and the mixture was warmed to room temperature. The volatile components were removed *in vacuo*, and the resulting residue was diluted with Et_2O. The solution was filtered through a Celite cake, and the filtrate was concentrated to an oil was purified by flash column chromatography (20% EtOAc-hexanes). Aldehyde **33** was obtained as a colorless oil in 40% yield (1.67 g). ^{1}H NMR ($CDCl_3$, 500 MHz): 9.80 (t, *J* = 1.2 Hz, 1H), 6.05 (s, 1H), 2.47 (td, *J* = 7.2, 1.2 Hz, 2H), 2.30 (d, *J* = 7.1 Hz, 2H), 2.16 (t, *J* = 7.3 Hz, 2H), 2.16-2.11 (m, 1H), 2.13 (d, *J* = 1.2 Hz, 3H), 1.84 (p, *J* = 7.5 Hz, 2H), 0.94 (d, *J* = 6.4 Hz, 6H). ^{13}C NMR ($CDCl_3$, 125 MHz): 202.0, 201.4, 156.7, 124.4, 53.7, 43.3, 40.3, 25.4, 22.9, 20.0, 19.3. IR (cm^{-1}): 2956, 2871, 1725, 1684, 1618, 1389, 1366, 1055. ES-HRMS [M+Na^+] Calcd. for $C_{12}H_{20}O_2Na$: 219.1361, Found: 219.1361.

8,12-Dimethyl-trideca-3,8-diene-2,10-dione (16). A flame-dried flask was charged with aldehyde **33** (1.65 g, 8.41 mmol), CH_2Cl_2 (42 mL), and Ph_3P=CHCOMe (4.01 g, 12.6 mmol). The resulting mixture was stirred for 3 d, after which time it was concentrated. Chromatographic

purification (15% EtOAc-hexanes) of the crude material yielded 661 mg (33%) of bisenone **16** as a colorless oil. ^{1}H NMR ($CDCl_3$, 500 MHz): 6.79 (dt, *J* = 16.1, 6.8 Hz, 1H), 6.10 (dt, *J* = 15.9, 1.5 Hz, 1H), 6.05 (q, *J* = 1.2 Hz, 1H), 2.30 (d, *J* = 7.1 Hz, 2H), 2.26 (s, 3H), 2.26-2.22 (m, 2H), 2.18-2.11 (m, 3H), 2.13 (d, *J* = 1.2 Hz, 3H), 1.68 (p, *J* = 7.6 Hz, 2H), 0.93 (d, *J* = 6.6 Hz, 6H). ^{13}C NMR ($CDCl_3$, 125 MHz): 201.4, 198.7, 157.1, 147.4, 132.0, 124.2, 53.8, 40.7, 32.1, 27.2, 26.1, 25.4, 22.9, 19.4. IR (cm^{-1}): 2956, 2871, 1678, 1619, 1364, 1254, 978. ES-HRMS [M+Na$^+$] Calcd. for $C_{15}H_{24}O_2Na$: 259.1674, Found: 259.1680.



4,12-Dimethyl-trideca-3,8-diene-2,10-dione (18). To a slurry of NaH (60% dispersion in oil, 311 mg, 7.78 mmol) in THF (9 mL) was added dimethyl 4-methyl-2-oxopentanephosphonate[6] (1.76 g, 8.43 mmol) added dropwise over 10 min. The solution turned from cloudy to clear over the addition period. This mixture was added dropwise over 10 min to an ice-cold solution of aldehyde **28** (1.00 g, 6.49 mmol) in 50 mL of THF. TLC analysis of the mixture indicated that the aldehyde was consumed within 5 min. Et_2O and brine were added, and the aqueous layer was extracted twice with Et_2O. The combined organics were dried, filtered and concentrated to an oil that was purified by flash column chromatography (20% EtOAc-hexanes). This procedure gave 1.13 g (74% yield) of bisenone **18**. ^{1}H NMR ($CDCl_3$, 500 MHz): 6.80 (dt, *J* = 15.9, 6.8 Hz, 1H), 6.12 (dt, *J* = 15.9, 1.4 Hz, 1H), 6.07 (s, 1H), 2.41 (d, *J* = 6.8 Hz, 2H), 2.23 (app q, *J* = 6.8 Hz, 2H), 2.19 (s, 3H), 2.18-2.14 (m, 3H), 2.13 (d, *J* = 1.0 Hz, 3H), 1.67 (p, *J* = 7.6 Hz, 2H), 0.95 (d, *J* = 6.8 Hz, 6H). ^{13}C NMR ($CDCl_3$, 125 MHz): 200.6, 198.9, 157.6, 146.2, 131.3, 124.2, 49.5, 40.6, 32.0, 32.0, 26.1, 25.3, 22.9, 19.3. IR (cm^{-1}): 2956, 2971, 1688, 1618, 1366, 1214, 977. ES-HRMS [M+Na$^+$] Calcd. for $C_{15}H_{24}O_2Na$: 259.1674, Found: 259.1682.

