N,N-Dimethylaminobenzoates Enable Highly Enantioselective Sharpless Dihydroxylations of 1,1-Disubstituted Alkenes

Yaohong Zhao†, Xiangyou Xing†, Shaolong Zhang and David Zhigang Wang*

Key Laboratory of Chemical Genomics,
School of Chemical Biology and Biotechnology,
Shenzhen Graduate School of Peking University, Shenzhen University Town,
Nanshan District, Shenzhen, China 518055
E-mails: dzw@pku.sz.edu.cn;

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†These two authors contributed equally to the work.
1. General Information

All reactions were carried out under a nitrogen atmosphere with dry solvents under anhydrous conditions, unless otherwise noted. All the chemicals were purchased commercially, and used without further purification. Anhydrous THF and toluene were distilled from sodium-benzophenone, and dichloromethane, and acetonitrile were distilled from calcium hydride. Thin-layer chromatography (TLC) was conducted with 0.25 mm Tsingdao silica gel plates (60F-254) and visualized by exposure to UV light (254 nm) or stained with potassium permanganate. Flash column chromatography was performed using Tsingdao silica gel (60, particle size 0.040–0.063 mm). Reagents were purchased at the highest commercial quality and used without further purification, unless otherwise stated. The 2-methylprop-2-en-1-ol was purchased from Adamas. Other alcohols were synthesized from literature\(^1\), unless otherwise stated. \(^1\)H NMR spectra were recorded on Bruker spectrometers (at 300, 400 or 500 MHz) and are reported relative to deuterated solvent signals. Data for \(^1\)H NMR spectra are reported as follows: chemical shift (δ ppm), multiplicity, coupling constant (Hz) and integration. \(^13\)C NMR spectra were recorded on Bruker Spectrometers (at 75, 100 or 125 MHz). Data for \(^13\)C NMR spectra are reported in terms of chemical shift. Mass spectrometric data were obtained using Bruker Apex IV RTMS. The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad.

2. General Procedure for the Preparation of the Olefin Substrate

A solution of the N,N-dimethyl amino benzoic acid (1.5 equiv.), 4-(dimethylamino) pyridine (DMAP) (0.5 equiv.) in dried methylene chloride (0.1 M) was treated with EDC-HCl (1.5 equiv.) and Et$_3$N (1.5 equiv.) at 23 °C under nitrogen atmosphere. The resulting mixture was stirred for 30 min and then was treated with the corresponding alcohol. After completion (monitored by TLC analysis), the reaction mixture was quenched with saturated NaHCO$_3$ (aq.), and extracted with methylene chloride. The combined organic layer was washed with brine, dried over Na$_2$SO$_4$, and concentrated in vacuo to give crude product, which was purified by flash chromatography to afford the indicated yield of product.

3. $^1$H NMR and $^{13}$C NMR spectra data of compounds 1a-1f, 3a-19a

2-methylallyl 6-methoxy-2-naphthoate (1a): Following the general procedure, 2-methylprop-2-en-1-ol (104 mg, 1.21 mmol) and the corresponding acid afforded the olefin 1a (248 mg, 80% yield). $^1$H NMR (400 MHz, CDCl$_3$) δ 8.56 (s, 1H), 8.06 (dd, $J$ = 8.8, 2.4 Hz, 1H), 7.84 (d, $J$ = 8.8 Hz, 1H), 7.76 (d, $J$ = 8.8 Hz, 1H), 7.20 (dd, $J$ = 2.4, 8.8 Hz, 2H), 7.15 (d, $J$ = 2.4 Hz, 1H), 5.13 (s, 1H), 5.02 (s, 1H), 4.81 (s, 2H), 3.94 (s, 3H), 1.88 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 166.5, 159.5, 140.1, 137.2, 130.8, 127.9, 126.8, 125.9, 125.2, 119.6, 112.9, 105.6, 68.1, 55.3, 19.6; HRMS calculated for C$_{16}$H$_{17}$O$_3$ (M + H$^+$): 257.1172, found: 257.1175.

2-methylallyl benzo[d][1,3]dioxole-5-carboxylate (1b): Following the general procedure, 2-methylprop-2-en-1-ol (104 mg, 1.21 mmol) and the corresponding acid afforded the olefin 1b (223 mg, 79% yield). $^1$H NMR (400 MHz, CDCl$_3$) δ 7.69 (dd, $J$ = 8.4, 1.6 Hz, 1H), 7.49 (d, $J$ = 1.6 Hz, 1H), 6.84 (d, $J$ = 8.4 Hz, 1H), 6.04 (s, 2H), 5.10 (s, 1H), 4.79 (s, 1H), 3.94 (s, 3H), 1.88 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 163.7, 159.5, 140.1, 137.2, 130.8, 127.9, 126.8, 125.9, 125.2, 119.6, 112.9, 105.6, 68.1, 55.3, 19.6; HRMS calculated for C$_{16}$H$_{17}$O$_3$ (M + H$^+$): 257.1172, found: 257.1175.
5.05 (s, 1H), 4.97 (s, 1H), 4.70 (s, 2H), 1.82 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 166.5, 151.6, 147.7, 140.0, 125.4, 124.1, 109.5, 101.7, 68.0, 19.5; HRMS calculated for C\(_{13}\)H\(_{13}\)O\(_4\) (M + H\(^{+}\)): 221.0808, found: 221.0809.

2-methylallyl 4-phenoxybenzoate (1c): Following the general procedure, 2-methylprop-2-en-1-ol (104 mg, 1.21 mmol) and the corresponding acid afforded the olefin 1c (269 mg, 83% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 8.04 (d, \(J = 8.8\) Hz, 2H), 7.41-7.37 (m, 2H), 7.19 (t, \(J = 7.2\) Hz, 1H), 7.07 (dd, \(J = 1.2, 8.8\) Hz, 2H), 7.00 (d, \(J = 8.8\) Hz, 2H), 5.07 (s, 1H), 4.98 (s, 1H), 4.73 (s, 2H), 1.83 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 165.7, 161.8, 155.6, 140.0, 131.7, 130.0, 124.5, 124.4, 120.0, 117.3, 112.8, 67.9, 19.5; HRMS calculated for C\(_{17}\)H\(_{17}\)O\(_3\) (M + H\(^{+}\)): 269.1172, found: 269.1173.

2-methylallyl 4-ethoxybenzoate (1d): Following the general procedure, 2-methylprop-2-en-1-ol (104 mg, 1.21 mmol) and the corresponding acid afforded the olefin 1d (200 mg, 75% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 8.01 (d, \(J = 8.8\) Hz, 2H), 6.90 (d, \(J = 8.8\) Hz, 2H), 5.06 (s, 1H), 4.96 (s, 1H), 4.71 (s, 2H), 4.08 (q, \(J = 7.2\) Hz, 2H), 1.83 (s, 3H), 1.43 (t, \(J = 7.2\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 166.0, 162.8, 140.2, 131.6, 122.3, 114.0, 112.6, 67.7, 63.6, 19.5, 14.6; HRMS calculated for C\(_{13}\)H\(_{17}\)O\(_3\) (M + H\(^{+}\)): 221.1172, found: 221.1173.

2-methylallyl 4-methoxybenzoate (1e): Following the general procedure, 2-methylprop-2-en-1-ol (104 mg, 1.21 mmol) and the corresponding acid afforded the
olefin 1e (220 mg, 88% yield). $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.03 (d, $J = 8.8$ Hz, 2H), 6.92 (d, $J = 8.8$ Hz, 2H), 5.06 (s, 1H), 4.97 (s, 1H), 4.72 (s, 2H), 3.86 (s, 3H), 1.83 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 165.9, 163.4, 140.2, 131.6, 122.6, 113.6, 112.6, 67.8, 55.4, 19.5; HRMS calculated for C$_{12}$H$_{15}$O$_3$ (M + H$^+$): 207.1016, found: 207.1012.

