

## **A Metal-Catalyzed New Approach for $\alpha$ -Alkynylation of Cyclic Amines**

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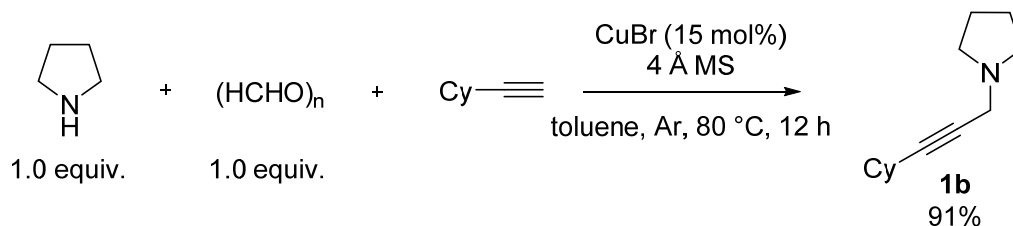
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<b>General information</b>	<b>S1</b>
<b>Experimental details and analytical data</b>	<b>S1</b>
<b>References</b>	<b>S35</b>

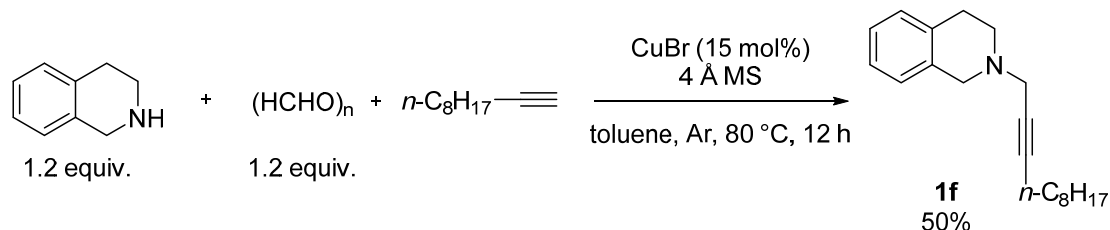


(2) 1-(3-Cyclohexylprop-2-ynyl)pyrrolidine (**1b**) (lwl-8-38)



To a flame-dried Schlenk bottle were added CuBr (219.2 mg, 1.5 mmol), 4 Å molecular sieves (3.0020 g), paraformaldehyde (302.1 mg, 10 mmol), toluene (10 mL), pyrrolidine (711.5 mg, 10 mmol), toluene (10 mL), 1-cyclohexylacetylene (1.0751 g, 10 mmol), and toluene (10 mL) sequentially under Ar atmosphere. The resulting mixture was then stirred at 80 °C for 12 h. After the completion of the reaction as monitored by TLC, the crude reaction mixture was filtrated through a short column of silica gel eluted with EtOAc (100 mL). After evaporation, the residue was purified by column chromatography on silica gel to afford **1b** (1.7405 g, 91%) (eluent: petroleum ether/ ethyl acetate = 5/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 3.37 (s, 2 H, NCH<sub>2</sub>), 2.60 (s, 4 H, 2×NCH<sub>2</sub>), 2.38 (s, 1 H, CH), 1.86-1.62 (m, 8 H, 4×CH<sub>2</sub>), 1.56-1.22 (m, 6 H, 3×CH<sub>2</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 88.6, 75.3, 52.4, 43.4, 32.8, 29.0, 25.8, 24.8, 23.7; MS (ESI) *m/z* 192 ([M+H]<sup>+</sup>); IR (neat) *v* = 2926, 2852, 2780, 2727, 1628, 1447, 1371, 1346, 1322, 1294, 1258, 1235, 1198, 1159, 1124, 1030 cm<sup>-1</sup>; HRMS calcd for C<sub>13</sub>H<sub>22</sub>N ([M+H]<sup>+</sup>): 192.1747. Found: 192.1748.

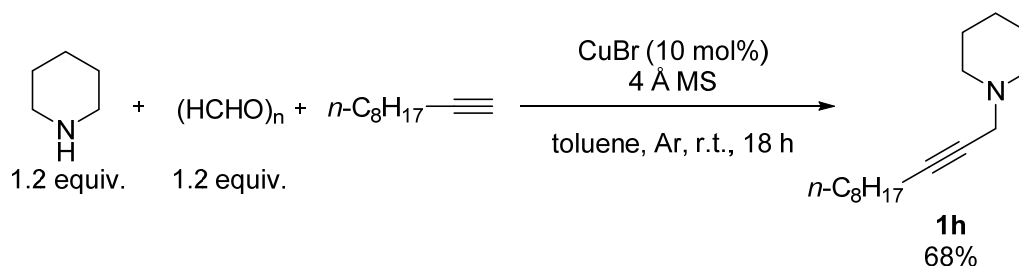
(3) 2-(2-Undecynyl)-1,2,3,4-tetrahydroisoquinoline (**1f**) (cyf-1-103)



To a flame-dried Schlenk bottle were added CuBr (110.5 mg, 0.75 mmol), 4 Å molecular sieves (1.5 g), paraformaldehyde (191.6 mg, 6.0 mmol), 1,2,3,4-tetrahydroisoquinoline (817.5 mg, 6.0 mmol), toluene (7.5 mL), 1-decyne (726.2 mg, 5.0 mmol), and toluene (7.5 mL) sequentially under Ar atmosphere. The

resulting mixture was then stirred at 80 °C for 12 h. After the completion of the reaction as monitored by TLC, the crude reaction mixture was filtrated through a short column of silica gel eluted with DCM (50 mL). After evaporation, the residue was purified by column chromatography on silica gel to afford **1f** (867.2 mg, 50%) (eluent: petroleum ether/ acetone = 100/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.16-7.07 (m, 3 H, ArH), 7.07-7.01 (m, 1 H, ArH), 3.75 (s, 2 H, NCH<sub>2</sub>), 3.46 (s, 2 H, NCH<sub>2</sub>), 2.94 (t, *J* = 5.6 Hz, 2 H, CH<sub>2</sub>), 2.81 (t, *J* = 6.0 Hz, 2 H, CH<sub>2</sub>), 2.20 (t, *J* = 6.8 Hz, 2 H, CH<sub>2</sub>), 1.50 (q, *J* = 7.1 Hz, 2 H, CH<sub>2</sub>), 1.43-1.17 (m, 10 H, 5×CH<sub>2</sub>), 0.87 (t, *J* = 6.4 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 134.7, 133.9, 128.6, 126.6, 126.0, 125.5, 85.7, 74.6, 54.5, 49.8, 47.2, 31.8, 29.3, 29.2, 28.89, 28.86, 22.6, 18.7, 14.1; MS (EI) *m/z* (%) 283 (M<sup>+</sup>, 36.97), 282 (100); IR (neat) *ν* = 3022, 2923, 1585, 1497, 1456, 1429, 1381, 1364, 1328, 1277, 1230, 1192, 1132, 1089, 1056, 1039, 1006 cm<sup>-1</sup>; HRMS calcd for C<sub>20</sub>H<sub>29</sub>N (M<sup>+</sup>): 283.2300. Found: 283.2294.

