

Supporting Information

For

**Diastereoselection during 1,2-addition of
3-bromomethyl-5*H*-furan-2-one to α - chiral aldehydes mediated by
indium in aqueous and organic solvent systems: Direct route to
optically α -methylene- γ -butyrolactones**

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- **General Comments**
- **Crystal Structures and X-ray Diffraction Analysis Data**
- **Experimental Section**
- **NMR Spectra**

General Comments

All solvents were dried prior to use using the standard methods. ¹H and ¹³C NMR spectra were recorded at 400 and 101 MHz, respectively, and chemical shifts were represented as δ -values relative to the internal standard TMS. ¹H: Chemical shifts are reported in ppm with the solvent resonance as the internal standard (CHCl₃: δ 7.27 ppm). Multiplicity was indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiple), dd (doublet of doublet). Coupling constants were reported in Hertz (Hz). The melting points were determined and uncorrected. High-resolution

mass Spectra were conducted using an Ionspec 7.0T spectrometer by ESI-FTICR technique. Flash column chromatography was performed on silica gel 60 (230-400 mesh). Optical rotations were determined using a Perkin Elmer 341 MC polarimeter. NMR spectroscopy data of the known compounds matches with those reported in the corresponding references. All new compounds were further characterized by HRMS.

Crystal Structures and X-ray Diffraction Analysis Data

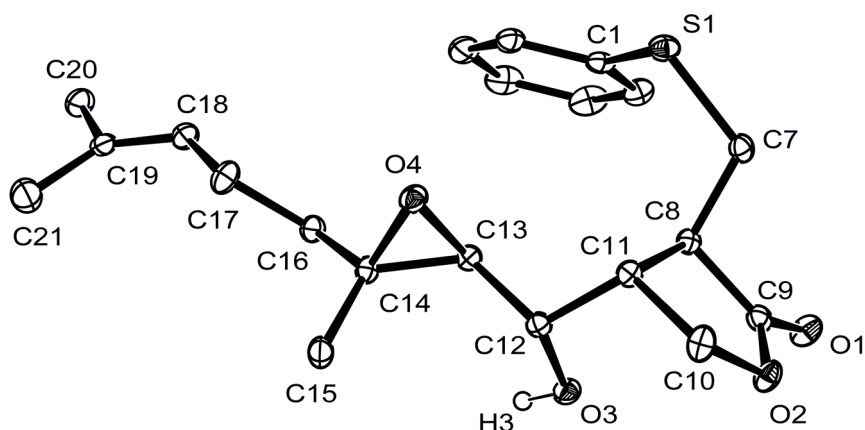


Figure 1. Ortep drawing of **12h'** with 30% probability ellipsoids. Hydrogen atoms have been omitted for clarity. Selected bond lengths (Å) and angles (deg): O3–C12=1.428(2), O4–C13=1.447(2), S1–C7=1.8048(17), C10–C11=1.539(2), C1–S1–C7=102.71(9), O3–C12–C13=110.23(12).

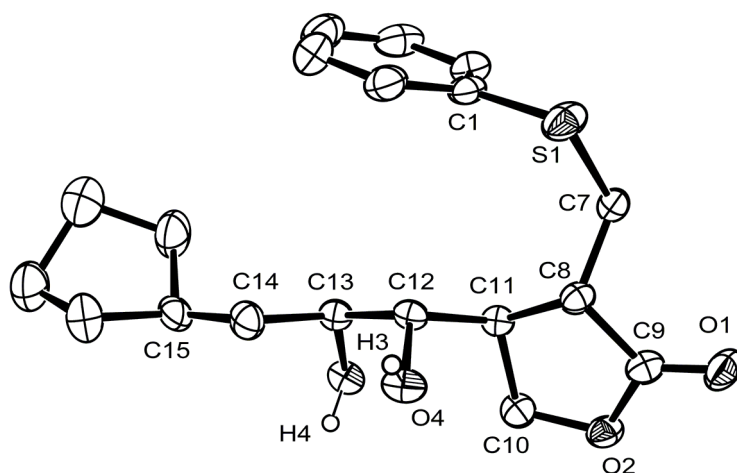


Figure 2. Ortep drawing of **13g'** with 30% probability ellipsoids. Hydrogen atoms have been omitted for clarity. Selected bond lengths (Å) and angles (deg): S1–C1=1.770(2), S1–C7=1.817(2), O2–C9=1.343(3), O3–C12=1.428(2), C1–S1–C7=104.13(12), C9–O2–C10=112.09(15).