![olefin 1e](image)

2-methylallyl 4-(dimethylamino)benzoate (1f): Following the general procedure, 2-methylprop-2-en-1-ol (113mg, 1.57 mmol) and the corresponding acid afforded the olefin 1f (258 mg, 75% yield). $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 7.95 (d, $J = 9.0$ Hz, 2H), 6.65 (d, $J = 9.0$ Hz, 2H), 5.06 (s, 1H), 4.95 (s, 1H), 4.70 (s, 2H), 3.01 (s, 6H), 1.83 (s, 3H); $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ 166.6, 153.3, 140.6, 131.3, 116.9, 112.2, 110.7, 67.3, 40.0, 19.6; HRMS calculated for C$_{13}$H$_{18}$NO$_2$ (M + H$^+$): 220.1332, found: 220.1335.

![olefin 1f](image)

2-methylenebutyl 4-(dimethylamino)benzoate (3a): Following the general procedure, the alcohol$^1$ (91 mg, 1.05 mmol) and the corresponding acid afforded the olefin 3a (163 mg, 70% yield). $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.94 (d, $J = 9.2$ Hz, 2H), 6.64 (d, $J = 9.2$ Hz, 2H), 5.10 (s, 1H), 4.96 (s, 1H), 4.74 (s, 2H), 3.03 (s, 6H), 2.16 (q, $J = 7.2$ Hz, 2H), 1.11 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 166.6, 153.3, 146.2, 131.3, 116.9, 110.7, 110.4, 66.6, 40.0, 26.1, 12.0; HRMS calculated for C$_{14}$H$_{20}$NO$_2$ (M + H$^+$): 234.1489, found: 234.1488.
2-methylenepentyl 4-(dimethylamino)benzoate (4a): Following the general procedure, the alcohol\(^1\) (150 mg, 1.50 mmol) and the corresponding acid afforded the olefin 5a (203 mg, 55% yield). \(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.94 (d, \(J = 9.0\) Hz, 2H), 6.65 (d, \(J = 9.0\) Hz, 2H), 5.11 (s, 1H), 4.96 (s, 1H), 4.72 (s, 2H), 3.04 (s, 6H), 2.12 (q, \(J = 7.2\) Hz, 2H), 1.60-1.47 (m, 2H), 0.94 (t, \(J = 7.2\) Hz, 3H); \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 166.6, 153.3, 144.6, 131.3, 116.9, 111.6, 110.7, 66.5, 40.0, 35.5, 20.7, 13.8; HRMS calculated for C\(_{13}\)H\(_{22}\)NO\(_2\) (M + H\(^+\)): 248.1645, found: 248.1646.

2-methylenehexyl 4-(dimethylamino)benzoate (5a): Following the general procedure, the alcohol\(^1\) (114 mg, 1.00 mmol) and the corresponding acid afforded the olefin 5a (144 mg, 55% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.94 (d, \(J = 8.8\) Hz, 2H), 6.64 (d, \(J = 8.8\) Hz, 2H), 5.10 (s, 1H), 4.95 (s, 1H), 4.73 (s, 2H), 3.04 (s, 6H), 2.14 (t, \(J = 7.2\) Hz, 2H), 1.51-1.45 (m, 2H), 1.38-1.33 (m, 2H), 0.92 (t, \(J = 7.2\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 166.6, 153.3, 144.7, 131.3, 117.0, 111.4, 110.7, 66.5, 40.0, 33.0, 29.7, 22.4, 13.9; HRMS calculated for C\(_{16}\)H\(_{24}\)NO\(_2\) (M + H\(^+\)): 262.1802, found: 262.1802.

2-methylenheptyl 4-(dimethylamino)benzoate (6a): Following the general procedure, the alcohol\(^1\) (200 mg, 1.58 mmol) and the corresponding acid afforded the olefin 6a (259 mg, 60% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.94 (d, \(J = 8.8\) Hz, 2H), 6.65 (d, \(J = 8.8\) Hz, 2H), 5.10 (d, \(J = 1.2\) Hz, 1H), 4.95 (d, \(J = 1.2\) Hz, 1H), 4.72 (s, 2H), 3.04 (s, 6H), 2.13 (t, \(J = 8.0\) Hz, 2H), 1.51-1.47 (m, 2H), 1.34-1.29 (m, 4H), 0.90 (t, \(J = 6.8\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 166.6, 153.3, 144.7, 131.3, 117.0, 111.4, 110.7, 66.5, 40.0, 33.3, 31.5, 27.2, 22.5, 14.0; HRMS calculated for C\(_{17}\)H\(_{26}\)NO\(_2\) (M + H\(^+\)): 276.1958, found: 276.1957.
2-methyleneoctyl 4-(dimethylamino)benzoate (7a): Following the general procedure, the alcohol\(^1\) (195 mg, 1.50 mmol) and the corresponding acid afforded the olefin 7a (340 mg, 82% yield). \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta 7.94\) (d, \(J = 8.8\) Hz, 2H), 6.65 (d, \(J = 8.8\) Hz, 2H), 5.10 (s, 1H), 4.95 (s, 1H), 4.72 (s, 2H), 3.04 (s, 6H), 2.13 (t, \(J = 8.0\) Hz, 2H), 1.54-1.46 (m, 2H), 1.35-1.26 (m, 6H), 0.89 (t, \(J = 6.8\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 166.6, 153.3, 144.7, 131.3, 117.0, 111.4, 110.7, 66.5, 40.0, 33.4, 31.7, 29.0, 27.5, 22.6, 14.0\); HRMS calculated for C\(_{18}\)H\(_{28}\)N\(_2\)O\(_2\) (M + H\(^+\)): 290.2120, found: 290.2123.

2-(((tert-butyldimethylsilyl)oxy)methyl)allyl 4-(dimethylamino)benzoate (8a): Following the general procedure, the alcohol\(^1\) (244 mg, 1.20 mmol) and the corresponding acid afforded the olefin 8a (267 mg, 62% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 7.92\) (d, \(J = 8.8\) Hz, 2H), 6.65 (d, \(J = 8.8\) Hz, 2H), 5.10 (t, \(J = 0.8\) Hz, 1H), 4.95 (d, \(J = 1.2\) Hz, 1H), 4.79 (s, 2H), 4.25 (s, 2H), 3.04 (s, 6H), 0.91 (d, \(J = 2.8\) Hz, 9H), 0.08 (t, \(J = 2.8\) Hz, 6H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 166.6, 153.3, 143.8, 131.3, 116.9, 112.3, 110.7, 64.4, 63.9, 40.0, 25.9, 18.4, 5.4\); HRMS calculated for C\(_{19}\)H\(_{32}\)NO\(_3\)Si (M + H\(^+\)): 350.2146, found: 350.2142.