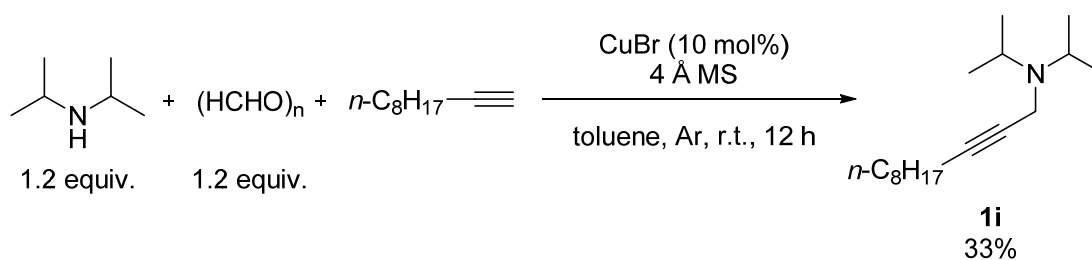
(4) 1-(2-Undecynyl) piperidine (**1h**) (cyf-2-94)



To a flame-dried Schlenk bottle were added CuBr (146.8 mg, 1.0 mmol), 4 Å molecular sieves (3.0113 g), paraformaldehyde (384.2 mg, 12.0 mmol), piperidine (1.0256 g, 12.0 mmol), toluene (15 mL), 1-decyne (1.4535 g, 10.0 mmol), and toluene (15 mL) sequentially under Ar atmosphere. The resulting mixture was then stirred at room temperature for 18 h. After the completion of the reaction as monitored by TLC, the crude reaction mixture was filtrated through a short column of silica gel eluted with ethyl ether (100 mL). After evaporation, the residue was purified by column chromatography on silica gel to afford **1h** (1.6009 g, 68%) (eluent: petroleum ether/ ethyl acetate = 5/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 3.21 (s, 2 H, NCH<sub>2</sub>),

2.48 (s, 4 H, 2×NCH<sub>2</sub>), 2.19 (t, *J* = 7.0 Hz, 2 H, CH<sub>2</sub>), 1.62 (quint, *J* = 5.5 Hz, 4 H, 2×CH<sub>2</sub>), 1.55-1.20 (m, 14 H, 7×CH<sub>2</sub>), 0.88 (t, *J* = 6.6 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 85.1, 75.1, 53.2, 48.0, 31.7, 29.1, 29.0, 28.79, 28.77, 25.8, 23.9, 22.6, 18.6, 14.0; MS (ESI) *m/z* 236 ([M+H]<sup>+</sup>); IR (neat) *ν* = 2927, 2854, 2794, 2752, 2681, 1466, 1453, 1379, 1367, 1340, 1324, 1308, 1298, 1275, 1252, 1203, 1188, 1156, 1105, 1067, 1039 cm<sup>-1</sup>; HRMS calcd for C<sub>16</sub>H<sub>30</sub>N ([M+H]<sup>+</sup>): 236.2373. Found: 236.2376.

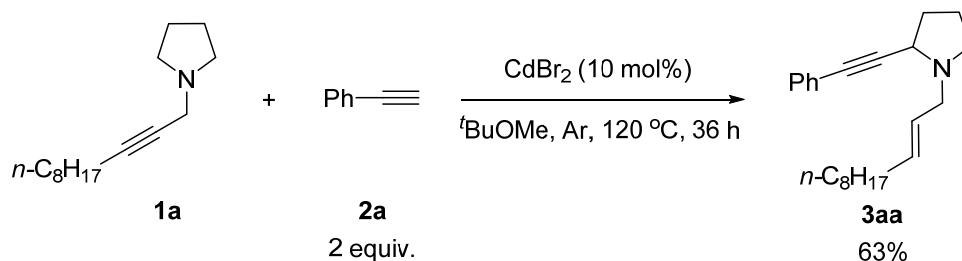
(5) N-(2-undecynyl)-diisopropylamine (**1i**) (cyf-2-88)



To a flame-dried Schlenk bottle were added CuBr (147.0 mg, 1.0 mmol), 4 Å molecular sieves (3.0117 g), paraformaldehyde (383.7 mg, 12.0 mmol), diisopropylamine (1.2301 g, 12.0 mmol), toluene (15 mL), 1-decyne (1.4551 g, 10.0 mmol), and toluene (15 mL) sequentially under Ar atmosphere. The resulting mixture was then stirred at room temperature for 12 h. After the completion of the reaction as monitored by TLC, the crude reaction mixture was filtrated through a short column of silica gel eluted with EtOAc (100 mL). After evaporation, the residue was purified by column chromatography on silica gel to afford **1i** (822.4 mg, 33%) (eluent: petroleum ether/ ethyl acetate = 100/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 3.39 (t, *J* = 2.0 Hz, 2 H, NCH<sub>2</sub>), 3.19 (heptet, *J* = 6.5 Hz, 2 H, 2×NCH), 2.18-2.12 (m, 2 H, CH<sub>2</sub>), 1.48 (quint, *J* = 7.1 Hz, 2 H, CH<sub>2</sub>), 1.42-1.21 (m, 10 H, 5×CH<sub>2</sub>), 1.09 (d, *J* = 6.4 Hz, 12 H, 4×CH<sub>3</sub>), 0.88 (t, *J* = 6.6 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 83.5, 78.7, 48.20, 48.18, 34.3, 31.8, 29.2, 29.1, 28.9, 28.8, 22.6, 20.5, 18.8, 14.1; MS (ESI) *m/z* 252 ([M+H]<sup>+</sup>); IR (neat) *ν* = 2961, 2926, 2855, 1463, 1434, 1379, 1362, 1324, 1204, 1176, 1139, 1118, 1025 cm<sup>-1</sup>; HRMS calcd for C<sub>17</sub>H<sub>34</sub>N ([M+H]<sup>+</sup>): 252.2686. Found: 252.2686.

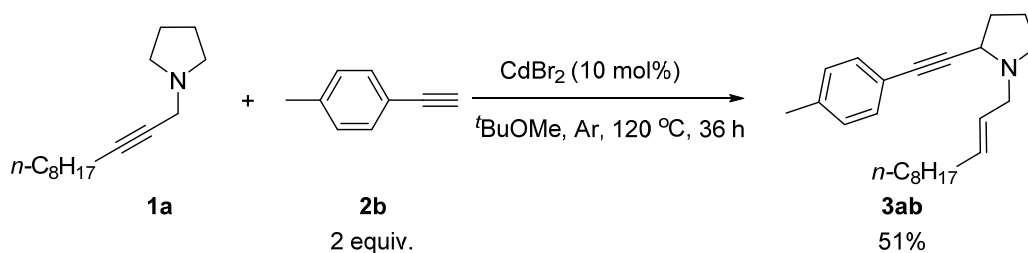
## 2. The CdBr<sub>2</sub>-catalyzed reaction of propargylic amines with terminal alkynes

(1) (*E*)-2-(Phenylethynyl)-1-(2-undecenyl)pyrrolidine (**3aa**) (lwl-7-195, lwl-7-93)



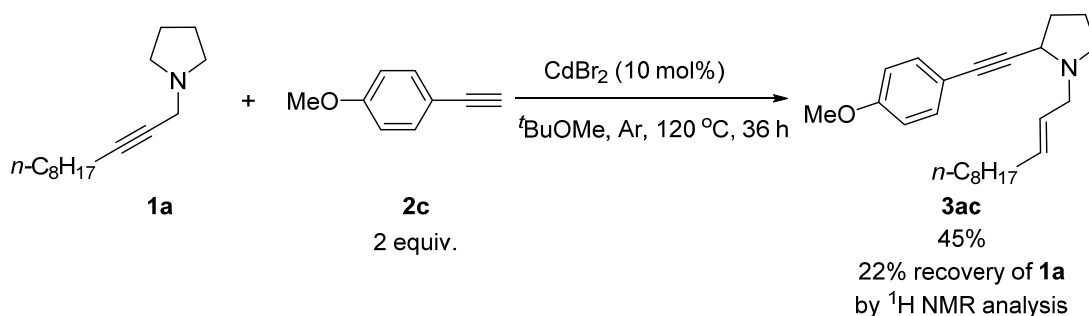
To a dry Schlenk tube with a polytetrafluoroethylene plug was added CdBr<sub>2</sub> (27.6 mg, 0.1 mmol). Then the catalyst was dried under vacuum with heating. After cooling to room temperature, **1a** (221.7 mg, 1.0 mmol), MTBE (3 mL), phenylacetylene **2a** (205.1 mg, 2.0 mmol), and MTBE (3 mL) were added sequentially under Ar atmosphere. The resulting mixture was stirred at 120 °C for 36 h. After the completion of the reaction as monitored by TLC, the crude reaction mixture was filtrated through a short column of Al<sub>2</sub>O<sub>3</sub> eluted with EtOAc (50 mL). After evaporation, the residue was purified by column chromatography on Al<sub>2</sub>O<sub>3</sub> to afford **3aa** (203.3 mg, 63%) (eluent: petroleum ether/ ethyl acetate = 100/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.50-7.37 (m, 2 H, ArH), 7.34-7.21 (m, 3 H, ArH), 5.67 (dt, *J* = 15.2, 6.4 Hz, 1 H, =CH), 5.58 (dt, *J* = 15.2, 6.0 Hz, 1 H, =CH), 3.57 (dd, *J* = 7.3, 5.5 Hz, 1 H, NCH), 3.49 (dd, *J* = 12.8, 5.9 Hz, 1 H, one proton of NCH<sub>2</sub>), 3.01 (dd, *J* = 12.5, 7.5 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.84 (td, *J* = 8.8, 4.9 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.50 (td, *J* = 8.9, 6.5 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.23-2.12 (m, 1 H, one proton of CH<sub>2</sub>), 2.06-1.75 (m, 5 H, 2×CH<sub>2</sub> and one proton of CH<sub>2</sub>), 1.41-1.17 (m, 12 H, 6×CH<sub>2</sub>), 0.88 (t, *J* = 6.6 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 134.1, 131.6, 128.1, 127.8, 126.8, 123.4, 88.7, 84.5, 55.3, 54.5, 51.6, 32.3, 31.8, 31.7, 29.4, 29.24, 29.18, 29.1, 22.6, 22.0, 14.1; MS (EI) *m/z* (%) 323 (M<sup>+</sup>, 19.57), 170 (100); IR (neat) *ν* = 2955, 2923, 2853, 2807, 1695, 1599, 1489, 1460, 1443, 1354, 1178 cm<sup>-1</sup>; HRMS calcd for C<sub>23</sub>H<sub>33</sub>N (M<sup>+</sup>): 323.2613. Found: 323.2610.