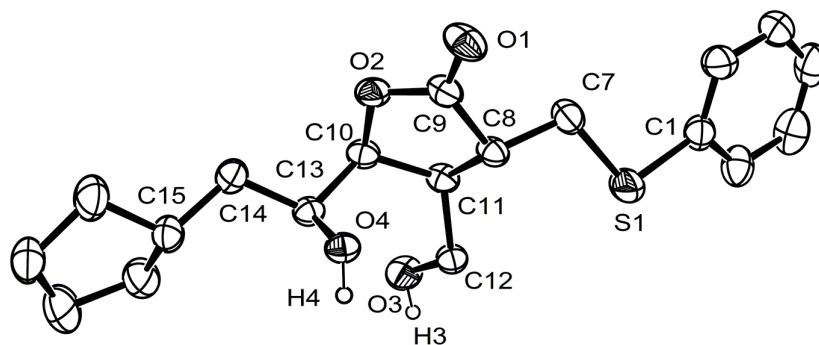


Figure 3. Ortep drawing of **13g''** with 30% probability ellipsoids. Hydrogen atoms have been omitted for clarity. Selected bond lengths (Å) and angles (deg): S1–C1=1.767(3), O2–C10=1.461(3), O3–C12=1.411(3), C1–S1–C7=103.17(11), C9–O2–C10=111.22(17).

All intensity data of **12h'**, **13g'** and **13g''** were collected with a Rigaku Saturn 724 CCD diffractometer using graphite-monochromated Mo K α radiation ($\lambda = 0.71073$ Å) at 113(2) or 293(2) K. The structures were resolved by direct methods^{S4, S5} and refined by full-matrix least-squares on F^2 . Hydrogen atoms were considered in calculated positions. All non-hydrogen atoms were refined anisotropically. Crystals of **12h'** suitable for X-ray analysis were grown from acetidine, **13g'** were grown from acetidine, and **13g''** were grown from acetidine. Crystallographic data for **12h'**, **13g'** and **13g''** are given in Table 1.

Table 4. Crystallographic data for **12h'**, **13g'** and **13g''**.

	12h'	13g'	13g''
formula	C ₂₁ H ₂₈ O ₄ S	C ₁₉ H ₂₆ O ₄ S	C ₁₉ H ₂₆ O ₄ S
fw	376.49	350.46	350.46
<i>T</i> (K)	113(2)	293(2)	293(2)
space group	P2(1)	P2(1)	P2(1)2(1)2(1)
<i>a</i> (Å)	9.514(7)	11.605(2)	9.1195(18)
<i>b</i> (Å)	9.975(7)	5.5973(11)	10.663(2)
<i>c</i> (Å)	10.636(7)	14.561(3)	19.003(4)
α (deg.)	90	90	90
β (deg.)	90.313(9)	104.23(3)	90
γ (deg.)	90	90	90

$V (\text{\AA}^3)$	1009.3(12)	916.8(3)	1847.9(6)
Z	2	2	4
$d_{\text{calcd.}} (\text{g/cm}^3)$	1.239	1.269	1.260
$F(000)$	404	376	752
GOF	1.022	0.991	1.000
$R_1 (I > 2\sigma(I))$	0.0305	0.0396	0.0523
wR_2 (all data)	0.0587	0.1029	0.1368