2-(((tert-butyldiphenylsilyl)oxy)methyl)allyl 4-(dimethylamino)benzoate (9a): Following the general procedure, the alcohol\(^1\) (200 mg, 0.61 mmol) and the corresponding acid afforded the olefin 9a (284 mg, 60% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 7.87\) (d, \(J = 9.2\) Hz, 2H), 7.72-7.66 (m, 4H), 7.46-7.36 (m, 6H), 6.64 (d, \(J = 9.2\) Hz, 2H), 5.37 (s, 1H), 5.27 (s, 1H), 4.81 (s, 2H), 4.31 (s, 2H), 3.05 (s, 6H), 1.09 (s,
2-(((triisopropylsilyl)oxy)methyl)allyl 4-(dimethylamino)benzoate  (10a):
Following the general procedure, the alcohol\(^1\) (243 mg, 1.00 mmol) and the corresponding acid afforded the olefin 10a (300 mg, 77% yield). \(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta 7.92\) (d, \(J = 8.8\) Hz, 2H), 6.65 (d, \(J = 8.8\) Hz, 2H), 5.32 (s, 1H), 5.22 (s, 1H), 4.80 (s, 2H), 4.34 (s, 2H), 3.04 (s, 6H), 1.16-1.11 (m, 3H), 1.09 (s, 12H), 1.07 (s, 6H); \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 166.6, 153.3, 143.9, 131.3, 116.9, 111.9, 110.7, 64.5, 64.1, 40.0, 18.0, 12.0; HRMS calculated for C\(_{22}\)H\(_{38}\)NO\(_3\)Si (M + H\(^+\)): 392.6215, found: 392.6212.

2-(methoxymethyl)allyl 4-(dimethylamino)benzoate (11a): Following the general procedure, the alcohol\(^1\) (153 mg, 1.50 mmol) and the corresponding acid afforded the olefin 11a (224 mg, 60% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 7.93\) (d, \(J = 9.2\) Hz, 2H), 6.65 (d, \(J = 9.2\) Hz, 2H), 5.29 (s, 1H), 5.25 (s, 1H), 4.80 (s, 2H), 4.01 (s, 2H), 3.35 (s, 3H), 3.04 (s, 6H); \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 166.5, 153.4, 141.2, 131.3, 116.8, 114.4, 110.7, 73.3, 64.3, 58.0, 40.0; HRMS calculated for C\(_{14}\)H\(_{20}\)NO\(_3\) (M + H\(^+\)): 250.1438, found: 250.1435.

2-((benzylxy)methyl)allyl 4-(dimethylamino)benzoate (12a): Following the general procedure, the alcohol\(^1\) (216 mg, 1.20 mmol) and the corresponding acid afforded the olefin 12a (213 mg, 65% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 7.92\) (d, \(J = 9.2\) Hz, 2H), 6.65 (d, \(J = 9.2\) Hz, 2H), 5.29 (s, 1H), 5.25 (s, 1H), 4.80 (s, 2H), 4.01 (s, 2H), 3.35 (s, 3H), 3.04 (s, 6H); \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 166.5, 153.4, 141.2, 131.3, 116.8, 114.4, 110.7, 73.3, 64.3, 58.0, 40.0; HRMS calculated for C\(_{14}\)H\(_{20}\)NO\(_3\) (M + H\(^+\)): 250.1438, found: 250.1435.
= 8.8 Hz, 2H), 7.36-7.28 (m, 5H), 6.65 (d, J = 8.8 Hz, 2H), 5.33 (s, 1H), 5.30 (s, 1H), 4.85 (s, 2H), 4.55 (s, 2H), 4.13 (s, 2H), 3.04 (s, 6H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 166.5, 153.4, 141.3, 138.1, 131.3, 128.4, 127.7, 127.6, 116.8, 114.7, 110.7, 72.2, 70.9, 64.4, 40.0; HRMS calculated for C\(_{20}\)H\(_{24}\)N O\(_3\) (M + H\(^+\)): 326.1751, found: 326.1752.

\[ \text{2-((prop-2-yn-1-yloxy)methyl)allyl 4-(dimethylamino)benzoate (13a):} \]

Following the general procedure, the alcohol\(^1\) (254 mg, 2.00 mmol) and the corresponding acid afforded the olefin \(13\)a (431 mg, 78% yield). \(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.93 (d, \(J = 9.0\) Hz, 2H), 6.65 (d, \(J = 9.0\) Hz, 2H), 5.33 (s, 1H), 5.29 (s, 1H), 4.18-4.17 (overlapped, 4H), 3.04 (s, 6H), 2.42 (s, 1H); \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 166.5, 153.4, 140.5, 131.3, 116.7, 115.5, 110.7, 79.5, 74.6, 70.2, 64.2, 57.2, 40.0; HRMS calculated for C\(_{16}\)H\(_{20}\)NO\(_3\) (M + H\(^+\)): 274.1438, found: 274.1440.

\[ \text{4-(benzyloxy)-2-methylenebutyl 4-(dimethylamino)benzoate (14a):} \]

Following the general procedure, the alcohol\(^1\) (384 mg, 2.00 mmol) and the corresponding acid afforded the olefin \(14\)a (427 mg, 63% yield). \(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.94 (dd, \(J = 3.3, 8.6\) Hz, 2H), 7.36-7.28 (overlapped, 5H), 6.65 (d, \(J = 8.6\) Hz, 2H), 5.20 (s, 1H), 5.06 (s, 1H), 4.77 (s, 2H), 4.54 (d, \(J = 1.8\) Hz, 2H), 3.66 (td, \(J = 1.8, 6.6\) Hz, 2H), 3.04 (s, 6H), 2.50 (t, \(J = 6.6\) Hz, 2H); \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta\) 166.5, 153.3, 141.7, 138.3, 131.3, 128.4, 127.6, 127.5, 116.8, 113.4, 110.7, 73.0, 68.7, 66.6, 40.0, 33.7; HRMS calculated for C\(_{21}\)H\(_{26}\)NO\(_3\) (M + H\(^+\)): 340.1907, found: 340.1911.
(15a): Following the general procedure, the alcohol (1702 mg, 5.00 mmol) and the corresponding acid afforded the olefin 15a (1485 mg, 60% yield). $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.95-7.92 (m, 2H), 7.70-7.68 (overlapped, 4H), 7.44-7.40 (overlapped, 6H), 6.65 (dd, $J= 1.6, 8.8$ Hz, 2H), 5.18 (s, 1H), 5.00 (s, 1H), 4.72 (s, 2H), 3.88-3.84 (m, 2H), 3.04 (s, 6H), 2.42 (t, $J= 6.4$ Hz, 2H), 1.08 (d, $J= 3.2$ Hz, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 166.5, 153.3, 141.7, 135.6, 133.8, 131.3, 129.6, 127.6, 117.0, 113.7, 110.7, 66.6, 62.7, 40.0, 36.6, 26.8, 19.2; HRMS calculated for C$_{30}$H$_{38}$NO$_3$Si (M + H$^+$): 488.2615, found: 488.2615.

4-hydroxy-2-methylenebutyl 4-(dimethylamino)benzoate (S15): To a solution of 15a (2.26 g, 4.65 mmol) in acetonitrile at 0°C, HF aqueous solution (4.65 mL) was added dropwise. Then the mixture was allowed elevated to room temperature. After completion (monitored by TLC analysis), the reaction was quenched by saturated aqueous NaHCO$_3$, diluted with Et$_2$O, washed with brine, and dried over Na$_2$SO$_4$. Concentration in reduced pressure afforded the crude product. Purification by flash column chromatography to deliver the hydroxy product S15 (1.1g, 95% yield). $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.92 (d, $J= 9.2$ Hz, 2H), 6.64 (d, $J= 9.2$ Hz, 2H), 5.22 (s, 1H), 5.06 (s, 1H), 4.75 (s, 2H), 3.79 (t, $J= 5.6$ Hz, 2H), 3.03 (s, 6H), 2.41 (t, $J= 5.6$ Hz, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 166.7, 153.4, 141.3, 131.3, 116.6, 114.3, 110.7, 66.2, 60.8, 40.0, 36.7; HRMS calculated for C$_{14}$H$_{20}$NO$_3$ (M + H$^+$): 250.1438, found: 250.1442.