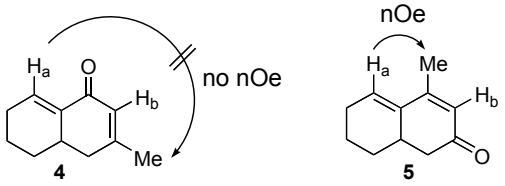
General procedure for the tandem cyclization:

The bisenone (1 equiv) was dissolved in CF_3CH_2OH or *t*-Amyl alcohol (0.05 M) in a flame-dried glass reaction vessel bearing a Kontes teflon stopper. The solution was then degassed by three freeze-pump-thaw cycles. To the oxygen-free solution was added PMe_3 or PBu_3 (0.25-5 equiv) via syringe. The solution was stirred at 23 °C, 60 °C, or 80 °C. For reactions performed in *t*-Amyl alcohol, the progress of the reaction was monitored by TLC analysis. Reactions conducted in CF_3CH_2OH were also monitored by TLC, but only after workup of small aliquots; presumably, a phosphonium adduct of the product (that appears baseline on the TLC plate) is stabilized by

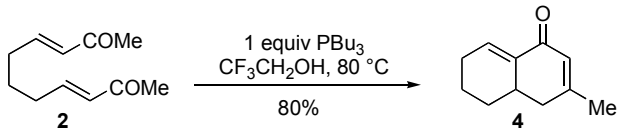
CF_3CH_2OH, and the product is not released from the phosphine until the workup step. After the reaction was complete (3-48 h), the mixture was partially concentrated to reduce the bulk of the alcoholic solvent.[7] This step is particularly important for the reactions performed in CF_3CH_2OH; if the mixture is concentrated to dryness, the residue decomposes and the yield of product is low. The resulting residue was then diluted with ether, and TLC analysis of this solution revealed the presence of product. After washing this mixture with 1 N $NaHSO_4$ (aq), the aqueous layer was extracted twice with Et_2O. The combined organic layers were washed with brine, dried over Na_2SO_4, filtered, and concentrated. The crude material was purified by flash column chromatography.

Assignment of Regiochemistry:

Aldol regiochemistry of the dienone products was assigned based on relevant nOe's and ^{13}C NMR carbonyl shifts. 1-Dimensional nOe experiments of aldol regioisomers **4** and **5** established the presence of a nOe between the methyl group and the electron-deficient vinylic hydrogen (H_a) in **5**, and the lack of such a nOe in **4**:

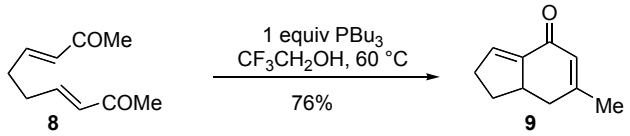


Aldol regiochemical assignments for other compounds were made by comparison of their ^{13}C NMR carbonyl chemical shifts to those of **4** and **5** (cross-conjugated isomer **4**, □ = 199.6 ppm; linearly-conjugated isomer **5**, □= 188.5 ppm); the carbonyls present in other cross-conjugated isomers consistently appeared more upfield (186.8-189.2 ppm) than those present in the corresponding linearly-conjugated isomers (199.3-200.5 ppm). The regiochemistry for those compounds that could not be assigned based on their ^1H and ^{13}C NMR spectra alone (i.e., **11**) was established by nOe and decoupling experiments.