Experimental Section

Additions Involving Bromide 2 and Aldehyde 1a. A. In H₂O. A magnetically stirred solution of **1a** (188 mg, 1.0 mmol) in water (11 ml) was treated with indium powder (230 mg, 2.0 mmol) and allyl bromide **2** (264 mg, 1.5 mmol). After 12 h, ethyl acetate was added, stirring was maintained for 60 min, and the separated aqueous phase was extracted with ethyl acetate (2 × 20 mL). The combined organic layers were dried and evaporated. Chromatography of the residue on silica gel (elution with petroleum ether/ethyl acetate) gave the products containing a 1.2:1 mixture of **7a** and **8a** as a colourless oil (216 mg, 75.6% yield). The components were identified on the basis of their ¹H NMR chemical shifts and coupling constants in CDCl₃ (at 400MHz): **7a**, δ 6.31 (d, $J = 1.7$ Hz, 1H), 5.91 (s, 1H), 4.03 (dd, $J = 9.2, 6.3$ Hz, 2H), 3.72 (dt, $J = 10.8, 5.5$ Hz, 1H), 3.30 (ddd, $J = 10.6, 7.8, 2.4$ Hz, 1H, H-4), 3.15 – 3.06 (m, 1H), 2.42 (d, $J = 7.8$ Hz, 1H), 1.51 (s, 3H), 0.83 (d, $J = 3.9$ Hz, 9H), 0.05 – 0.01 (m, 6H); **8a**, δ 6.33 (d, $J = 2.2$ Hz, 1H) 6.01 (d, $J = 1.5$ Hz, 1H), 4.33 – 4.25 (m, 2H), 3.72 (dt, $J = 10.8, 5.5$ Hz, 1H), 3.53 – 3.49 (m, 1H, H-4), 2.34 (d, $J = 2.9$ Hz, 1H), 1.51 (s, 3H), 0.83 (d, $J = 3.9$ Hz, 9H), 0.05 – 0.01 (m, 6H). **7a+8a**, ¹³C NMR (101 MHz,): 171.36, 171.26, 135.95, 135.70, 126.31, 125.72, 77.30, 77.02,

69.98, 69.18, 68.05, 67.93, 42.19, 41.46, 26.46, 21.28, 18.68, 18.49, 1.72, -3.27, -3.59, -4.11, -4.20. **HRMS** (ESI) m/z calcd for $C_{14}H_{26}O_4Si$ ($M-H^+$) 285.1522; found 285.1519.

B. In THF. A mixture of **1a** (188 mg, 1.0 mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in THF (11 ml) was stirred 30h. Following product isolation in the prescribed manner, there was isolated 220mg of a 0.8:1 mixture of **7a** and **8a** (77% yield). The products were identified on the basis of their 1H NMR chemical shifts as above.

Additions Involving Bromide 2 and Aldehyde 1b. A. In H₂O. A mixture of **1b** (250mg, 1.0mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in water(11 ml) was stirred at rt for 12 h and worked up in the prescribed manner. The mixture was subjected to flash chromatography on silica gel (elution with petroleum ether/ethyl acetate) gave the products containing a 4:1 mixture of **7b** and **8b** as a colourless oil (279mg, 80% yield). The components were identified on the basis of their 1H NMR chemical shifts and coupling constants in $CDCl_3$ (at 400MHz): **7b**, δ 7.57 (ddd, $J = 11.4, 8.5, 5.7$ Hz, 5H), 6.61 (d, $J = 2.0$ Hz, 1H), 6.18 (d, $J = 1.4$ Hz, 1H), 4.86 (d, $J = 5.6$ Hz, 1H, H-5), 4.54 (t, $J = 8.8$ Hz, 1H), 4.34 – 4.27 (m, 1H), 4.01 (t, $J = 6.4$ Hz, 1H), 3.43 (dddt, $J = 9.0, 6.8, 4.5, 2.2$ Hz, 1H), 2.35 (s, 1H), 1.11 (d, $J = 2.3$ Hz, 9H), 0.28 (t, $J = 6.0$ Hz, 6H); **8b**, 6.56 (d, $J = 2.3$ Hz, 1H), 6.13 (d, $J = 1.9$ Hz, 1H), 4.80 (d, $J = 6.4$ Hz, 1H, H-5), 4.42 (t, $J = 8.8$ Hz, 1H), 3.95 (t, $J = 6.0$ Hz, 1H), 3.29 – 3.22 (m, 1H), 3.12 (s, 1H); **7b+8b**, ^{13}C NMR (101 MHz,): 169.71, 169.66, 139.24, 138.92, 133.63, 127.65, 127.56, 126.32, 126.04, 124.36, 123.88, 76.62, 75.36,

75.22, 67.38, 67.15, 39.43, 39.35, 24.77, 17.07, -5.42, -5.98, -6.13. **HRMS** (ESI) m/z calcd for $C_{19}H_{28}O_4Si$ ($M-H^+$) 347.1679; found 347.1690.