4-((tert-butyldimethylsilyl)oxy)-2-methylenebutyl 4-(dimethylamino)benzoate (16a): To a solution of S15 (114 mg, 0.45 mmol) in dried DCM (5 mL) was added Et$_3$N (90 mg, 0.90 mmol) and DMAP (18 mg, 0.15 mmol) at 0°C. Subsequently, TBSCI (135 mg, 0.90 mmol) was added as one portion. The resulting mixture was
allowed to reach room temperature. After completion (monitored by TLC analysis), the reaction was quenched with saturated aqueous NH₄Cl, extracted with DCM. The combined organic phase was washed with brine, dried over Na₂SO₄, filtered and concentrated to afford the crude product. Purification via flash column chromatography gave 16a (142 mg, 87% yield). ¹H NMR (400 MHz, CDCl₃) δ 7.93 (d, J = 9.2 Hz, 2H), 6.64 (d, J = 9.2 Hz, 2H), 5.16 (d, J = 1.2 Hz, 1H), 5.00 (d, J = 1.2 Hz, 1H), 4.74 (s, 2H), 3.78 (t, J = 6.8 Hz, 2H), 3.04 (s, 6H), 2.37 (t, J = 6.8 Hz, 2H), 0.89 (s, 9H), 0.06 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 166.5, 153.3, 141.9, 131.3, 116.9, 113.4, 110.7, 66.7, 62.1, 40.0, 36.9, 25.9, 25.6, 18.3; HRMS calculated for C₂₀H₃₄N₂O₃Si (M + H⁺): 364.2302, found: 364.2303.

4-chloro-2-methylenebutyl 4-(dimethylamino)benzoate (17a): To a stirred solution of S15 (80 mg, 0.32 mmol) and PPh₃ (168 mg, 0.64 mmol) in dried DCM (6 mL) was added hexachloroacetone (169 mg, 0.64 mmol) at room temperature. The resulting mixture was maintained at this temperature for 2h. The reaction was quenched with cold water, extracted with DCM. The combined organic phase was washed with brine, dried over Na₂SO₄, filtered and concentrated to afford the crude product. Purification via flash column chromatography afforded 17a (80 mg, 93% yield). ¹H NMR (300 MHz, CDCl₃) δ 7.92 (d, J = 9.0 Hz, 2H), 6.65 (d, J = 9.0 Hz, 2H), 5.27 (s, 1H), 5.09 (s, 1H), 4.75 (s, 2H), 3.69 (t, J = 7.2 Hz, 2H), 3.04 (s, 6H), 2.63 (t, J = 7.2 Hz, 2H); ¹³C NMR (75 MHz, CDCl₃) δ 166.5, 153.4, 140.7, 131.3, 116.5, 115.3, 110.7, 66.2, 42.4, 40.0, 36.5; HRMS calculated for C₁₄H₁₉NO₂Cl (M + H⁺): 268.1099, found: 268.1094.

4-fluoro-2-methylenebutyl 4-(dimethylamino)benzoate (18a): To a solution of S15 (80 mg, 0.32 mmol) in dried DCM (6 mL) was added DAST (128 mg, 0.8 mmol) at
-78°C. The resulting mixture was maintained at this temperature until completion (monitored by TLC analysis). The reaction was quenched with saturated aqueous NaHCO₃, extracted with DCM. The combined organic phase was washed with brine, dried over Na₂SO₄, filtered and concentrated to afford the crude product. Purification via flash column chromatography afforded 18a (37 mg, 46% yield). ¹H NMR (400 MHz, CDCl₃) δ 7.93 (d, J = 8.8 Hz, 2H), 6.65 (d, J = 8.8 Hz, 2H), 5.25 (s, 1H), 5.10 (s, 1H), 4.77 (s, 2H), 4.67 (t, J = 6.0 Hz, 1H), 4.55 (t, J = 6.0 Hz, 1H), 3.04 (s, 6H), 2.58 (t, J = 6.0 Hz, 1H), 2.52 (t, J = 6.0 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 166.5, 153.4, 140.0, 140.0, 131.3, 116.6, 114.8, 110.7, 82.9, 81.3, 66.4, 40.0, 34.3, 34.1; HRMS calculated for C₁₄H₁₉NO₂F (M + H⁺): 252.1394, found: 252.1393.

2-phenylallyl 4-(dimethylamino)benzoate (19a): Following the general procedure, the alcohol (134 mg, 1.00 mmol) prepared from oxidation of prop-1-en-2-ylbenzene via SeO₂ and the corresponding acid afforded the olefin 19a (166 mg, 60% yield). ¹H NMR (400 MHz, CDCl₃) δ 7.90 (d, J = 9.2 Hz, 2H), 7.50 (d, J = 7.2 Hz, 2H), 7.38-7.30 (m, 3H), 6.63 (d, J = 9.2 Hz, 2H), 5.58 (s, 1H), 5.45 (s, 1H), 5.17 (s, 2H), 3.03 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 166.6, 153.4, 143.0, 138.4, 131.4, 131.2, 128.4, 127.9, 126.0, 116.8, 114.6, 110.7, 65.4, 40.0; HRMS calculated for C₁₈H₂₀NO₂ (M + H⁺): 282.1489, found: 282.1490.

4. General Procedure for the Asymmetric Dihydroxylation
A suspension of AD-mix-β in 'BuOH/H₂O (0.1M, 1:1) was cooled to 0°C, and treated with the corresponding olefin (0.1 mmol). The resulting mixture was stirred vigorously and maintained at 0°C until the starting material disappeared by TLC analysis. After completion, the reaction mixture was quenched with saturated Na₂SO₄ (aq.), stirred for 10 min, and warmed to room temperature. Then the mixture was diluted with EtOAc and minimal water, extracted with EtOAc. The combined organic
layer was washed with brine, dried over Na$_2$SO$_4$, and concentrated in vacuo to give crude product, which was purified by flash chromatography to afford the indicated yield of product.

5. $^1$H NMR and $^{13}$C NMR spectra data of compounds 2a-2f, 3b-20b

(S)-2,3-dihydroxy-2-methylpropyl 6-methoxy-2-naphthoate (2a): Compound 2a was obtained via the general procedure in 68% yield. Chiral HPLC analysis (CHIRALCEL AD-H column), 85:15 hexane/ethanol at 1.0 mL/min flow rate; $t_R$ (R)-enantiomer (minor) = 39.7 min., $t_R$ (S)-enantiomer (major) = 41.6 min.; 29:71 er. $^1$H NMR (500 MHz, CDCl$_3$) δ 8.49 (s, 1H), 7.98 (dd, $J$ = 7.5, 1.5 Hz, 1H), 7.81 (d, $J$ = 8.5 Hz, 1H), 7.72 (d, $J$ = 8.5 Hz, 1H), 7.18 (dd, $J$ = 2.5, 8.5 Hz, 2H), 7.12 (d, $J$ = 2.5 Hz, 1H), 4.44 (d, $J$ = 11.5 Hz, 1H), 4.29 (d, $J$ = 11.5 Hz, 1H), 3.92 (s, 3H), 3.63 (d, $J$ = 11.5 Hz, 1H), 3.52 (d, $J$ = 11.5 Hz, 1H), 1.31 (s, 3H); $^{13}$C NMR (125 MHz, CDCl$_3$) δ 167.4, 159.8, 137.4, 131.2, 130.9, 127.8, 127.0, 125.8, 124.5, 119.8, 105.7, 72.2, 68.4, 67.0, 55.4, 21.4; HRMS calculated for C$_{16}$H$_{18}$O$_5$Na (M + Na$^+$): 313.1046, found: 313.4048.