(2) (*E*)-2-(4-tolyethynyl)-1-(2-undecenyl)pyrrolidine (**3ab**) (cyf-2-62)



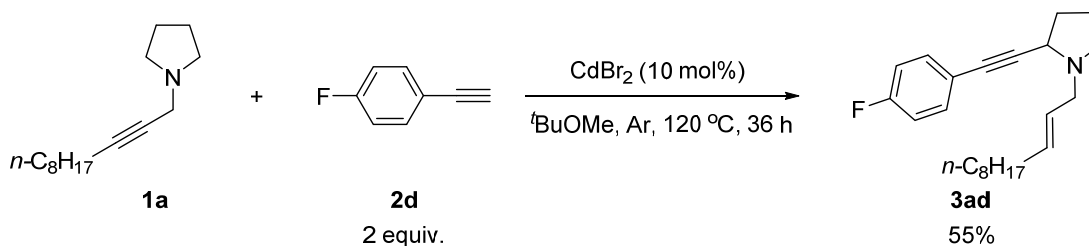
**Typical Procedure I:** To a dry Schlenk tube with a polytetrafluoroethylene plug was added  $\text{CdBr}_2$  (27.7 mg, 0.1 mmol). Then the catalyst was dried under vacuum with heating. **1a** (221.1 mg, 1.0 mmol), MTBE (3 mL), 4-tolylacetylene **2b** (238.5 mg, 2.0 mmol), and MTBE (3 mL) were then added sequentially under Ar atmosphere. The resulting mixture was stirred at 120 °C for 36 h. After the completion of the reaction as monitored by TLC, the crude reaction mixture was filtrated through a short column of  $\text{Al}_2\text{O}_3$  eluted with EtOAc (50 mL). After evaporation, the residue was purified by column chromatography on silica gel to afford **3ab** (172.0 mg, 51%) (eluent: petroleum ether/ acetone = 100/1 (300 mL) to 50/1 (200 mL)) as a liquid:  $\delta$  7.32 (d,  $J = 7.6$  Hz, 2 H, ArH), 7.09 (d,  $J = 8.0$  Hz, 2 H, ArH), 5.66 (dt,  $J = 15.2, 6.4$  Hz, 1 H, =CH), 5.57 (dt,  $J = 15.2, 6.6$  Hz, 1 H, =CH), 3.55 (t,  $J = 6.2$  Hz, 1 H, NCH), 3.48 (dd,  $J = 13.0, 5.8$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 3.00 (dd,  $J = 12.8, 7.2$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.84 (td,  $J = 8.5, 5.2$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.53-2.44 (m, 1 H, one proton of  $\text{NCH}_2$ ), 2.33 (s, 3 H,  $\text{CH}_3$ ), 2.22-2.12 (m, 1 H, one proton of  $\text{CH}_2$ ), 2.07-1.74 (m, 5 H,  $2 \times \text{CH}_2$  and one proton of  $\text{CH}_2$ ), 1.42-1.17 (m, 12 H,  $6 \times \text{CH}_2$ ), 0.88 (t,  $J = 6.6$  Hz, 3 H,  $\text{CH}_3$ );  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  137.7, 133.9, 131.5, 128.8, 126.8, 120.2, 87.8, 84.5, 55.3, 54.5, 51.5, 32.3, 31.8, 31.7, 29.4, 29.2, 29.12, 29.06, 22.6, 21.9, 21.3, 14.0; MS (ESI)  $m/z$  338 ( $[\text{M}+\text{H}]^+$ ); IR (neat)  $\nu = 2954, 2922, 2852, 2805, 1668, 1509, 1456, 1376, 1319, 1277, 1257, 1212, 1139, 1107, 1049, 1020 \text{ cm}^{-1}$ ; HRMS calcd for  $\text{C}_{24}\text{H}_{36}\text{N}$  ( $[\text{M}+\text{H}]^+$ ): 338.2842. Found: 338.2838.

(3) (*E*)-2-((4-Methoxyphenyl)ethynyl)-1-(2-undecenyl)pyrrolidine (**3ac**) (cyf-2-60)



Following **Typical Procedure I**, the reaction of CdBr<sub>2</sub> (27.7 mg, 0.1 mmol), **1a** (221.6 mg, 1.0 mmol), 4-methoxyphenylacetylene **2c** (270.2 mg, 2.0 mmol), and MTBE (6.0 mL) afforded **3ac** (159.1 mg, 45%) (22% recovery of **1a** as determined by <sup>1</sup>H NMR analysis of the crude product using CH<sub>2</sub>Br<sub>2</sub> as internal standard) (eluent: petroleum ether/ acetone = 100/1 (300 mL) to 50/1 (200 mL)) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.36 (d, *J* = 8.8 Hz, 2 H, ArH), 6.82 (d, *J* = 8.8 Hz, 2 H, ArH), 5.66 (dt, *J* = 14.8, 6.4 Hz, 1 H, =CH), 5.58 (dt, *J* = 15.2, 6.6 Hz, 1 H, =CH), 3.80 (s, 3 H, OCH<sub>3</sub>), 3.57-3.46 (m, 2 H, NCH and one proton of NCH<sub>2</sub>), 2.99 (dd, *J* = 12.8, 7.2 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.85 (td, *J* = 8.7, 4.9 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.52-2.44 (m, 1 H, one proton of NCH<sub>2</sub>), 2.23-2.12 (m, 1 H, one proton of CH<sub>2</sub>), 2.08-1.74 (m, 5 H, 2×CH<sub>2</sub> and one proton of CH<sub>2</sub>), 1.42-1.18 (m, 12 H, 6×CH<sub>2</sub>), 0.88 (t, *J* = 6.8 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 159.2, 134.0, 133.0, 126.7, 115.4, 113.7, 87.0, 84.3, 55.3, 55.1, 54.6, 51.5, 32.3, 31.8, 31.7, 29.4, 29.2, 29.15, 29.08, 22.6, 21.9, 14.0; MS (ESI) *m/z* 354 ([M+H]<sup>+</sup>); IR (neat)  $\nu$  = 2954, 2922, 2852, 2806, 1606, 1570, 1508, 1461, 1441, 1376, 1354, 1319, 1288, 1245, 1171, 1105, 1033 cm<sup>-1</sup>; HRMS calcd for C<sub>24</sub>H<sub>36</sub>NO ([M+H]<sup>+</sup>): 354.2791. Found: 354.2785.