B. In THF. A mixture of **1b** (250mg, 1.0mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in THF (11 ml) was stirred 30h. Following product isolation in the predescribed manner, there was isolated 261mg of a 2.5:1 mixture of **7b** and **8b** (75% yield). The products were identified on the basis of their 1H NMR chemical shifts as above.

Additions Involving Bromide 2 and Aldehyde 1c. A. In H₂O. A mixture of **1c** (312mg, 1.0 mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in water(11 ml) was stirred at rt for 12 h and worked up in the predescribed manner. The mixture was subjected to flash chromatography on silica gel (elution with petroleum ether/ethyl acetate) gave the products containing a 2:1 mixture of **7c** and **8c** as a colourless oil (324mg, 79% yield). The components were identified on the basis of their 1H NMR chemical shifts and coupling constants in $CDCl_3$ (at 400MHz): **7c**, δ 7.58-7.36 (20H), 6.23 (t, $J = 2.4$ Hz, 2H), 5.81 (d, $J = 1.6$ Hz, 2H), 3.24 (ddd, $J = 10.8, 8.0, 2.8$ Hz, 2H, H-4), 2.50 (d, $J = 7.8$ Hz, 2H), 1.12 (d, $J = 6.3$ Hz, 6H), 1.01 (d, $J = 3.1$ Hz, 18H); **8c**, δ 7.58-7.36 (10H), 6.23 (t, $J = 2.4$ Hz, 1H), 5.90 (d, $J = 1.6$ Hz, 1H), 2.38 (d, $J = 2.5$ Hz, 1H), 1.18 (s, 3H), 1.01 (d, $J = 3.1$ Hz, 9H); **7c+8c**, ^{13}C NMR (101 MHz,): 169.66, 169.47, 134.90, 134.76, 134.64, 134.03, 133.78, 132.19, 131.46, 129.33, 129.22, 129.04, 127.08, 126.96, 126.74, 126.67, 124.59, 124.08, 75.54, 75.16, 68.77, 68.50, 66.01, 65.56, 40.34, 39.31, 28.66, 26.03, 25.94, 19.44, 18.25, 18.10, 15.54. **HRMS** (ESI) m/z calcd for $C_{24}H_{30}O_4Si$ ($M-H^+$) 409.1835; found

409.1844.

B. In THF. A mixture of **1c** (312mg, 1.0 mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in THF (11 ml) was stirred 30h. Following product isolation in the predescribed manner, there was isolated 309mg of a 1.5:1 mixture of **7c** and **8c** (75.4% yield). The products were identified on the basis of their ¹H NMR chemical shifts as above.

Additions Involving Bromide 2 and Aldehyde 1d. A. In H₂O. A mixture of **1d** (374mg, 1.0mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in water(11 ml) was stirred at rt for 12 h and worked up in the predescribed manner. The mixture was subjected to flash chromatography on silica gel (elution with petroleum ether/ethyl acetate) gave the products containing a 1:1.2 mixture of **7d** and **8d** as a colourless oil (369mg, 78.2% yield). The components were identified on the basis of their ¹H NMR chemical shifts and coupling constants in CDCl₃ (at 400MHz): **7d**, δ 7.58–7.07 (15H), 6.12 (t, $J = 2.9$ Hz, 1H), 5.56 (d, $J = 1.6$ Hz, 1H), 4.47 (d, $J = 4.4$ Hz, 1H, H-5), 4.03 (d, $J = 8.8$ Hz, 1H), 3.57 (dd, $J = 9.3, 5.4$ Hz, 1H), 2.79 – 2.71 (m, 1H), 2.31 (d, $J = 2.8$ Hz, 1H), 0.95 (d, $J = 11.5$ Hz, 9H); **8d**, δ 7.58–7.07 (18H), 6.12 (t, $J = 2.9$ Hz, 1.2H), 5.51 (d, $J = 1.9$ Hz, 1.2H), 4.53 (d, $J = 6.3$ Hz, 1.2H, H-5), 3.83 (dd, $J = 9.3, 4.6$ Hz, 1.2H), 2.79 – 2.71 (m, 1.2H), 0.95 (d, $J = 11.5$ Hz, 11H); **7c+8c**, ¹³C NMR (101 MHz,): 170.55, 169.52, 138.84, 137.37, 134.99, 134.84, 134.72, 134.68, 133.32, 131.99, 131.24, 131.11, 129.89, 129.26, 129.14, 128.95, 128.90, 127.53, 127.38, 126.97, 126.71, 126.59, 126.54, 126.26, 124.58, 123.70, 76.40, 76.20, 75.23, 67.04, 66.13, 64.54, 39.28, 39.01, 28.67, 25.93, 18.35,