![Chromatogram](image.png)

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(S)-2,3-dihydroxy-2-methylpropyl benzo[d][1,3]dioxole-5-carboxylate (2b):

Compound 2b was obtained via the general procedure in 67% yield. Chiral HPLC analysis (CHIRALCEL AD-H column), 70:30 hexane/ethanol at 1.0 mL/min flow rate; t<sub>R</sub> (R)-enantiomer (minor) = 25.7 min., t<sub>R</sub> (S)-enantiomer (major) = 27.3 min.; 15:85 er. ¹H NMR (300 MHz, CDCl₃) δ 7.62 (dd, J = 8.1, 1.5 Hz, 1H), 7.42 (d, J = 1.5 Hz, 1H), 6.81 (d, J = 8.1Hz, 1H), 4.14 (d, J = 11.2 Hz, 1H), 6.02 (s, 2H), 4.32 (d, J = 11.4 Hz , 1H), 4.37 (d, J = 11.4 Hz, 1H), 4.36 (d, J = 11.4 Hz, 1H), 3.45 (d, J = 11.4 Hz, 1H), 1.24 (s, 3H); ¹³C NMR (75 MHz, CDCl₃) δ 166.4, 151.9, 147.7, 125.6, 123.4, 109.5, 108.0, 101.9, 72.1, 68.2, 66.9, 21.3; HRMS calculated for C₁₂H₁₄O₆Na (M + Na⁺): 277.0683, found: 277.0687.
(S)-2,3-dihydroxy-2-methylpropyl 4-phenoxybenzoate (2c): Compound 2c was obtained via the general procedure in 83% yield. Chiral HPLC analysis (CHIRALCEL AD-H column), 85:15 hexane/ethanol at 1.0 mL/min flow rate; \( t_R \) (R)-enantiomer (minor) = 23.1 min., \( t_R \) (S)-enantiomer (major) = 21.7 min.; 18:82 er. 

\[ ^1H \text{NMR} (400 MHz, CDCl}_3\quad \delta \ 7.99 \ (d, \ J = 8.8 Hz, 2H), 7.41-7.37 \ (m, 2H), 7.19 \ (t, \ J = 7.2 Hz, 1H), 7.05 \ (dd, \ J = 1.2, 8.8 Hz, 2H), 6.98 \ (d, \ J = 8.8 Hz, 2H), 4.37 \ (d, \ J = 11.2 Hz, 1H), 4.21 \ (d, \ J = 11.2 Hz, 1H), 3.57 \ (d, \ J = 11.2 Hz, 1H), 3.47 \ (d, \ J = 11.2 Hz, 1H), 1.26 \ (s, 3H); \]

\[ ^13C \text{NMR} (100 MHz, CDCl}_3\quad \delta \ 166.6, 162.2, 155.3, 131.8, 130.0, 124.6, 123.6, 120.1, 117.3, 72.1, 68.1, 66.8, 21.3; \] HRMS calculated for
\[ \text{C}_{17}\text{H}_{18}\text{O}_{3}\text{Na (M + Na\(^+\)): 325.1046, found: 325.1043.} \]

\[ (S)-2,3\text{-dihydroxy-2-methylpropyl 4-ethoxybenzoate (2d): Compound 2d was obtained via the general procedure in 76% yield. Chiral HPLC analysis (CHIRALCEL AD-H column), 85:15 hexane/ethanol at 1.0 mL/min flow rate; } t_R (R)-enantiomer (minor) = 32.4\text{ min.}, t_R (S)-enantiomer (major) = 30.2\text{ min.}; 16:84 \text{ er.} \]

\[ ^1\text{H NMR (300 MHz, CDCl}_3\text{) } \delta 7.96 (d, J = 9.0 \text{ Hz, 2H}), 6.89 (d, J = 9.0 \text{ Hz, 2H}), 4.35 (d, J = 11.4 \text{ Hz, 1H}), 4.18 (d, J = 11.4 \text{ Hz, 1H}), 4.06 (d, J = 7.2 \text{ Hz, 2H}), 3.56 (d, J = 11.4 \text{ Hz, 1H}), 3.45 (d, J = 11.4 \text{ Hz, 1H}), 1.42 (d, J = 7.2 \text{ Hz, 1H}), 1.25 (s, 3H); ^{13}\text{C NMR (75 MHz, CDCl}_3\text{) } \delta 166.9, 163.1, 131.8, 121.5, 114.1, 72.2, 68.0, 66.8, 21.3, 14.6; \text{ HRMS calculated for C}_{13}\text{H}_{18}\text{O}_{3}\text{Na (M + Na\(^+\)): 277.1046, found: 277.1046.}} \]
(S)-2,3-dihydroxy-2-methylpropyl 4-methoxybenzoate (2e): Compound 2e was obtained via the general procedure in 88% yield. Chiral HPLC analysis (CHIRALCEL OD-H column), 95:5 hexane/ethanol at 1.0 mL/min flow rate; t<sub>R</sub> (R)-enantiomer (minor) = 23.8 min., t<sub>R</sub> (S)-enantiomer (major) = 25.1 min.; 7:93 er. 

$^1$H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.97 (d, J = 8.8 Hz, 2H), 6.90 (d, J = 8.8 Hz, 2H), 4.35 (d, J = 11.2 Hz, 1H), 4.19 (d, J = 11.2 Hz, 1H), 3.84 (s, 3H), 3.56 (d, J = 11.6 Hz, 1H), 3.45 (d, J = 11.6 Hz, 1H), 1.25 (s, 3H); $^{13}$C NMR (100 MHz, CDCl<sub>3</sub>) δ 166.8, 163.7, 131.8, 121.8, 113.7, 72.1, 68.0, 66.8, 55.4, 21.3; HRMS calculated for C<sub>12</sub>H<sub>16</sub>O<sub>5</sub>Na (M + Na<sup>+</sup>): 263.0890, found: 263.0893.
(S)-2,3-dihydroxy-2-methylpropyl 4-(dimethylamino)benzoate (2f): Compound 2f was obtained via the general procedure in 92% yield. Chiral HPLC analysis (CHIRALCEL AS-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; tR (R)-enantiomer (minor) = 14.8 min., tR (S)-enantiomer (major) = 15.6 min.; 2:98 er.

AD-mix-α: Chiral HPLC analysis (CHIRALCEL AS-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; tR (S)-enantiomer (minor) = 14.8 min., tR (R)-enantiomer (major) = 15.6 min.; 3:97 er. 1H NMR (400 MHz, CDCl3) δ 7.88 (d, J = 9.2 Hz, 2H), 6.61 (d, J = 9.2 Hz, 2H), 4.34 (d, J = 11.2 Hz, 1H), 4.14 (d, J = 11.2 Hz, 1H), 3.53 (d, J = 11.2 Hz, 1H), 3.42 (d, J = 11.2 Hz, 1H), 3.02 (s, 6H), 1.24 (s,
\(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 167.6, 153.6, 131.5, 115.8, 110.7, 72.2, 67.6, 66.8, 40.0, 21.3; HRMS calculated for C\(_{13}\)H\(_{19}\)NO\(_4\)Na (M + Na\(^+\)): 276.1206, found: 276.1027.

\[(S)-2\text{-hydroxy-2-(hydroxymethyl)butyl 4-(dimethylamino)benzoate (3b):} \]

Compound 3b was obtained via the general procedure in 85% yield. Chiral HPLC analysis (CHIRALCEL AS-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; \(t_R\) (\(R\))-enantiomer (minor) = 12.0 min., \(t_R\) (\(S\))-enantiomer (major) = 14.8 min.; 5:95 er.