(4) (*E*)-2-((4-Fluorophenyl)ethynyl)-1-(2-undecenyl)pyrrolidine (**3ad**) (cyf-2-58)

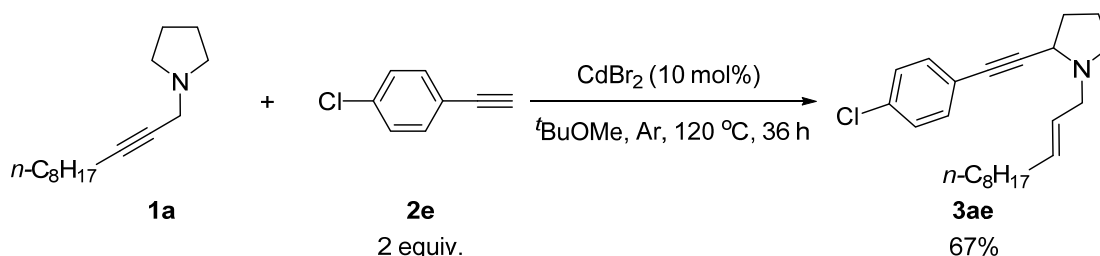


Following **Typical Procedure I**, the reaction of CdBr<sub>2</sub> (27.7 mg, 0.1 mmol), **1a** (222.0 mg, 1.0 mmol), 4-fluorophenylacetylene **2d** (245.3 mg, 2.0 mmol), and MTBE



(6.0 mL) afforded **3ad** (187.8 mg, 55%) (eluent: petroleum ether/ acetone = 100/1 (300 mL) to 50/1 (200 mL)) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.40 (dd,  $J = 8.0, 6.0$  Hz, 2 H, ArH), 6.98 (t,  $J = 8.8$  Hz, 2 H, ArH), 5.66 (dt,  $J = 15.6, 6.4$  Hz, 1 H, =CH), 5.57 (dt,  $J = 15.2, 6.6$  Hz, 1 H, =CH), 3.57-3.43 (m, 2 H, NCH and one proton of  $\text{NCH}_2$ ), 2.99 (dd,  $J = 12.8, 7.2$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.85 (td,  $J = 8.4, 5.1$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.54-2.43 (m, 1 H, one proton of  $\text{NCH}_2$ ), 2.23-2.12 (m, 1 H, one proton of  $\text{CH}_2$ ), 2.07-1.74 (m, 5 H,  $2\times\text{CH}_2$  and one proton of  $\text{CH}_2$ ), 1.42-1.20 (m, 12 H,  $6\times\text{CH}_2$ ), 0.88 (t,  $J = 6.8$  Hz, 3 H,  $\text{CH}_3$ );  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  162.2 ( $J = 247.1$  Hz), 134.1, 133.5 ( $J = 8.5$  Hz), 126.7, 119.4 ( $J = 3.6$  Hz), 115.4 ( $J = 21.8$  Hz), 88.5, 83.4, 55.4, 54.5, 51.6, 32.3, 31.9, 31.8, 29.4, 29.3, 29.25, 29.17, 22.6, 22.0, 14.1;  $^{19}\text{F}$  NMR (376 MHz,  $\text{CDCl}_3$ )  $\delta$  -112.1- -112.3 (m); MS (EI)  $m/z$  (%) 341 ( $\text{M}^+$ , 8.03), 83 (100); IR (neat)  $\nu = 2955, 2924, 2853, 2806, 1601, 1505, 1462, 1354, 1320, 1228, 1154, 1112, 1091$   $\text{cm}^{-1}$ ; Raman:  $\nu = 2231$   $\text{cm}^{-1}$ ; HRMS calcd for  $\text{C}_{23}\text{H}_{32}\text{NF}$  ( $\text{M}^+$ ): 341.2519. Found: 341.2514.

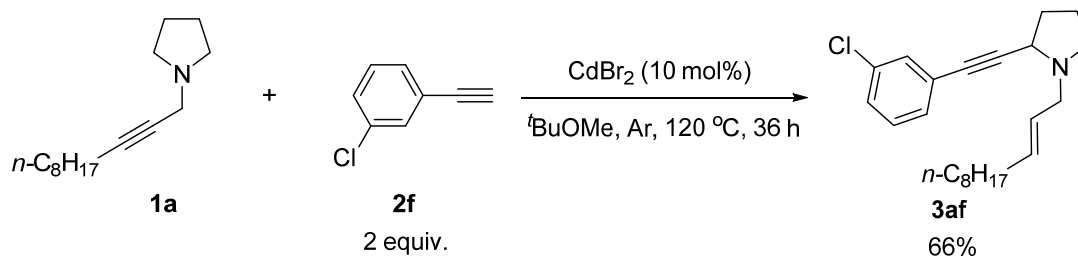
(5) (*E*)-2-((4-Chlorophenyl)ethynyl)-1-(2-undecenyl)pyrrolidine (**3ae**) (lwl-7-198)



Following **Typical Procedure I**, the reaction of CdBr<sub>2</sub> (27.6 mg, 0.1 mmol), **1a** (220.5 mg, 1.0 mmol), 4-chlorophenylacetylene **2e** (273.1 mg, 2.0 mmol), and MTBE (6.0 mL) afforded **3ae** (238.9 mg, 67%) (eluent: petroleum ether/ ethyl acetate/ dichloromethane/ aqueous ammonia = 20/1/1/0.08) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.34 (d,  $J = 8.3$  Hz, 2 H, ArH), 7.26 (d,  $J = 8.5$  Hz, 2 H, ArH), 5.66 (dt,  $J = 15.3, 6.4$  Hz, 1 H, =CH), 5.57 (dt,  $J = 15.5, 6.3$  Hz, 1 H, =CH), 3.54 (t,  $J = 6.4$  Hz, 1 H, NCH), 3.47 (dd,  $J = 12.7, 5.5$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.99 (dd,  $J = 12.9, 7.3$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.85 (td,  $J = 8.7, 4.9$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.53-2.41 (m, 1 H, one proton of  $\text{NCH}_2$ ), 2.23-2.11 (m, 1 H, one proton of  $\text{CH}_2$ ),

2.07-1.74 (m, 5 H, 2×CH<sub>2</sub> and one proton of CH<sub>2</sub>), 1.42-1.15 (m, 12 H, 6×CH<sub>2</sub>), 0.88 (t, *J* = 6.7 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 134.1, 133.8, 132.9, 128.5, 126.7, 121.8, 89.9, 83.4, 55.4, 54.5, 51.2, 32.3, 31.8, 31.7, 29.4, 29.25, 29.2, 29.1, 22.6, 22.0, 14.1; MS (EI) *m/z* (%) 359 (M<sup>+</sup>(Cl<sup>37</sup>), 2.11), 357 (M<sup>+</sup>(Cl<sup>35</sup>), 6.13), 83 (100); IR (neat) *ν* = 2955, 2923, 2853, 2807, 1488, 1462, 1374, 1353, 1319, 1256, 1139, 1092, 1014 cm<sup>-1</sup>; HRMS calcd for C<sub>23</sub>H<sub>32</sub>NCl (M<sup>+</sup>(Cl<sup>35</sup>)): 357.2223. Found: 357.2225.