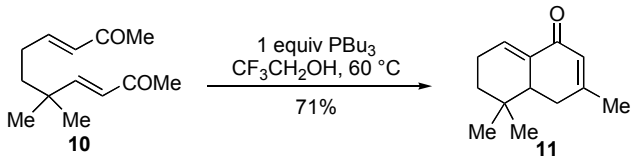


3-Methyl-4a,5,6,7-tetrahydro-4H-naphthalen-1-one (4). This compound was prepared in CF_3CH_2OH (2.2 mL) according to the general procedure for tandem cyclization (80 °C, 24 h) from **2** (20 mg, 0.11 mmol) and PBu_3 (28 □L, 0.11 mmol). Dienone **4** was isolated as a colorless oil after flash column chromatography (33% Et_2O-hexanes) in 80% yield (14 mg). ^1H NMR ($CDCl_3$, 500 MHz): □ 6.91-6.89 (m, 1H), 5.98-5.97 (m, 1H), 2.72-2.65 (br m, 1H), 2.31 (dd, *J* = 17.3, 5.9 Hz, 1H), 2.29-2.16 (m, 2H), 2.14-2.08 (m, 1H), 2.01-1.96 (m, 1H), 1.97 (s, 3H), 1.82-1.78 (m, 1H), 1.57-1.47 (m, 1H),

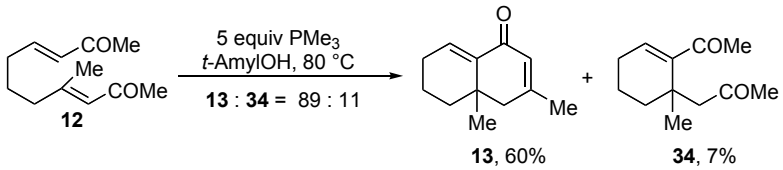
1.38-1.30 (m, 1H). ^{13}C NMR ($CDCl_3$, 125 MHz): 188.5, 161.4, 136.4, 135.6, 127.3, 38.3, 35.2, 30.1, 26.2, 24.9, 21.3. IR (cm^{-1}): 2925, 2859, 1618, 1633, 1426, 1272. EI-HRMS [M^+] Calcd. for $C_{11}H_{14}O$: 162.1045, Found: 162.1045.



6-Methyl-1,2,7,7a-tetrahydro-inden-4-one (9). This compound was prepared in CF_3CH_2OH (6.0 mL) according to the general procedure for tandem cyclization (60 ºC, 3 h) from **8** (50 mg, 0.30 mmol) and PBu_3 (75 L, 0.30 mmol). Dienone **9** was isolated as a white solid after flash column chromatography (33% Et_2O-hexanes) in 76% yield (34 mg). ^{1}H NMR ($CDCl_3$, 500 MHz): 6.71-6.69 (m, 1H), 6.00-5.99 (m, 1H), 3.20-3.12 (br m, 1H), 2.60-2.52 (m, 2H), 2.50-2.41 (m, 1H), 2.35 (dtd, *J* = 12.5, 7.8, 1.5 Hz, 1H), 2.16-2.09 (m, 1H), 2.00 (app t, *J* = 1.2 Hz, 3H), 1.60 (dq, *J* = 12.5, 9.8 Hz, 1H). ^{13}C NMR ($CDCl_3$, 125 MHz): 186.8, 161.7, 141.9, 137.1, 128.4, 43.1, 39.4, 32.5, 32.4, 24.9. IR (cm^{-1}): 2928, 1646, 1625, 1270. EI-HRMS [M^+] Calcd. for $C_{10}H_{12}O$: 148.0888, Found: 148.0891.