18.27. **HRMS** (ESI) m/z calcd for $C_{29}H_{32}O_4Si$ ($M-H^+$) 471.1992; found 471.1987.

B. In THF. A mixture of **1d** (374mg, 1.0mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in THF (11 ml) was stirred 30h. Following product isolation in the predescribed manner, there was isolated 359mg of a 1:2 mixture of **7d** and **8d** (76% yield). The products were identified on the basis of their 1H NMR chemical shifts as above.

Additions Involving Bromide 2 and Aldehyde 1e. A. In H₂O. A mixture of **1e** (164mg, 1.0mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in water(11 ml) was stirred at rt for 8h and worked up in the predescribed manner. The mixture was subjected to flash chromatography on silica gel (elution with petroleum ether/ethyl acetate) gave the products containing a 0.55:1:0.4 mixture of **7e**, **8e** and **10e** as a colourless oil (211mg, 80.5% yield). The components were identified by comparison with literature¹⁵ and their 1H NMR chemical shifts in $CDCl_3$ (at 400MHz): δ 7.33 – 7.23 (m, 10H), 6.28 (d, $J = 2.4$ Hz, 0.96H), 6.21 (d, $J = 2.4$ Hz, 1H), 5.83 (d, $J = 2.0$ Hz, 0.55H), 5.77 (d, $J = 1.7$ Hz, 0.41H), 5.30 (d, $J = 2.1$ Hz, 1H), 4.66 – 4.56 (m, 2H), 4.47 (dd, $J = 9.2, 4.4$ Hz, 1H), 4.41 – 4.21 (m, 4H), 4.08 – 4.00 (m, 1H), 3.96 (dd, $J = 9.3, 4.9$ Hz, 0.55H), 3.67 – 3.62 (m, 0.41H), 3.53 (tt, $J = 10.1, 5.1$ Hz, 1H), 3.50 – 3.42 (m, 2H), 3.38 (s, 0.55H), 3.24 – 3.18 (m, 1H), 3.17 – 3.12 (m, 1H), 2.40 (dd, $J = 10.4, 3.1$ Hz, 1.37H), 2.19 (d, $J = 4.5$ Hz, 0.37H), 1.26 – 1.20 (m, 6H); ^{13}C NMR (101 MHz,): 169.76, 169.60, 136.70, 136.57, 136.47, 134.77, 134.22, 133.72, 127.62, 127.57, 127.16, 127.11, 127.02, 126.97, 126.80, 124.37, 123.77, 122.34, 75.02, 74.28, 74.13, 73.95, 72.48, 72.42, 69.64, 69.47, 69.39, 66.99, 66.49,

65.91, 41.11, 40.26, 39.81, 28.66, 14.70, 14.67, 13.55. **HRMS** (ESI) m/z calcd for $C_{15}H_{18}O_4$ ($M-H^+$) 261.1127; found 261.1160.

B. In THF. A mixture of **1e** (164mg, 1.0mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in THF (11 ml) was stirred 24h. Following product isolation in the predescribed manner, there was isolated 186mg of a 0.7:1:0.75 mixture of **7e**, **8e** and **10e** (71% yield). The products were identified on the basis of their 1H NMR chemical shifts as above.