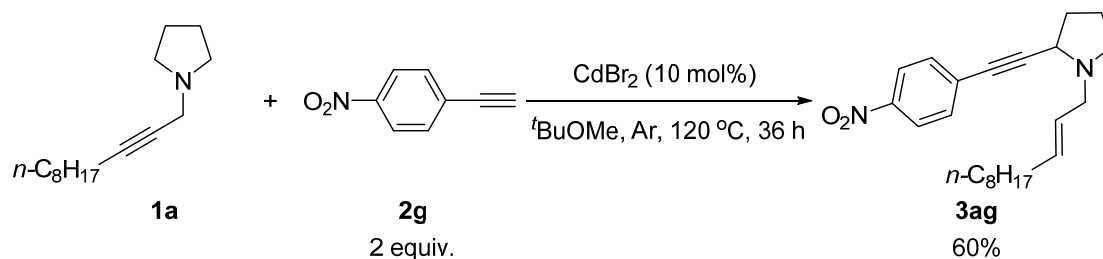
(6) (*E*)-2-((3-Chlorophenyl)ethynyl)-1-(2-undecenyl)pyrrolidine (**3af**) (lwl-8-57)



Following **Typical Procedure I**, the reaction of CdBr<sub>2</sub> (27.2 mg, 0.1 mmol), **1a** (221.5 mg, 1.0 mmol), 3-chlorophenylacetylene **2f** (273.2 mg, 2.0 mmol), and MTBE (6.0 mL) afforded **3af** (235.1 mg, 66%) (eluent: petroleum ether/ ethyl acetate/ dichloromethane/ aqueous ammonia = 20/1/1/0.08) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.41 (s, 1 H, ArH), 7.32-7.17 (m, 3 H, ArH), 5.67 (dt, *J* = 15.3, 6.4 Hz, 1 H, =CH), 5.56 (dt, *J* = 15.4, 6.1 Hz, 1 H, =CH), 3.56 (dd, *J* = 7.3, 5.3 Hz, 1 H, NCH), 3.46 (dd, *J* = 12.7, 5.7 Hz, 1 H, one proton of NCH<sub>2</sub>), 3.00 (dd, *J* = 12.8, 7.3 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.83 (td, *J* = 8.8, 5.2 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.51 (td, *J* = 8.9, 6.4 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.23-2.12 (m, 1 H, one proton of CH<sub>2</sub>), 2.07-1.87 (m, 4 H, CH<sub>2</sub> and 2×one proton of CH<sub>2</sub>), 1.87-1.75 (m, 1 H, one proton of CH<sub>2</sub>), 1.43-1.16 (m, 12 H, 6×CH<sub>2</sub>), 0.88 (t, *J* = 6.8 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 134.1, 133.9, 131.5, 129.7, 129.3, 128.1, 126.6, 125.0, 90.2, 83.1, 55.3, 54.4, 51.6, 32.3, 31.8, 31.6, 29.4, 29.24, 29.15, 29.1, 22.6, 22.0, 14.1; MS (EI) *m/z* (%) 359 (M<sup>+</sup>(Cl<sup>37</sup>), 9.85), 357 (M<sup>+</sup>(Cl<sup>35</sup>), 31.73), 204 (100); IR (neat) *ν* = 3066, 2925, 2854, 2807, 1695, 1593, 1562, 1474, 1406, 1377, 1354, 1318, 1246, 1139, 1112, 1093,

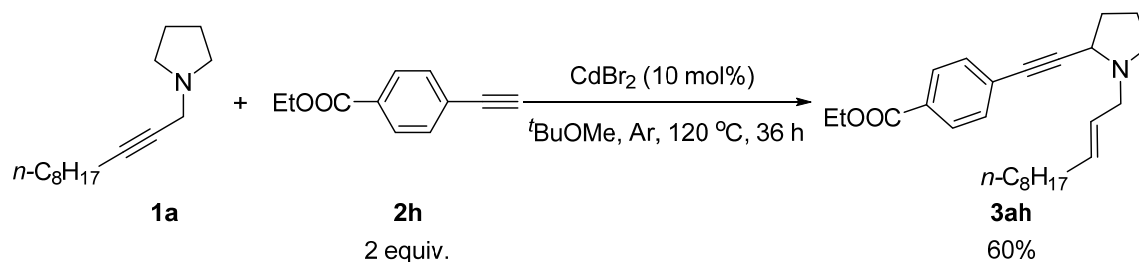
1078  $\text{cm}^{-1}$ ; HRMS calcd for  $\text{C}_{23}\text{H}_{32}\text{NCl}$  ( $\text{M}^+(\text{Cl}^{35})$ ): 357.2223. Found: 357.2231.

(7) (*E*)-2-((4-Nitrophenyl)ethynyl)-1-(2-undecenyl)pyrrolidine (**3ag**) (lwl-8-10)



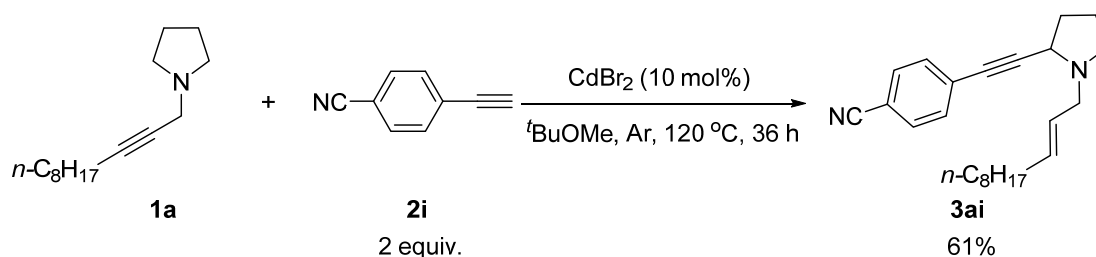
To a dry Schlenk tube with a polytetrafluoroethylene plug was added  $\text{CdBr}_2$  (27.4 mg, 0.1 mmol). Then the catalyst was dried under vacuum with heating. After cooling to room temperature, **1a** (221.5 mg, 1.0 mmol), MTBE (3 mL), 4-nitrophenylacetylene **2g** (295.1 mg, 2.0 mmol), and MTBE (3 mL) were added sequentially under Ar atmosphere. The resulting mixture was stirred at  $120\text{ }^\circ\text{C}$  for 36 h. After the completion of the reaction as monitored by TLC, the crude reaction mixture was filtrated through a short column of  $\text{Al}_2\text{O}_3$  eluted with EtOAc (50 mL). After evaporation, the residue was purified by column chromatography on  $\text{Al}_2\text{O}_3$  to afford **3ag** (222.2 mg, 60%) (eluent: petroleum ether/ dichloromethane / ethyl acetate = 200/20/1 to 100/10/1) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.17 (d,  $J = 8.8$  Hz, 2 H, ArH), 7.56 (d,  $J = 8.6$  Hz, 2 H, ArH), 5.68 (dt,  $J = 15.1, 6.6$  Hz, 1 H, =CH), 5.57 (dt,  $J = 15.4, 6.1$  Hz, 1 H, =CH), 3.62 (dd,  $J = 7.2, 5.5$  Hz, 1 H, NCH), 3.48 (dd,  $J = 12.7, 5.7$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 3.03 (dd,  $J = 12.7, 7.2$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.87 (td,  $J = 8.8, 5.2$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.56-2.48 (m, 1 H, one proton of  $\text{NCH}_2$ ), 2.28-2.16 (m, 1 H, one proton of  $\text{CH}_2$ ), 2.10-1.79 (m, 5 H,  $2\times\text{CH}_2$  and one proton of  $\text{CH}_2$ ), 1.43-1.17 (m, 12 H,  $6\times\text{CH}_2$ ), 0.87 (t,  $J = 6.8$  Hz, 3 H,  $\text{CH}_3$ );  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  146.8, 134.5, 132.3, 130.3, 126.3, 123.4, 94.9, 82.9, 55.4, 54.5, 51.7, 32.3, 31.8, 31.5, 29.4, 29.2, 29.14, 29.10, 22.6, 22.1, 14.1; MS (ESI)  $m/z$  369 ( $[\text{M}+\text{H}]^+$ ); IR (neat)  $\nu = 2924, 2854, 2805, 2224, 1594, 1520, 1491, 1461, 1377, 1344, 1318, 1285, 1256, 1175, 1139, 1108, 1013\text{ cm}^{-1}$ ; HRMS calcd for  $\text{C}_{23}\text{H}_{33}\text{N}_2\text{O}_2$  ( $[\text{M}+\text{H}]^+$ ): 369.2537. Found: 369.2538.