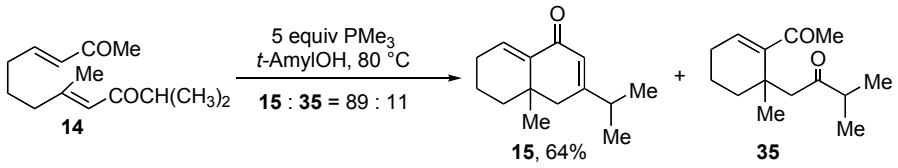


3,5,5-Trimethyl-4a,5,6,7-tetrahydro-4H-naphthalen-1-one (11). This compound was prepared in CF_3CH_2OH (1.0 mL) according to the general procedure for tandem cyclization (60 ºC, 48 h) from **10** (10 mg, 0.048 mmol) and PBu_3 (12 L, 0.048 mmol). Dienone **11** was isolated as a colorless oil after flash column chromatography (33% Et_2O-hexanes) in 71% yield (6.5 mg). ^{1}H NMR ($CDCl_3$, 500 MHz): 6.96 (m, 1H), 5.97 (m, 1H), 2.49-2.44 (m, 1H), 2.28 (dd, *J* = 17.2, 5.8 Hz, 1H), 2.24-2.11 (m, 3H), 1.99 (s, 3H), 1.46-1.38 (m, 2H), 1.02 (s, 3H), 0.86 (s, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz): 188.0, 161.3, 135.2, 135.1, 126.8, 44.8, 36.3, 31.4, 31.4, 29.0, 24.9, 23.4, 21.4. IR (cm^{-1}): 2920, 1668, 1617, 1380, 1284, 1261. EI-HRMS [M^+] Calcd. for $C_{13}H_{18}O$: 190.1357, Found: 190.1352 .



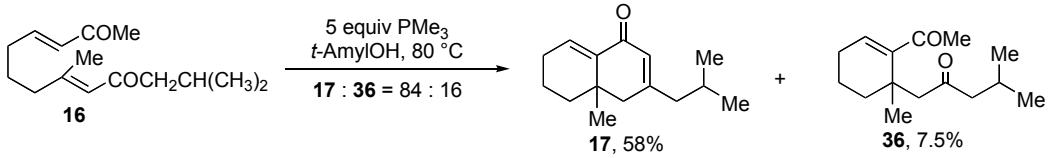
3,4a-Dimethyl-4a,5,6,7-tetrahydro-4H-naphthalen-1-one (13). This compound was prepared in *t*-AmylOH (21 mL) according to the general procedure for tandem cyclization (80 ºC, 24 h) using **12** (200 mg, 1.03 mmol) and PMe_3 (523 L, 5.15 mmol). Dienone **13** and the MBH intermediate **34** were isolated as a mixture (**13** : **34** = 89 : 11) after flash column chromatography (12%

EtOAc-hexanes) in 75% yield (137 mg). Separation of this mixture by preparative HPLC (10% EtOAc-hexanes) afforded dienone **13** (108 mg, 60% yield). Enone **34** was also isolated (14 mg, 7% yield). Data for **13**: ^{1}H NMR ($CDCl_3$, 400 MHz): 6.71 (dd, *J* = 4.6, 3.1 Hz, 1H), 5.92 (dd, *J* = 2.6, 1.5 Hz, 1H), 2.31 (d, *J* = 17.2 Hz, 1H), 2.26-2.11 (m, 2H), 2.07 (d, *J* = 17.6 Hz, 1H), 1.91 (d, *J* = 1.1 Hz, 3H), 1.69-1.56 (m, 3H), 1.51-1.43 (m, 1H), 1.08 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): 188.8, 159.9, 140.6, 134.7, 126.3, 46.7, 37.8, 35.8, 26.4, 26.2, 25.1, 18.3. IR (cm^{-1}): 2933, 1665, 1636, 1616, 1270. EI-HRMS [M^+] Calcd. for $C_{12}H_{16}O$: 176.1201, Found: 176.1203. Data for **34**: ^{1}H NMR ($CDCl_3$, 500 MHz): 6.85 (dd, *J* = 4.6, 3.7 Hz, 1H), 3.32 (d, *J* = 16.8 Hz, 1H), 2.54 (d, *J* = 16.6 Hz, 1H), 2.30-2.25 (m, 2H), 2.27 (s, 3H), 2.05 (s, 3H), 1.86-1.80 (m, 1H), 1.67-1.62 (m, 2H), 1.36 (dt, *J* = 13.2, 4.1 Hz, 1H), 1.21 (s, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz): 208.9, 200.7, 145.5, 141.8, 52.7, 36.7, 35.4, 31.9, 27.3, 27.3, 26.5, 18.1. IR (cm^{-1}): 2930, 2870, 1715, 1666, 1627, 1425, 1360, 1244. ES-HRMS [M+Na^+] Calcd. for $C_{12}H_{18}O_2Na$: 217.1204, Found: 217.1201.