\(^1\)H NMR (300 MHz, CDCl\(_3\)) \(\delta\) 7.89 (d, \(J = 9.0\) Hz, 2H), 6.64 (d, \(J =9.0\) Hz, 2H), 4.40
(S)-2-hydroxy-2-(hydroxymethyl)pentyl 4-(dimethylamino)benzoate (4b):

Compound 4b was obtained via the general procedure in 84% yield. Chiral HPLC analysis (CHIRALCEL AD-H column), 80:20 hexane/ethanol at 1.0 mL/min flow rate; t_R (R)-enantiomer (minor) = 27.1 min., t_R (S)-enantiomer (major) = 22.0 min.; 5:95 er. 1H NMR (400 MHz, CDCl_3) δ 7.99 (d, J = 9.2 Hz, 2H), 6.63 (d, J = 9.2 Hz, 2H), 4.37 (d, J = 11.2 Hz, 1H), 4.17 (d, J = 11.2 Hz, 1H), 3.53 (dd, J = 11.6, 4.0 Hz, 2H), 3.43 (d, J = 11.4 Hz, 1H), 3.05 (s, 6H), 1.61 (q, J = 7.8 Hz, 2H), 0.99 (t, J = 7.8 Hz, 3H); 13C NMR (75 MHz, CDCl_3) δ 167.7, 153.6, 131.5, 115.8, 110.7, 73.9, 66.6, 65.2, 40.0, 27.0, 7.1; HRMS calculated for C_{14}H_{21}NO_2Na (M + Na^+): 290.1363, found: 290.1360.
1H), 3.44 (dd, J = 11.6, 5.6 Hz, 1H), 3.04 (s, 6H), 2.99 (s, 1H), 2.84 (s, 1H), 1.57-1.42 (m, 4H), 0.94 (t, J = 6.8 Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 167.6, 153.6, 131.5, 116.9, 115.9, 110.7, 73.8, 66.0, 65.4, 40.0, 36.8, 16.0, 14.7; HRMS calculated for C$_{15}$H$_{23}$NO$_4$Na (M + Na$^+$): 304.1519, found: 304.1519.

$^{(S)}$-2-hydroxy-2-(hydroxymethyl)hexyl 4-(dimethylamino)benzoate (5b):

Compound 4b was obtained via the general procedure in 90% yield. Chiral HPLC analysis (CHIRALCEL AS-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; t$_R$ (R)-enantiomer (minor) = 9.7 min., t$_R$ (S)-enantiomer (major) = 10.3 min.; 8:92 er.

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.89 (d, J = 9.2 Hz, 2H), 6.64 (d, J =9.2 Hz, 2H), 4.38 (d, J = 11.6 Hz, 1H), 4.17 (d, J = 11.6 Hz, 1H), 3.53 (d, J = 11.6 Hz, 1H), 3.44 (d, J =
11.4 Hz, 1H), 3.04 (s, 6H), 1.57-1.44 (m, 2H), 1.42-1.36 (m, 4H), 0.92 (t, J = 7.2 Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 167.6, 153.6, 131.5, 115.9, 110.7, 73.8, 65.9, 65.5, 40.0, 34.1, 24.8, 23.3, 14.0; HRMS calculated for C$_{16}$H$_{25}$NO$_4$Na (M + H$^+$): 318.1676, found: 318.1674.

(S)-2-hydroxy-2-(hydroxymethyl)heptyl 4-(dimethylamino)benzoate (6b):

Compound 6b was obtained via the general procedure in 85% yield. Chiral HPLC analysis (CHIRALCEL OJ-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; $t_R$ (R)-enantiomer (minor) = 16.8 min., $t_R$ (S)-enantiomer (major) = 17.9 min.; 8:92 er.
$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.88 (d, $J = 8.8$ Hz, 2H), 6.63 (d, $J = 8.8$ Hz, 2H), 4.38 (d, $J = 11.6$ Hz, 1H), 4.17 (d, $J = 11.6$ Hz, 1H), 3.54-3.51 (m, 1H), 3.46-3.41 (m, 1H), 3.04 (s, 6H), 2.95 (s, 1H), 2.81 (s, 1H), 1.58-1.53 (m, 2H), 1.45-1.41 (m, 2H), 1.34 -1.25 (m, 4H), 0.89 (t, $J = 6.8$ Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 167.6, 153.6, 131.5, 115.9, 110.7, 73.8, 65.9, 65.5, 40.0, 34.4, 32.4, 22.5, 22.3, 14.0; HRMS calculated for C$_{17}$H$_{27}$NO$_4$Na (M + Na$^+$): 332.1832, found: 332.1832.

(S)-2-hydroxy-2-(hydroxymethyl)octyl 4-(dimethylamino)benzoate (7b): Compound 7b was obtained via the general procedure in 70% yield. Chiral HPLC analysis (CHIRALCEL OD-H column), 85:15 hexane/ethanol at 1.0 mL/min flow rate;
t_R (R)-enantiomer (minor) = 9.5 min., t_R (S)-enantiomer (major) = 15.0 min.; 14:86 er.

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.89 (d, J = 8.8 Hz, 2H), 6.64 (d, J = 8.8 Hz, 2H), 4.39 (d, J = 11.6 Hz, 1H), 4.16 (d, J = 11.6 Hz, 1H), 3.54-3.50 (m, 1H), 3.46-3.41 (m, 1H), 3.05 (s, 6H), 2.92 (t, J = 6.4 Hz, 1H), 2.77 (s, 1H), 1.58-1.54 (m, 2H), 1.44-1.41 (m, 2H), 1.32-1.25 (m, 6H), 0.88 (t, J = 6.8 Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 167.7, 153.6, 131.5, 115.8, 110.7, 73.8, 65.9, 65.5, 40.0, 34.4, 31.7, 29.8, 22.6, 22.5, 14.0; HRMS calculated for C$_{18}$H$_{29}$NO$_4$Na (M + Na$^+$): 346.1989, found: 346.1992.

(8b) 

(S)-3-((tert-butyldimethylsilyl)oxy)-2-hydroxy-2-(hydroxymethyl)propyl 4-(dimethylamino)benzoate (8b): Compound 8b was obtained via the general
procedure in 90% yield. Chiral HPLC analysis (CHIRALCEL IB-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; t_R (R)-enantiomer (minor) = 9.1 min., t_R (S)-enantiomer (major) = 13.1 min.; 19:9 er. 1H NMR (400 MHz, CDCl₃) δ 7.88 (d, J = 9.2 Hz, 2H), 6.65 (d, J = 9.2 Hz, 2H), 4.35 (d, J = 11.2 Hz, 1H), 4.30 (d, J = 11.2 Hz, 1H), 3.70 (s, 2H), 3.62 (d, J = 6.4 Hz, 2H), 3.17 (s, 1H), 3.03 (s, 6H), 3.72 (t, J = 6.8 Hz, 1H), 0.90 (s, 9H), 0.08 (s, 6H); 13C NMR (100 MHz, CDCl₃) δ 167.4, 153.5, 131.4, 116.0, 110.7, 73.9, 64.7, 64.4, 64.1, 39.9, 25.8, 18.2, 5.6; HRMS calculated for C₁₉H₃₃NO₅NaSi (M + Na⁺): 406.2020, found: 406.2022.