(8) (*E*)-2-((4-ethoxycarbonylphenyl)ethynyl)-1-(2-undecenyl)pyrrolidine (**3ah**)  
(cyf-2-63)



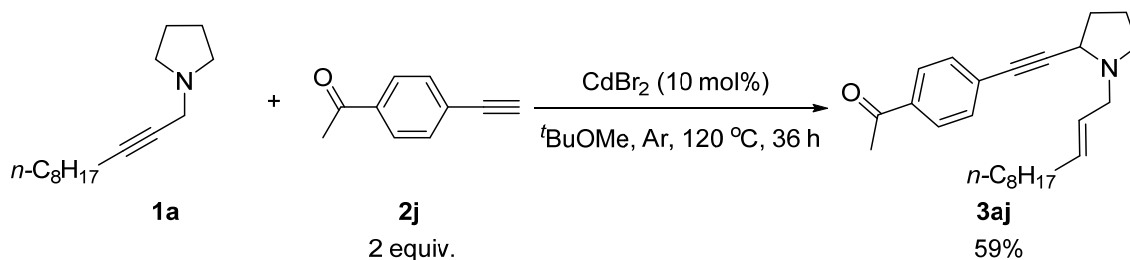
Following **Typical Procedure I**, the reaction of  $\text{CdBr}_2$  (27.7 mg, 0.1 mmol), **1a** (222.0 mg, 1.0 mmol), 4-ethoxycarbonylphenylacetylene **2h** (356.1 mg, 2.0 mmol), and MTBE (6.0 mL) afforded **3ah** (237.2 mg, 60%) (eluent: petroleum ether/ acetone = 100/1 (300 mL) to 50/1 (300 mL)) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.97 (d,  $J = 8.4$  Hz, 2 H, ArH), 7.47 (d,  $J = 8.0$  Hz, 2 H, ArH), 5.67 (dt,  $J = 15.2, 6.4$  Hz, 1 H, =CH), 5.57 (dt,  $J = 15.2, 6.4$  Hz, 1 H, =CH), 4.37 (q,  $J = 7.1$  Hz, 2 H,  $\text{OCH}_2$ ), 3.58 (dd,  $J = 7.4, 5.4$  Hz, 1 H, NCH), 3.47 (dd,  $J = 12.6, 5.8$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 3.02 (dd,  $J = 12.8, 7.2$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.85 (td,  $J = 8.7, 5.1$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.56-2.47 (m, 1 H, one proton of  $\text{NCH}_2$ ), 2.25-2.14 (m, 1 H, one proton of  $\text{CH}_2$ ), 2.08-1.76 (m, 5 H,  $2 \times \text{CH}_2$  and one proton of  $\text{CH}_2$ ), 1.44-1.17 (m, 15 H,  $6 \times \text{CH}_2$  and  $\text{CH}_3$ ), 0.87 (t,  $J = 6.6$  Hz, 3 H,  $\text{CH}_3$ );  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  165.9, 134.1, 131.4, 129.4, 129.2, 127.9, 126.6, 92.0, 83.9, 60.9, 55.3, 54.4, 51.6, 32.2, 31.8, 31.6, 29.3, 29.2, 29.1, 29.0, 22.6, 22.0, 14.2, 14.0; MS (EI)  $m/z$  (%) 395 ( $\text{M}^+$ , 9.22), 256 (100); IR (neat)  $\nu = 2956, 2924, 2853, 2805, 2224, 1720, 1605, 1462, 1404, 1367, 1269, 1174, 1102, 1021\text{ cm}^{-1}$ ; Raman:  $\nu = 2228\text{ cm}^{-1}$ ; HRMS calcd for  $\text{C}_{26}\text{H}_{37}\text{NO}_2$  ( $\text{M}^+$ ): 395.2824. Found: 395.2819.

(9) (*E*)-2-((4-cyanophenyl)ethynyl)-1-(2-undecenyl)pyrrolidine (**3ai**) (lwl-8-58)



Following **Typical Procedure I**, the reaction of CdBr<sub>2</sub> (27.5 mg, 0.1 mmol), **1a** (222.0 mg, 1.0 mmol), 4-cyanophenylacetylene **2i** (254.1 mg, 2.0 mmol), and MTBE (6.0 mL) afforded **3ai** (213.1 mg, 61%) (eluent: petroleum ether/ ethyl acetate/ dichloromethane/ aqueous ammonia = 250/25/12.5/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.58 (d, *J* = 8.2 Hz, 2 H, ArH), 7.50 (d, *J* = 8.2 Hz, 2 H, ArH), 5.66 (dt, *J* = 15.3, 6.5 Hz, 1 H, =CH), 5.56 (dt, *J* = 15.4, 6.4 Hz, 1 H, =CH), 3.58 (dd, *J* = 7.5, 5.7 Hz, 1 H, NCH), 3.46 (dd, *J* = 12.8, 5.8 Hz, 1 H, one proton of NCH<sub>2</sub>), 3.01 (dd, *J* = 12.7, 7.3 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.86 (td, *J* = 8.6, 4.8 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.55-2.46 (m, 1 H, one proton of NCH<sub>2</sub>), 2.26-2.15 (m, 1 H, one proton of CH<sub>2</sub>), 2.07-1.89 (m, 4 H, CH<sub>2</sub> and 2×one proton of CH<sub>2</sub>), 1.89-1.77 (m, 1 H, one proton of CH<sub>2</sub>), 1.41-1.18 (m, 12 H, 6×CH<sub>2</sub>), 0.88 (t, *J* = 6.9 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 134.3, 132.1, 131.9, 128.3, 126.5, 118.5, 111.1, 94.0, 83.0, 55.4, 54.4, 51.7, 32.3, 31.8, 31.6, 29.4, 29.2, 29.14, 29.10, 22.6, 22.1, 14.1; MS (ESI) *m/z* 349 ([M+H]<sup>+</sup>); IR (neat) *v* = 2964, 2926, 2854, 2806, 2228, 1604, 1500, 1461, 1406, 1377, 1354, 1319, 1270, 1256, 1178, 1139, 1107 cm<sup>-1</sup>; HRMS calcd for C<sub>24</sub>H<sub>33</sub>N<sub>2</sub> ([M+H]<sup>+</sup>): 349.2638. Found: 349.2640.

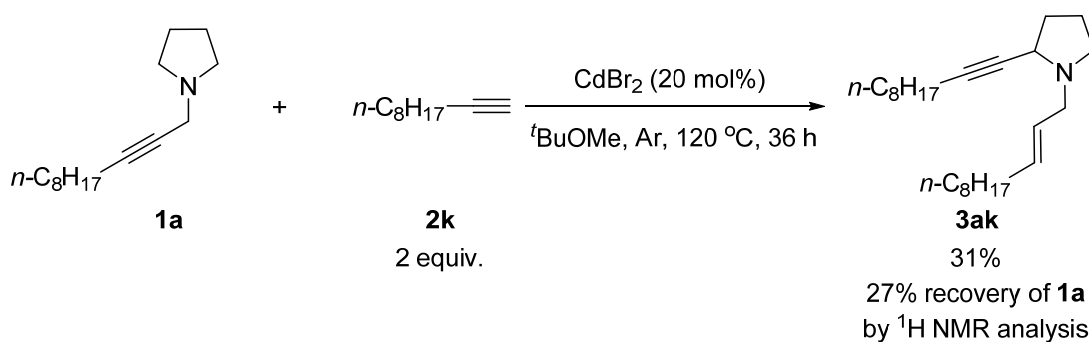
(10)(*E*)-2-((4-Acetylphenyl)ethynyl)-1-(2-undecenyl)pyrrolidine (**3aj**) (lwl-9-68)