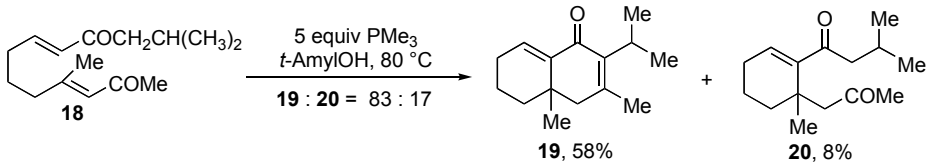


3-Isopropyl-4a-methyl-4a,5,6,7-tetrahydro-4H-naphthalen-1-one (15). This compound was prepared in *t*-AmylOH (4.5 mL) according to the general procedure for tandem cyclization (80 ºC, 14 h) using **14** (50 mg, 0.23 mmol) and PMe_3 (183 L, 1.80 mmol). Dienone **15** and MBH intermediate **35** were isolated as a mixture (**15** : **35** = 89 : 11, 36 mg) after flash column chromatography (12% EtOAc-hexanes). Separation of this mixture was accomplished by preparative HPLC (10% EtOAc-hexanes), which afforded dienone **15** in 64% yield (29 mg) as a white solid. An analytical sample of enone **35** was also isolated. mp 60-61 °C. Data for **15**: ^{1}H NMR ($CDCl_3$, 500 MHz): 6.77 (dd, *J* = 2.9, 4.9 Hz, 1H), 5.97 (dd, *J* = 2.5, 0.9 Hz, 1H), 2.41 (sept, *J* = 6.8 Hz, 1H), 2.31 (dd, *J* = 17.1, 2.4 Hz, 1H), 2.29-2.24 (m, 1H), 2.23-2.15 (m, 1H), 2.18 (d, *J* = 17.1 Hz, 1H), 1.76-1.65 (m, 3H), 1.53 (td, *J* = 11.2, 3.9 Hz, 1H), 1.12 (d, *J* = 4.6 Hz, 3H), 1.11 (s, 3H), 1.10 (d, *J* = 4.6 Hz, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz): 189.2, 168.5, 141.1, 134.7, 123.4, 43.3, 37.9, 36.1, 35.9, 26.2, 26.0, 20.6, 20.3, 18.3. IR (cm^{-1}): 2963, 2932, 1666, 1630, 1614, 1270. EI-HRMS [M^+] Calcd. for $C_{14}H_{20}O$: 204.1514, Found: 204.1513. Data for **35**: ^{1}H NMR ($CDCl_3$, 500 MHz): 6.82 (dd, *J* = 4.6, 3.4 Hz, 1H), 3.34 (d, *J* = 17.1 Hz, 1H), 2.60 (d, *J* = 17.1 Hz, 1H), 2.50 (sept, *J* = 7.0 Hz, 1H), 2.30-2.25 (m, 2H), 2.27 (s, 3H), 1.81-1.76 (m, 1H), 1.68-1.62 (m, 2H), 1.34 (dt, *J* = 13.2, 3.4 Hz, 1H), 1.22 (s, 3H), 1.03 (d, *J* = 7.1 Hz, 3H), 1.01 (d, *J* = 6.8 Hz, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz): 214.8, 200.7, 145.8, 141.1, 49.8, 41.9, 36.8,

35.3, 27.4, 27.2, 26.5, 18.3, 18.2, 18.1. IR (cm^{-1}): 2967, 2932, 1710, 1666, 1628, 1467, 1366, 1242, 1049. ES-HRMS [M+Na^+] Calcd. for $C_{14}H_{22}O_2Na$: 245.1517, Found: 245.1524.