(S)-3-((tert-butyldiphenylsilyl)oxy)-2-hydroxy-2-(hydroxymethyl)propyl 4-(dimethylamino)benzoate (9b): Compound 9b was obtained via the general
procedure in 70% yield. Chiral HPLC analysis (CHIRALCEL IB-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; $t_R$ (R)-enantiomer (minor) = 11.5 min., $t_R$ (S)-enantiomer (major) = 18.5 min.; 2:98 er. $^1$H NMR (400 MHz, CDCl$_3$) δ 7.84 (d, $J$ = 9.2 Hz, 2H), 7.68-7.66 (m, 4H), 7.43-7.34 (m, 6H), 6.63 (d, $J$ = 9.2 Hz, 2H), 4.42-4.42 (m, 2H), 3.75 (s, 2H), 3.66 (d, $J$ = 6.4 Hz, 2H), 3.04 (s, 6H), 2.50 (t, $J$ = 6.4 Hz, 2H), 1.08 (s, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 167.4, 153.5, 135.5, 132.7, 132.6, 131.5, 129.8, 127.8, 116.0, 110.6, 74.3, 64.8, 64.6, 64.1, 40.0, 26.8, 19.2; HRMS calculated for C$_{29}$H$_{37}$NO$_5$NaSi (M + Na$^+$): 530.2333, found: 530.2332.

\[\text{(S)-2,3-dihydroxy-2-(((triisopropylsilyl)oxy)methyl)propyl}}\]

4-(dimethylamino)benzoate (10b): Compound 10b was obtained via the general
procedure in 83% yield. Chiral HPLC analysis (CHIRALCEL IB-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; $t_R$ ($R$)-enantiomer (minor) = 8.3 min., $t_R$ ($S$)-enantiomer (major) = 12.6 min.; 2:98 er. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.88 (d, $J$ = 9.2 Hz, 2H), 6.63 (d, $J$ = 9.2 Hz, 2H), 4.39 (d, $J$ = 11.6 Hz, 1H), 4.33 (d, $J$ = 11.6 Hz, 1H), 3.80 (s, 2H), 3.65 (d, $J$ = 6.8 Hz, 2H), 3.22 (s, 1H), 3.01 (s, 6H), 3.69 (t, $J$ = 6.8 Hz, 1H), 1.17-1.10 (m, 3H), 1.09-1.06 (overlapped, 18H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 167.4, 153.5, 131.5, 116.0, 110.6, 74.0, 64.7, 64.2, 40.0, 17.9, 11.8; HRMS calculated for C$_{22}$H$_{39}$NO$_5$NaSi (M + Na$^+$): 448.2490, found: 448.2488.

(R)-2,3-dihydroxy-2-(methoxymethyl)propyl 4-(dimethylamino)benzoate (11b): Compound 11b was obtained via the general procedure in 81% yield. Chiral HPLC
(S)-enantiomer (minor) = 13.8 min., \( t_R (R) \)-enantiomer (major) = 17.2 min.; 2:98 er.

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.90 (d, \( J = 12.0 \) Hz, 2H), 6.64 (d, \( J = 12.0 \) Hz, 2H), 4.34 (s, 2H), 3.64 (dd, \( J = 8.8 \) Hz, 2H), 3.50 (s, 2H), 3.40 (s, 3H), 3.17 (s, 1H), 3.04 (s, 6H), 2.75 (d, \( J = 8.8 \) Hz, 1H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 167.4, 153.6, 131.5, 115.9, 110.7, 74.2, 73.6, 64.9, 64.2, 59.6, 40.0; HRMS calculated for C\(_{14}\)H\(_{21}\)NO\(_3\)Na (M + Na\(^+\)) = 306.1312, found: 306.1310.

\((R)-3\)-(benzyloxy)-2-hydroxy-2-(hydroxymethyl)propyl 4-(dimethylamino)benzoate (12b): Compound 4b was obtained via the general procedure in 78% yield. Chiral HPLC analysis (CHIRALCEL OD-H column), 85:15 hexane/ethanol at 1.0 mL/min flow rate; \( t_R \) (S)-enantiomer (minor) = 18.2 min., \( t_R \) (R)-enantiomer (major) = 20.5 min.; 2:98 er.
hexane/ethanol at 1.0 mL/min flow rate; \( t_R \) (S)-enantiomer (minor) = 24.7 min., \( t_R \) (R)-enantiomer (major) = 21.1 min.; >1:99 er. 

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \): 7.86 (d, \( J = 8.8 \) Hz, 2H), 7.34-7.30 (m, 5H), 6.62 (d, \( J = 8.8 \) Hz, 2H), 4.58 (d, \( J = 1.2 \) Hz, 2H), 4.38 (d, \( J = 1.2 \) Hz, 2H), 3.64 (dd, \( J = 6.8, 2.4 \) Hz, 2H), 3.59 (s, 2H), 3.17 (s, 1H), 3.04 (s, 6H), 2.68 (t, \( J = 6.8 \) Hz, 1H); 

\(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \): 167.4, 153.5, 137.7, 131.5, 128.4, 127.8, 127.7, 116.0, 110.7, 73.8, 73.7, 71.5, 64.9, 64.3, 40.0; HRMS calculated for \( C_{20}H_{25}NO_5Na \) (M + Na\(^+\)): 382.1625, found: 382.1628.

(R)-2,3-dihydroxy-2-((prop-2-yn-1-yloxy)methyl)propyl

4-(dimethylamino)benzoate (13b): Compound 13b was obtained via the general procedure in 77% yield. Chiral HPLC analysis (CHIRALCEL IB-H column), 90:10
hexane/ethanol at 1.0 mL/min flow rate; $t_R$ (S)-enantiomer (minor) = 20.7 min., $t_R$ (R)-enantiomer (major) = 25.1 min.; 2:98 er. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.89 (d, $J = 8.8$ Hz, 2H), 6.63 (d, $J = 8.8$ Hz, 2H), 4.36 (s, 2H), 4.21 (d, $J = 2.4$ Hz, 2H), 3.65-3.63 (overlapped, 4H), 3.19 (s, 1H), 3.04 (s, 6H), 2.73 (s, 1H), 2.43 (d, $J = 2.4$ Hz, 1H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 167.4, 153.6, 131.5, 115.9, 110.7, 79.2, 75.0, 71.0, 64.8, 64.0, 58.8, 40.0; HRMS calculated for C$_{16}$H$_{21}$NO$_3$Na (M + Na$^+$): 330.1312, found: 330.1312.

(S)-4-(benzyloxy)-2-hydroxy-2-(hydroxymethyl)butyl 4-(dimethylamino)benzoate (14b): Compound 14b was obtained via the general procedure in 80% yield. Chiral HPLC analysis (CHIRALCEL IB-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; $t_R$ (R)-enantiomer (minor) = 21.3 min., $t_R$ (S)-enantiomer (major) = 22.8
min.; 2:98 er. $^1$H NMR (400 MHz, CDCl$_3$) δ 7.89 (d, $J$= 8.8 Hz, 2H), 7.37-7.26 (overlapped, 5H), 6.63 (d, $J$= 8.8 Hz, 2H), 4.55 (d, $J$= 11.6 Hz, 1H), 4.31 (s, 2H), 3.83-3.78 (m, 2H), 3.75-3.71 (m, 2H), 3.57 (d, $J$= 6.4 Hz, 2H), 3.04 (s, 6H), 2.03-1.97 (m, 1H), 1.91-1.85 (m, 1H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 167.2, 153.5, 137.4, 131.4, 128.5, 127.9, 127.7, 116.0, 110.6, 73.7, 73.4, 66.4, 66.3, 65.8, 39.9, 33.5; HRMS calculated for C$_{21}$H$_{27}$NO$_5$Na (M + Na$^+$): 396.1781, found: 396.1779.