Following **Typical Procedure I**, the reaction of CdBr<sub>2</sub> (27.5 mg, 0.1 mmol), **1a** (221.5 mg, 1.0 mmol), 4-acetylphenylacetylene **2j** (288.7 mg, 2.0 mmol), and MTBE (6.0 mL) afforded **3aj** (215.7 mg, 59%) (eluent: petroleum ether/ acetone = 40/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.89 (d, *J* = 8.0 Hz, 2 H, ArH), 7.50 (d, *J* = 7.6 Hz, 2 H, ArH), 5.67 (dt, *J* = 15.2, 6.6 Hz, 1 H, =CH), 5.58 (dt, *J* = 15.2, 6.8 Hz, 1 H, =CH), 3.59 (t, *J* = 6.2 Hz, 1 H, NCH), 3.48 (dd, *J* = 12.8, 5.6 Hz, 1 H, one proton of NCH<sub>2</sub>), 3.02 (dd, *J* = 12.6, 7.4 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.90-2.81 (m, 1 H, one

proton of NCH<sub>2</sub>), 2.59 (s, 3 H, CH<sub>3</sub>), 2.51 (q, *J* = 7.9 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.26-2.14 (m, 1 H, one proton of CH<sub>2</sub>), 2.08-1.75 (m, 5 H, 2×CH<sub>2</sub> and one proton of CH<sub>2</sub>), 1.43-1.15 (m, 12 H, 6×CH<sub>2</sub>), 0.87 (t, *J* = 6.2 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 197.2, 135.9, 134.2, 131.7, 128.3, 128.1, 126.6, 92.7, 83.8, 55.4, 54.5, 51.7, 32.3, 31.8, 31.6, 29.4, 29.2, 29.15, 29.08, 26.5, 22.6, 22.0, 14.0; MS (EI) *m/z* (%) 365 (M<sup>+</sup>, 16.03), 83 (100); IR (neat) *ν* = 2955, 2922, 2853, 2804, 1685, 1600, 1460, 1440, 1403, 1356, 1318, 1283, 1260, 1178, 1138, 1109, 1015 cm<sup>-1</sup>; HRMS calcd for C<sub>25</sub>H<sub>36</sub>ON<sup>+</sup> (M+H<sup>+</sup>): 366.2791. Found: 366.2790.

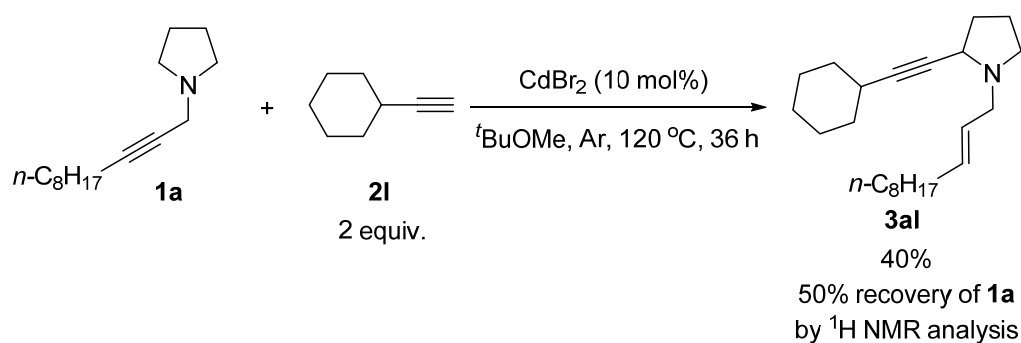
(11) (*E*)-2-(Decynyl)-1-(2-undecenyl)pyrrolidine (**3ak**) (lwl-8-1)



Following **Typical Procedure I**, the reaction of CdBr<sub>2</sub> (54.5 mg, 0.2 mmol) **1a** (220.5 mg, 1.0 mmol), 1-decyne **2k** (278.1 mg, 2.0 mmol), and MTBE (6.0 mL) afforded **3ak** (111.4 mg, 31%) (27% recovery of **1a** as determined by <sup>1</sup>H NMR analysis of the crude product using CH<sub>2</sub>Br<sub>2</sub> as internal standard) (eluent: petroleum ether/ ethyl acetate/ dichloromethane/ aqueous ammonia = 20/1/1/0.08) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 5.63 (dt, *J* = 15.2, 6.4 Hz, 1 H, =CH), 5.54 (dt, *J* = 15.6, 6.0 Hz, 1 H, =CH), 3.44 (dd, *J* = 12.8, 5.6 Hz, 1 H, one proton of NCH<sub>2</sub>), 3.30-3.21 (m, 1 H, NCH), 2.87 (dd, *J* = 14.8, 7.6 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.79 (td, *J* = 8.5, 4.8 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.37 (td, *J* = 8.9, 6.1 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.19 (td, *J* = 7.2, 2.0 Hz, 2 H, CH<sub>2</sub>), 2.11-1.96 (m, 3 H, CH<sub>2</sub> and one proton of CH<sub>2</sub>), 1.91-1.79 (m, 2 H, CH<sub>2</sub>), 1.79-1.67 (m, 1 H, one proton of CH<sub>2</sub>), 1.55-1.45 (m, 2 H, CH<sub>2</sub>), 1.43-1.18 (m, 22 H, CH<sub>2</sub>×11), 0.88 (t, *J* = 6.6 Hz, 6 H, 2×CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 133.7, 126.9, 84.6, 79.0, 55.2, 54.3, 51.4, 32.3, 31.84, 31.80, 29.4, 29.3, 29.2, 29.12, 29.06, 28.9, 28.8, 22.63, 22.62, 21.8, 18.7, 14.1; MS (EI) *m/z* (%)

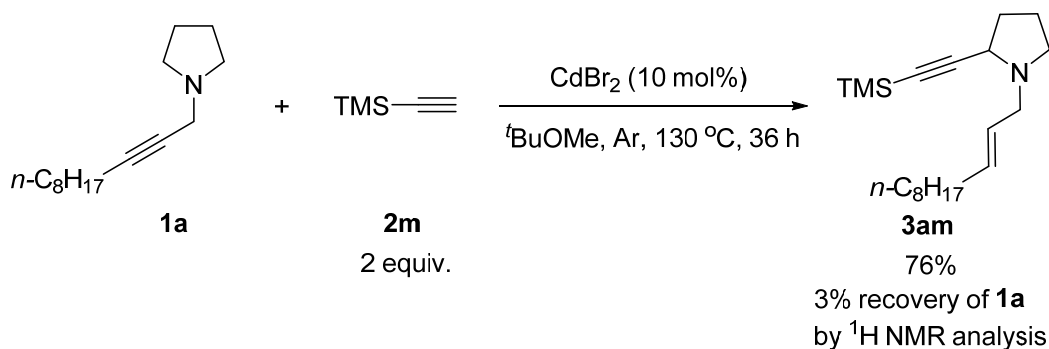
359 ( $M^+$ , 55.37), 246 (100); IR (neat)  $\nu$  = 2925, 2854, 2809, 1494, 1443, 1377, 1354, 1320, 1184, 1143, 1107  $\text{cm}^{-1}$ ; HRMS calcd for  $C_{25}H_{45}N$  ( $M^+$ ): 359.3552. Found: 359.3546.

(12) (*E*)-2-(Cyclohexylethynyl)-1-(2-undecenyl)pyrrolidine (**3al**) (lw1-7-200)



Following **Typical Procedure I**, the reaction of  $\text{CdBr}_2$  (27.5 mg, 0.1 mmol), **1a** (221.5 mg, 1.0 mmol), cyclohexylacetylene **2** (216.1 mg, 2.0 mmol), and MTBE (6.0 mL) afforded **3al** (131.5 mg, 40%) (50% recovery of **1a** as determined by  $^1\text{H}$  NMR analysis of the crude product using  $\text{CH}_2\text{Br}_2$  as internal standard) (eluent: petroleum ether/ ethyl acetate/ dichloromethane/ aqueous ammonia = 20/1/1/0.08) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  5.63 (dt,  $J$  = 15.3, 6.4 Hz, 1 H, =CH), 5.54 (dt,  $J$  = 15.3, 6.4 Hz, 1 H, =CH), 3.43 (dd,  $J$  = 12.5, 5.5 Hz, 1 H, one proton of  $\text{NCH}_2$ ), 3.29 (t,  $J$  = 5.4 Hz, 1 H, NCH), 2.88 (dd,  $J$  = 12.7, 7.2 Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.78 (td,  $J$  = 8.8, 4.9 Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.44-2.33 (m, 2 H, CH and one proton of  $\text{NCH}_2$ ), 2.11-1.96 (m, 3 H,  $\text{CH}_2$  and one proton of  $\text{CH}_2$ ), 1.91-1.64 (m, 7 H,  $3 \times \text{CH}_2$  and one proton of  $\text{CH}_2$ ), 1.54-1.14 (m, 18 H,  $9 \times \text{CH}_2$ ), 0.88 (t,  $J$  = 6.7 Hz, 3 H,  $\text{CH}_3$ );  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  133.8, 126.9, 88.9, 78.8, 55.1, 54.2, 51.4, 32.91, 32.87, 32.3, 31.9, 31.8, 29.4, 29.3, 29.2, 29.1, 29.0, 25.9, 24.8, 22.6, 21.7, 14.1; MS (EI)  $m/z$  (%) 329 ( $M^+$ , 45.69), 176 (100); IR (neat)  $\nu$  = 2927, 2853, 2809, 1448, 1377, 1362, 1351, 1319, 1298, 1234, 1184, 1141, 1111  $\text{cm}^{-1}$ ; HRMS calcd for  $C_{23}H_{39}N$  ( $M^+$ ): 329.3083. Found: 329.3080.