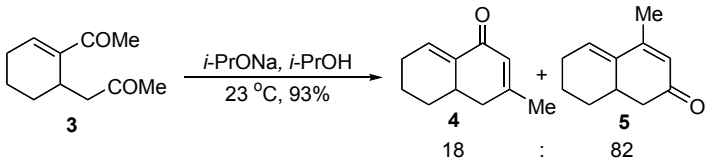


3-Isobutyl-4a-methyl-4a,5,6,7-tetrahydro-4H-naphthalen-1-one (17). This compound was prepared in *t*-AmylOH (8.5 mL) according to the general procedure for tandem cyclization (80 °C, 23 h) using **16** (100 mg, 0.423 mmol) and PMe_3 (215 μL, 2.12 mmol). Flash column chromatography (12% EtOAc-hexanes) afforded 68 mg of a mixture of dienone **17** and MBH intermediate **36** (**17** : **36** = 84 : 16). Separation of this mixture by preparative HPLC (10% EtOAc-hexanes) afforded dienone **17** in 58% yield (53 mg) as a colorless oil. Enone **36** was also isolated (7.5 mg/7.5% yield). Data for **17**: ^{1}H NMR ($CDCl_3$, 500 MHz): δ 6.77 (dd, *J* = 3.2, 4.6 Hz, 1H), 5.95 (m, 1H), 2.31 (d, *J* = 17.3 Hz, 1H), 2.27-2.18 (m, 2H), 2.15 (d, *J* = 17.3 Hz, 1H), 2.08 (d, *J* = 6.6 Hz, 2H), 1.89 (sept, *J* = 6.8 Hz, 1H), 1.74-1.63 (m, 3H), 1.56-1.44 (m, 1H), 1.13 (s, 3H), 0.94 (d, *J* = 6.6 Hz, 3H), 0.92 (d, *J* = 6.6 Hz, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz): δ 188.9, 162.7, 140.9, 134.8, 126.7, 48.3, 45.4, 37.8, 35.9, 26.4, 26.4, 26.2, 22.9, 22.8, 18.3. IR (cm^{-1}): 2957, 2930, 1666, 1631, 1616, 1271. ES-HRMS [M+Na^++MeOH] Calcd. for $C_{16}H_{26}O_2Na$: 273.1830, Found: 273.1825. Data for **36**: ^{1}H NMR ($CDCl_3$, 500 MHz): δ 6.84 (dd, *J* = 4.6, 3.4 Hz, 1H), 3.29 (d, *J* = 16.8 Hz, 1H), 2.49 (d, *J* = 17.1 Hz, 1H), 2.30-2.25 (m, 2H), 2.27 (s, 3H), 2.18 (dd, *J* = 6.6, 3.4 Hz, 2H), 2.06 (sept, *J* = 6.6 Hz, 1H), 1.86-1.80 (m, 1H), 1.67-1.62 (m, 2H), 1.34 (dt, *J* = 13.2, 4.2 Hz, 1H), 1.20 (s, 3H), 0.87 (d, *J* = 4.2 Hz, 3H), 0.86 (d, *J* = 4.2 Hz, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz): δ 210.8, 200.7, 145.7, 141.4, 53.5, 52.4, 36.7, 35.3, 27.4, 27.2, 26.5, 24.6, 22.8, 22.8, 18.1. IR (cm^{-1}): 2956, 2932, 2870, 1711, 1666, 1366, 1246. ES-HRMS [M+Na^+] Calcd. for $C_{15}H_{24}O_2Na$: 259.1674, Found: 259.1672.

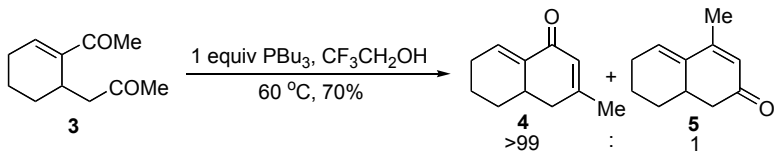


2-Isopropyl-3,4a-dimethyl-4a,5,6,7-tetrahydro-4H-naphthalen-1-one (19). This compound was prepared in *t*-AmylOH (21 mL) according to the general procedure for tandem cyclization (80 °C, 23 h) using **18** (200 mg, 0.846 mmol) and PMe_3 (523 μL, 5.15 mmol). Separation of this mixture by flash column chromatography (10% EtOAc-hexanes) afforded dienone **19** in 58% yield (107 mg) as a white solid and MBH intermediate **20** in 8% yield (15 mg) as an oil. Data for **19**: ^{1}H NMR ($CDCl_3$, 500 MHz): δ 6.75 (dd, *J* = 4.7, 3.1 Hz, 1H), 3.03 (sept, *J* = 7.1 Hz, 1H), 2.39 (d, *J* = 17.1 Hz, 1H),