Additions Involving Bromide 2 and Aldehyde 1f. A. In H₂O. A mixture of **1f** (144mg, 1.0mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in water(11 ml) was stirred at rt for 6 h and worked up in the predescribed manner. The mixture was subjected to flash chromatography on silica gel (elution with petroleum ether/ethyl acetate) gave the products containing a 0.08:0.07:1.0:0.02 mixture of **11-14f** as a white power (192mg, 79.2% yield). The components were identified by comparison with adducts of **1g** and their 1H NMR chemical shifts in $CDCl_3$ (at 400MHz): **13f**, m.p : 61-63 °C; $[\alpha]_D^{25} = -0.31$ ($c = 0.01$, $CHCl_3$); δ 6.33 (d, $J = 2.5$ Hz, 1H), 5.68 (d, $J = 2.1$ Hz, 1H), 4.50 (dd, $J = 9.3, 4.6$ Hz, 1H), 4.36 – 4.29 (m, 1H), 3.68 – 3.62 (m, 1H), 3.52 (d, $J = 2.1$ Hz, 1H), 3.24 (dtd, $J = 7.8, 5.1, 2.5$ Hz, 1H), 2.55 (d, $J = 4.0$ Hz, 1H), 1.98 (s, 1H), 1.36 – 1.17 (m, 4H), 0.79 (dd, $J = 13.6, 7.2$ Hz, 7H); ^{13}C NMR (101 MHz,): 169.79, 134.83, 122.73, 73.46, 68.38, 66.19, 41.59, 36.55, 35.44, 28.67, 24.81, 23.79, 9.71, 9.35. **HRMS** (ESI) m/z calcd for $C_{13}H_{22}O_4$ ($M+COOH^-$) 287.1495; found 287.1499.

B. In THF. A mixture of **1f** (144mg, 1.0mmol), bromide **2**(264 mg, 1.5 mmol),

and indium powder (230 mg, 2.0 mmol) in THF (11 ml) was stirred 18h. Following product isolation in the prescribed manner, there was isolated 174mg of a 0.08:0:1.0:0.02 mixture of **11-14f** (72% yield). The products were identified on the basis of their ^1H NMR chemical shifts as above.

Additions Involving Bromide 2 and Aldehyde 1g. A. In H₂O. A mixture of **1g** (142mg, 1.0mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in water(11 ml) was stirred at rt for 6 h and worked up in the prescribed manner. The mixture was subjected to flash chromatography on silica gel (elution with petroleum ether/ethyl acetate) gave the products containing a 0.05:0.03:1.0:0.01 mixture of **11-14g** as a white power (204mg, 85% yield). The components were identified by single-crystal X-ray diffraction. **13g**, m.p : 62-64°C; $[\alpha]_{\text{D}}^{25} = -0.193$ ($c = 0.01$, CHCl_3); ^1H NMR (at 400MHz): δ 6.43 (d, $J = 2.3$ Hz, 1H), 5.77 (d, $J = 1.9$ Hz, 1H), 4.60 (dd, $J = 9.3, 4.5$ Hz, 1H), 4.42 (t, $J = 8.7$ Hz, 1H), 3.72 (s, 1H), 3.64 (s, 1H), 3.33 (d, $J = 2.4$ Hz, 1H), 2.46 (d, $J = 5.5$ Hz, 1H), 1.94 (dd, $J = 15.1, 7.3$ Hz, 2H), 1.85 (dd, $J = 17.8, 11.5$ Hz, 2H), 1.67 – 1.48 (m, 5H), 1.13 (ddd, $J = 19.9, 13.6, 8.0$ Hz, 2H); ^{13}C NMR (101 MHz,): 169.68, 134.74, 122.76, 73.08, 69.72, 66.23, 41.59, 39.31, 35.46, 32.16, 31.45, 24.00, 23.84. **HRMS** (ESI) m/z calcd for $\text{C}_{13}\text{H}_{20}\text{O}_4$ ($\text{M}+\text{COOH}^-$) 285.1338; found 285.1346.

B. In THF. A mixture of **1g** (142mg, 1.0mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in THF (11 ml) was stirred 18h. Following product isolation in the prescribed manner, there was isolated 173mg of a 0.06:0.04:1.0:0.01 mixture of **11-14g** (72% yield). The products were identified on the

basis of their ^1H NMR chemical shifts as above.