(S)-4-((tert-butyldiphenylsilyl)oxy)-2-hydroxy-2-(hydroxymethyl)butyl

4-(dimethylamino)benzoate (15b): Compound 15b was obtained via the general procedure in 69% yield. Chiral HPLC analysis (CHIRALCEL AD-H column), 80:20 hexane/ethanol at 1.0 mL/min flow rate; $t_R$ (R)-enantiomer (minor) = 9.3 min., $t_R$
(S)-enantiomer (major) = 7.1 min.; >1:99 er. \(^1^H\) NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.88 (d, \(J = 8.8\) Hz, 2H), 7.70-7.67 (overlapped, 4H), 7.45-7.39 (overlapped, 6H), 6.62 (d, \(J = 8.8\) Hz, 2H), 4.39 (d, \(J = 11.2\) Hz, 1H), 4.35 (d, \(J = 11.2\) Hz, 1H), 4.07 (s, 1H), 4.03-3.99 (m, 1H), 3.95-3.91 (m, 1H), 3.62 (d, \(J = 6.8\) Hz, 2H), 3.04 (s, 6H), 1.99-1.93 (m, 1H), 1.87-1.77 (m, 1H), 1.07 (s, 9H); \(^1^C\) NMR (100 MHz, CDCl\(_3\)) \(\delta\) 167.2, 153.5, 135.5, 132.6, 131.5, 130.0, 127.9, 127.9, 116.1, 110.7, 74.0, 66.4, 66.0, 60.7, 40.0, 35.3, 26.8, 19.0; HRMS calculated for C\(_{30}\)H\(_{39}\)NO\(_5\)NaSi (M + Na\(^+\)): 544.2490, found: 544.2488.
procedure in 88% yield. Chiral HPLC analysis (CHIRALCEL IB-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; \( t_R \) \((R)-\)enantiomer (minor) = 9.9 min., \( t_R \) \((S)-\)enantiomer (major) = 11.3 min.; \( >1:99 \) er. 

\( ^1 \)H NMR (300 MHz, CDCl) \( \delta \) 7.90 (d, \( J = 9.0 \) Hz, 2H), 6.62 (d, \( J = 9.0 \) Hz, 2H), 4.35 (d, \( J = 11.4 \) Hz, 1H), 4.26 (d, \( J = 11.4 \) Hz, 1H), 4.12 (s, 1H), 4.01-3.94 (m, 1H), 3.92-3.85 (m, 1H), 3.57 (d, \( J = 5.4 \) Hz, 1H), 3.10 (t, \( J = 6.0 \) Hz, 1H), 3.03 (s, 6H), 2.03-1.87 (m, 1H), 1.82-1.74 (m, 1H), 0.90 (s, 9H), 0.09 (d, \( J = 2.1 \) Hz, 6H); \( ^{13} \)C NMR (75 MHz, CDCl) \( \delta \) 167.2, 153.5, 131.5, 116.1, 110.6, 74.0, 66.3, 65.9, 59.7, 40.0, 35.1, 25.8, 18.0, 5.6; HRMS calculated for C\(_{20}\)H\(_{36}\)NO\(_5\)Si (M + H\(^+\)): 398.2357, found: 398.2357.

\[(S)-4\text{-chloro}-2\text{-hydroxy}-2\text{-(hydroxymethyl)}\text{butyl \ 4-(dimethylamino)benzoate}\]
(17b): Compound 17b was obtained via the general procedure in 70% yield. Chiral HPLC analysis (CHIRALCEL IB-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; tR (R)-enantiomer (minor) = 19.7 min., tR (S)-enantiomer (major) = 24.8 min.; 6:94 er. 1H NMR (400 MHz, CDCl3) δ 7.88 (d, J = 9.2 Hz, 2H), 6.64 (d, J = 9.2 Hz, 2H), 4.41 (d, J = 11.6 Hz, 1H), 4.17 (d, J = 11.6 Hz, 1H), 3.76-3.71 (m, 2H), 3.57-3.53 (m, 1H), 3.49-3.44 (m, 1H), 3.09 (s, 1H), 3.04 (s, 6H), 2.22-2.04 (m, 2H); 13C NMR (100 MHz, CDCl3) δ 167.7, 153.7, 131.6, 115.4, 110.7, 73.5, 65.7, 65.1, 40.0, 39.4, 35.6; HRMS calculated for C14H20NO4NaCl (M + Na+): 324.0973, found: 324.0976.
(18b): Compound 18b was obtained via the general procedure in 73% yield. Chiral HPLC analysis (CHIRALCEL AS-H column), 90:10 hexane/ethanol at 1.0 mL/min flow rate; t_R (R)-enantiomer (minor) = 18.7 min., t_R (S)-enantiomer (major) = 23.2 min.; 6:94 er. ^1H NMR (400 MHz, CDCl₃) δ 7.89 (d, J = 9.2 Hz, 2H), 6.64 (d, J = 9.2 Hz, 2H), 4.79 (t, J = 6.4 Hz, 1H), 4.67 (t, J = 6.4 Hz, 1H), 4.45 (d, J = 11.6 Hz, 1H), 4.22 (d, J = 11.6 Hz, 1H), 3.54 (q, J = 11.6 Hz, 1H), 3.04 (s, 6H), 2.04 (t, J = 6.0 Hz, 1H), 1.97 (t, J = 6.0 Hz, 1H); ^13C NMR (100 MHz, CDCl₃) δ 167.7, 153.7, 131.6, 115.5, 110.7, 81.0, 79.4, 73.1, 66.3, 66.4, 40.0, 35.1, 34.9; HRMS calculated for C₁₆H₂₁NO₄F (M + H⁺): 286.1449, found: 286.1451.

2,3-dihydroxy-2-phenylpropyl 4-(dimethylamino)benzoate (19b): Compound 19b
was obtained via the general procedure in 65% yield. Chiral HPLC analysis (CHIRALCEL OJ-H column), 85:15 hexane/ethanol at 1.0 mL/min flow rate; t\textsubscript{R} minor-enantiomer = 38.1 min., t\textsubscript{R} major-enantiomer = 48.1 min.; 29:72 er. \textsuperscript{1}H NMR (300 MHz, CDCl\textsubscript{3}) δ 7.84 (d, J = 9.0 Hz, 2H), 7.54 (d, J = 6.9 Hz, 2H), 7.39-7.29 (m, 3H), 6.60 (d, J = 9.0 Hz, 2H), 4.62 (d, J = 11.7 Hz, 1H), 4.50 (d, J = 11.7 Hz, 1H), 3.88 (d, J = 11.7 Hz, 1H), 3.74 (d, J = 8.1 Hz, 2H), 3.13 (s, 1H), 3.01 (s, 6H); \textsuperscript{13}C NMR (75 MHz, CDCl\textsubscript{3}) δ 167.6, 153.6, 141.2, 131.2, 128.3, 127.6, 125.6, 115.8, 110.7, 76.0, 68.0, 67.1, 40.0; HRMS calculated for C\textsubscript{18}H\textsubscript{21}NO\textsubscript{4}Na (M + Na\textsuperscript{+}): 338.1368, found: 338.1362.
6. Copies of $^1$H NMR and $^{13}$C NMR Spectra
zyh-8-101

--- CHANNEL 1 ---

--- CHANNEL 2 ---