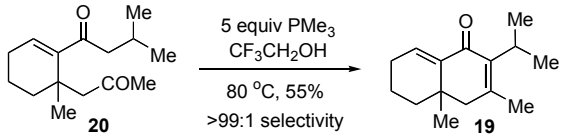
2.27-2.21 (m, 1H), 2.20-2.12 (m, 1H), 2.08 (d, *J* = 17.1 Hz, 1H), 1.96 (d, *J* = 1.2 Hz, 3H), 1.69-1.61 (m, 3H), 1.44 (m, 1H), 1.21 (d, *J* = 7.3 Hz, 6H), 1.10 (s, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz): 187.8, 151.4, 141.7, 139.6, 133.9, 48.6, 37.7, 34.8, 27.7, 26.2, 25.9, 22.1, 20.9, 20.6, 18.2. IR (cm^{-1}): 2931, 1661, 1615, 1456, 1380, 1290. ES-HRMS [M+H$^+$] Calcd. for $C_{15}H_{23}O$: 219.1749, Found: 219.1753. Data for **20**: ^{1}H NMR ($CDCl_3$, 400 MHz): 6.76 (t, *J* = 4.0 Hz, 1H), 3.23 (d, *J* = 16.8 Hz, 1H), 2.53 (d, *J* = 16.8 Hz, 1H), 2.46 (dd, *J* = 15.7, 7.0 Hz, 1H), 2.38 (dd, *J* = 15.7, 7.0 Hz, 1H), 2.24-2.18 (m, 2H), 2.06 (sept, *J* = 6.6 Hz, 1H), 1.99 (s, 3H), 1.85-1.78 (m, 1H), 1.62-1.55 (m, 2H), 1.30 (dt, *J* = 12.8, 4.2 Hz, 1H), 1.16 (s, 3H), 0.85 (d, *J* = 3.7 Hz, 3H), 0.83 (d, *J* = 3.7 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): 208.7, 202.7, 145.7, 140.5, 52.7, 47.6, 36.7, 35.5, 31.9, 27.3, 26.5, 25.4, 23.0, 22.8, 18.1. IR (cm^{-1}): 2956, 1717, 1666, 1365, 1193. EI-HRMS [M$^+$] Calcd. for $C_{15}H_{24}O_2$: 236.1776, Found: 236.1780.



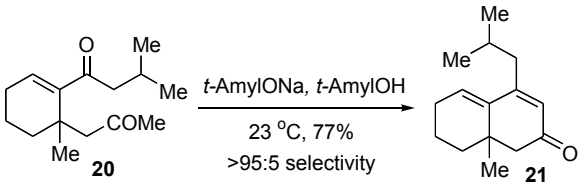
4-Methyl-6,7,8,8a-tetrahydro-1H-naphthalen-2-one (5). A mixture of Na metal (1.0 mg, 0.043 mmol) in *i*-PrOH (2.5 mL) was heated in a 60 °C oil bath until the Na dissolved. After the solution was cooled to room temperature, enone **3**[8] (30.0 mg, 0.166 mmol) in *i*-PrOH (0.8 mL) was added. TLC analysis of the reaction indicated that the starting material was consumed within 15 min. The solvent was removed *in vacuo*, and the residue was diluted with Et_2O. This solution was washed with 1 N $NaHSO_4$ (aq), then the aqueous layer was extracted twice with Et_2O. The combined organic layers were washed with brine, dried over Na_2SO_4, filtered, and concentrated. The crude material was purified by flash column chromatography (33% Et_2O-hexanes) to afford 93% yield (25 mg) of dienones **5** and **4** (ratio of **5** : **4** = 82 : 18). A sufficient amount of pure **5** for characterization was obtained by preparative HPLC (10% EtOAc-hexanes) separation of the mixture of **5** and **4**. Data for **5**: ^{1}H NMR ($CDCl_3$, 500 MHz): 6.26 (app t, *J* = 2.7 Hz, 1H), 5.89 (s, 1H), 2.68-2.63 (br m, 1H), 2.50 (dd, *J* = 4.9, 15.9 Hz, 1H), 2.35-2.30 (m, 1H), 2.28-2.21 (m, 1H), 2.17 (dd, *J* = 15.9, 14.2 Hz, 1H), 2.04 (d, *J* = 1.2 Hz, 3H), 2.00-1.95 (m, 1H), 1.89-1.84 (m, 1H), 1.57-1.47 (m, 1H), 1.36 (tdd, *J* = 13.4, 10.7, 2.7 Hz, 1H). ^{13}C NMR ($CDCl_3$, 125 MHz): 199.6, 155.1, 136.6, 131.5, 126.4, 44.8, 35.3, 30.8, 26.7, 21.4, 20.2. IR (cm^{-1}): 2925, 1662, 1626, 1587, 1395, 1274, 1262. ES-HRMS [M+Na$^+$] Calcd. for $C_{11}H_{14}ONa$: 185.0942, Found: 185.0944.