Additions Involving Bromide 2 and Aldehyde 1h. A. In H₂O. A mixture of **1h** (168mg, 1.0mmol), bromide **2**(264 mg, 1.5 mmol), and indium powder (230 mg, 2.0 mmol) in water(11 ml) was stirred at rt for 16 h and worked up in the predescribed manner. The mixture was subjected to flash chromatography on silica gel (elution with petroleum ether/ethyl acetate) resulted in separation of a 10:1 mixture of **12h** and **14h** from the 3,4-syn;4,5-syn diastereomer **13h** as a yellow oil (232mg, 87.4% containing yield). The components were identified by XRD and their ^1H NMR analyses in CDCl₃ (at 400MHz): **13h**, δ 6.41 (d, $J = 2.2$ Hz, 1H), 5.89 (d, $J = 1.8$ Hz, 1H), 5.05 (d, $J = 6.9$ Hz, 1H), 4.48 – 4.31 (m, 2H), 3.66 (ddd, $J = 4.9$ Hz, 1H), 3.45 – 3.31 (m, 1H), 2.78 (d, $J = 7.5$ Hz, 1H), 2.67 (d, $J = 2.8$ Hz, 1H), 2.02 (dd, $J = 11.5$, 4.1 Hz, 2H), 1.68 (s, 4H), 1.61 (s, 3H), 1.52 – 1.45 (m, 1H), 1.30 (s, 3H); **12h**, δ 6.40 (d, $J = 2.0$ Hz, 1H), 5.97 (d, $J = 1.7$ Hz, 1H), 5.09 (t, $J = 7.1$ Hz, 1H), 4.48 – 4.39 (m, 2H), 3.53 (td, $J = 7.8$, 3.6 Hz, 1H), 3.37 – 3.28 (m, 1H), 2.77 (d, $J = 8.2$ Hz, 1H), 2.36 (d, $J = 4.1$ Hz, 1H), 2.11 (q, $J = 7.5$ Hz, 2H), 1.69 (s, 4H), 1.62 (s, 3H), 1.53 – 1.44 (m, 1H), 1.36 (s, 3H); **14h**, δ 6.40 (d, $J = 2.0$ Hz, 1H), 5.81 (d, $J = 2.3$ Hz, 1H); **13h**, ^{13}C NMR (101 MHz,): 170.16, 134.20, 132.56, 125.01, 123.03, 70.31, 66.64, 63.34, 62.95, 42.71, 38.27, 25.68, 23.39, 17.68, 17.40; **12h+14h**, ^{13}C NMR (101 MHz,): 170.92, 134.40, 132.38, 125.52, 123.26, 70.49, 67.52, 63.29, 61.05, 43.62, 38.21, 25.66, 23.77, 17.69, 16.66. **HRMS** (ESI) m/z calcd for C₁₅H₂₂O₄ (M+H⁺) 267.1596; found 267.1567.

Additions Involving Bromide 2 and Aldehyde 1i. A. In H₂O. A mixture of **1i** (172mg, 0.81mmol), bromide **2**(214mg, 1.21mmol), and indium powder (186mg, 1.62mmol) in water(8.9 ml) was stirred at rt for 12 h and worked up in the prescribed manner. The mixture was subjected to flash chromatography on silica gel (elution with petroleum ether/ethyl acetate) gave the only products **12i** as a white solid (128mg, 70% yield). The absolute configuration of **12i** was determined by comparison with literature¹². $[\alpha]_D^{20} = -34.4$ ($c = 1.18$, CHCl₃); ¹H NMR (400 MHz, CDCl₃): δ 1.11 (d, $J = 7.1$ Hz, 3H), 1.76-1.81 (m, 4H), 1.96 (dt, $J = 4.6, 12.8$ Hz, 1H), 2.06 (ddd, $J = 3.1, 5.9, 8.9$ Hz, 1H), 2.13 (qd, $J = 6.7, 13.1$ Hz, 1H), 2.93-3.01 (m, 2H), 3.34 (s, 3H), 3.71 (d, $J = 6.3$ Hz, 1H), 4.04 (t, $J = 5.0$ Hz, 1H), 4.37 (dd, $J = 3.2, 4.9$ Hz, 1H), 4.55 (d, $J = 6.7$ Hz, 1H), 4.64 (d, $J = 6.7$ Hz, 1H), 4.85 (s, 1H), 4.92 (s, 1H), 5.69 (d, $J = 2.3$ Hz, 1H), 6.28 (d, $J = 2.3$ Hz, 1H); ¹³C NMR (100MHz, CDCl₃): δ 16.5, 23.2, 36.4, 37.7, 45.4, 46.2, 50.7, 55.4, 63.8, 79.5, 80.8, 95.6, 112.7, 123.0, 136.3, 144.0, 170.3; **HRMS** (ESI) calcd for C₁₇H₂₆O₅ (M+Na⁺) 333.1672, found 333.1667.