3-Methyl-4a,5,6,7-tetrahydro-4H-naphthalen-1-one (4). Bisenone **3**[8] (15 mg, 0.083 mmol) was dissolved in CF_3CH_2OH (1.7 mL) in a flame-dried glass reaction vessel bearing a Kontes teflon stopper. The solution was then degassed by three freeze-pump-thaw cycles. To the oxygen-free solution was added PBu_3 (21 μL, 0.083 mmol) via syringe. The solution was stirred at 60 °C for 24 h, and the mixture was partially concentrated to reduce the bulk of the alcoholic solvent. The resulting residue was then diluted with ether and washed with 1 N $NaHSO_4$ (aq), and then the aqueous layer was extracted twice with Et_2O. The combined organic layers were washed with brine, dried over Na_2SO_4, filtered, and concentrated. The crude material was purified by flash column chromatography (33% Et_2O-hexanes) to afford dienone **4** in 70% yield (9.5 mg) as a colorless oil.



3-Methyl-4a,5,6,7-tetrahydro-4H-naphthalen-1-one (19). Bisenone **20** (4.0 mg, 0.017 mmol) was dissolved in CF_3CH_2OH (0.34 mL) in a flame-dried glass reaction vessel bearing a Kontes teflon stopper. The solution was then degassed by three freeze-pump-thaw cycles. To the oxygen-free solution was added PMe_3 (8.6 μL, 0.085 mmol) via syringe. The solution was stirred at 80 °C for 24 h, and the mixture was partially concentrated to reduce the bulk of the alcoholic solvent. The resulting residue was then diluted with ether and washed with 1 N $NaHSO_4$ (aq), and then the aqueous layer was extracted twice with Et_2O. The combined organic layers were washed with brine, dried over Na_2SO_4, filtered, and concentrated. The crude material was purified by flash column chromatography (10% EtOAc-hexanes) to afford dienone **19** in 55% yield (2.0 mg).



4-Isobutyl-8a-methyl-6,7,8,8a-tetrahydro-1H-naphthalen-2-one (21). A mixture of Na metal (1.3 mg, 0.042 mmol) in *t*-AmylOH (0.66 mL) was heated in a 60 °C oil bath until the Na dissolved. After the solution was cooled to room temperature, enone **20** (10 mg, 0.042 mmol) in *t*-AmylOH (0.19 mL) was added. TLC analysis of the reaction indicated that the starting material was consumed within 10 min. The mixture was diluted with benzene, and the solvent was removed *in*

vacuo. The residue was diluted with Et_2O, and this solution was washed with 1 N $NaHSO_4$ (aq). The aqueous layer was extracted twice with Et_2O, and the combined organic layers were washed with brine, dried over Na_2SO_4, filtered, and concentrated. The crude material was purified by flash column chromatography (10% EtOAc-hexanes) to afford 77% yield (7.1 mg) of dienone **21**. ^1H NMR ($CDCl_3$, 500 MHz): 6.18 (dd, *J* = 5.1, 3.2 Hz, 1H), 5.79 (s, 1H), 2.47 (dd, *J* = 13.6, 5.5 Hz, 1H), 2.36 (d, *J* = 15.6 Hz, 1H), 2.31 (d, *J* = 15.9 Hz, 1H), 2.37-2.19 (m, 2H), 1.98 (dd, *J* = 13.4, 8.8 Hz, 1H), 1.87-1.81 (m, 1H), 1.74-1.66 (m, 3H), 1.59-1.53 (m, 1H), 1.13 (s, 3H), 0.96 (d, *J* = 6.6 Hz, 3H), 0.87 (d, *J* = 6.6 Hz, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz): 199.6, 157.3, 139.6, 130.6, 125.6, 52.8, 43.0, 38.1, 36.5, 27.9, 26.8, 25.5, 23.5, 22.3, 17.7. IR (cm^{-1}): 2956, 2932, 1667, 1623, 1465, 1263. ES-HRMS [$M+H^+$] Calcd. for $C_{15}H_{23}O$: 219.1749, Found: 219.1751.

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