Michael addition reaction of 11-14g with phenthioi. To a solution of **11-14g** (100 mg, 0.42 mmol) obtained from entry 20 and DMAP (5.0 mg, 0.1equiv) in CH₂Cl₂ (7.2 mL) was added benzenethiol (146mg, 3.2equiv) at room temperature. After stirring for 3 h at that temperature, the solution was concentrated directly, and the crude oil was chromatographed to give two major thioethers **13g'** (96.6 mg) and **13g''**(19.4 mg) which were crystalline. **13g'**, m.p : 53-55 °C; $[\alpha]_D^{25} = 0.023$ ($c = 0.01$, CHCl₃); HPLC: $t_R=4.797$ min; ¹H NMR (at 400MHz): δ 7.35 – 7.31 (m, 2H), 7.25 (dd, $J = 10.3, 4.8$ Hz, 2H), 7.16 (d, $J = 7.3$ Hz, 1H), 4.24 (d, $J = 8.4$ Hz, 2H), 3.52 (d, $J =$

4.3 Hz, 1H), 3.45 (dd, $J = 14.0, 3.8$ Hz, 1H), 3.35 – 3.26 (m, 1H), 3.07 (dd, $J = 14.0, 7.7$ Hz, 1H), 2.91 (ddd, $J = 9.4, 7.8, 3.8$ Hz, 1H), 2.62 (qd, $J = 8.6, 3.9$ Hz, 1H), 2.48 (d, $J = 4.2$ Hz, 1H), 1.98 (s, 1H), 1.78 (dd, $J = 11.5, 4.4$ Hz, 1H), 1.73 – 1.63 (m, 3H), 1.60 – 1.42 (m, 5H), 1.05 – 0.98 (m, 1H), 0.92 (ddd, $J = 7.4, 7.0, 4.4$ Hz, 1H), 0.84 – 0.75 (m, 1H); ^{13}C NMR (100MHz, CDCl_3): 176.26, 134.08, 128.58, 128.32, 125.87, 71.28, 71.15, 65.56, 42.68, 40.50, 38.92, 35.36, 32.56, 32.19, 31.29, 23.98, 23.88; **13g''**, m.p : 56-58°C; $[\alpha]_{\text{D}}^{25} = 0.019$ ($c = 0.01, \text{CHCl}_3$); HPLC: $t_{\text{R}}=4.449\text{min}$; ^1H NMR (at 400MHz): δ 7.32 (d, $J = 7.8$ Hz, 2H), 7.23 (t, $J = 7.5$ Hz, 2H), 7.18 – 7.12 (m, 1H), 4.36 (d, $J = 8.6$ Hz, 1H), 3.91 (dd, $J = 11.8, 3.2$ Hz, 1H), 3.88 – 3.79 (m, 2H), 3.46 (dd, $J = 13.4, 3.6$ Hz, 1H), 3.13 – 3.06 (m, 1H), 2.99 (dd, $J = 13.4, 8.2$ Hz, 1H), 2.84 – 2.71 (m, 2H), 1.77 – 1.65 (m, 4H), 1.57 – 1.44 (m, 6H), 1.09 – 1.00 (m, 2H); ^{13}C NMR (100MHz, CDCl_3): 176.50, 134.00, 128.72, 128.23, 125.81, 80.70, 68.85, 58.66, 44.10, 39.83, 38.84, 35.52, 33.58, 31.93, 31.45, 24.04, 23.83. **HRMS** (ESI) calcd for $\text{C}_{19}\text{H}_{26}\text{O}_4\text{S}$ ($\text{M}+\text{COOH}^-$) 395.1528, found 395.1535.

NMR Spectra