(13) (*E*)-2-((trimethylsilyl)ethynyl)-1-(2-undecenyl)pyrrolidine (**3am**) (cyf-1-017)

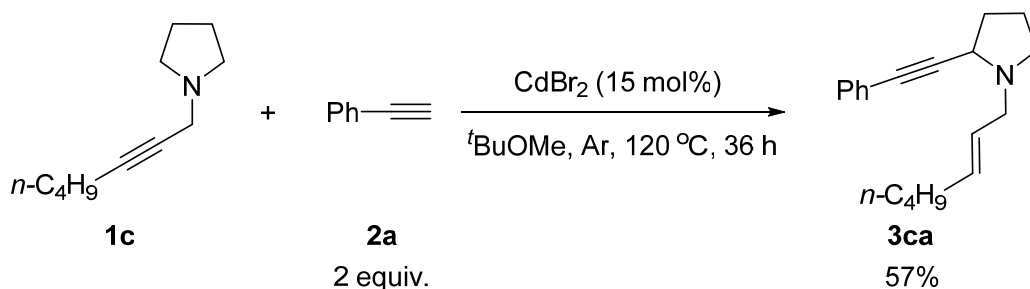


**Typical Procedure II:** To a dry Schlenk tube with a polytetrafluoroethylene plug was added  $\text{CdBr}_2$  (27.6 mg, 0.1 mmol). Then the catalyst was dried under vacuum with heating. **1a** (222.0 mg, 1.0 mmol), MTBE (3 mL), trimethylsilylacetylene **2m** (201.6 mg, 2.0 mmol), and MTBE (3 mL) were then added sequentially under Ar atmosphere. The resulting mixture was stirred at 130 °C for 36 h. After the completion of the reaction as monitored by TLC, the crude reaction mixture was filtrated through a short column of silica gel eluted with EtOAc (50 mL). After evaporation, the residue was purified by column chromatography on silica gel to afford **3am** (242.4 mg, 76%) (3% recovery of **1a** as determined by  ${}^1\text{H}$  NMR analysis of the crude product using  $\text{CH}_2\text{Br}_2$  as internal standard) (eluent: petroleum ether/ ethyl acetate = 100/1 (300 mL) to petroleum ether/ acetone = 100/1 (400 mL)) as a liquid:  ${}^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  5.63 (dt,  $J = 15.2, 6.4$  Hz, 1 H, =CH), 5.54 (dt,  $J = 15.2, 6.6$  Hz, 1 H, =CH), 3.41 (dd,  $J = 12.8, 5.4$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 3.33 (dd,  $J = 7.0, 5.4$  Hz, 1 H, NCH), 2.92 (dd,  $J = 12.4, 7.6$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.82-2.70 (m, 1 H, one proton of  $\text{NCH}_2$ ), 2.43 (dd,  $J = 14.6, 7.8$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.15-1.97 (m, 3 H,  $\text{CH}_2$  and one proton of  $\text{CH}_2$ ), 1.96-1.66 (m, 3 H,  $\text{CH}_2$  and one proton of  $\text{CH}_2$ ), 1.46-1.16 (m, 12 H,  $6 \times \text{CH}_2$ ), 0.88 (t,  $J = 6.8$  Hz, 3 H,  $\text{CH}_3$ ), 0.16 (s, 9 H,  $3 \times \text{SiCH}_3$ );  ${}^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  134.1, 126.7, 105.4, 88.6, 55.1, 54.5, 51.4, 32.3, 31.8, 31.6, 29.4, 29.3, 29.2, 29.1, 22.6, 21.9, 14.1, 0.1; MS (EI)  $m/z$  (%) 319 ( $\text{M}^+$ , 16.60), 139 (100); IR (neat)  $\nu = 2957, 2923, 2853, 2811, 2158, 1460, 1376, 1350, 1317, 1249, 1182, 1138, 1117, 1090$   $\text{cm}^{-1}$ ; HRMS calcd for  $\text{C}_{20}\text{H}_{37}\text{NSi}$  ( $\text{M}^+$ ): 319.2695. Found: 319.2690.

(14) (*E*)-1-(3-Cyclohexylallyl)-2-(phenylethynyl)pyrrolidine (**3ba**) (lwl-8-51)



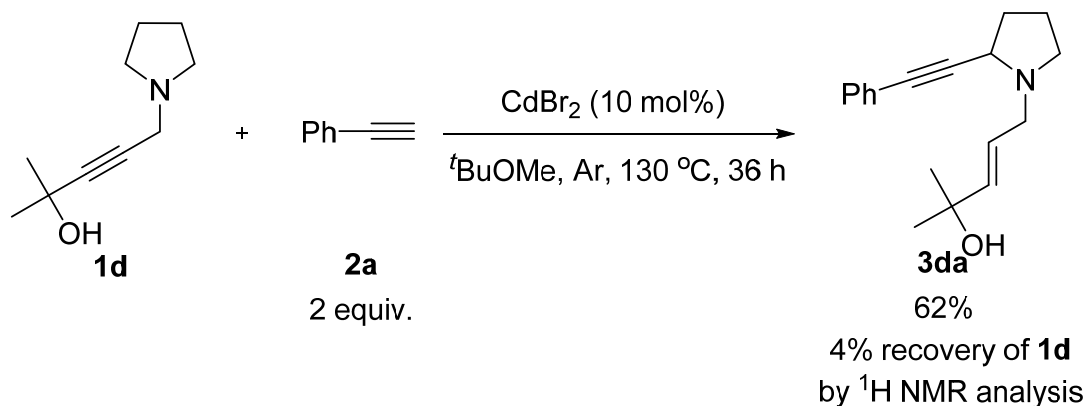




Following **Typical Procedure II**, the reaction of  $\text{CdBr}_2$  (41.5 mg, 0.15 mmol), **1c** (165.0 mg, 1.0 mmol), phenylacetylene **2a** (210.5 mg, 2.0 mmol), and MTBE (6.0 mL) afforded **3ca** (152.2 mg, 57%) (eluent: petroleum ether/ acetone = 200/1 (450 mL) to 50/1 (250 mL)) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.48-7.37 (m, 2 H, ArH), 7.32-7.23 (m, 3 H, ArH), 5.72-5.52 (m, 2 H,  $2\times=\text{CH}$ ), 3.56 (t,  $J = 6.4$  Hz, 1 H, NCH), 3.48 (dd,  $J = 12.4, 5.2$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 3.01 (dd,  $J = 12.6, 7.0$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.88-2.79 (m, 1 H, one proton of  $\text{NCH}_2$ ), 2.50 (dd,  $J = 15.4, 8.2$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.24-2.11 (m, 1 H, one proton of  $\text{CH}_2$ ), 2.08-1.87 (m, 4 H,  $\text{CH}_2$  and  $2\times$ one proton of  $\text{CH}_2$ ), 1.85-1.73 (m, 1 H, one proton of  $\text{CH}_2$ ), 1.41-1.19 (m, 4 H,  $2\times\text{CH}_2$ ), 0.88 (t,  $J = 6.6$  Hz, 3 H,  $\text{CH}_3$ );  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  133.9, 131.6, 128.1, 127.8, 126.8, 123.3, 88.7, 84.5, 55.3, 54.5, 51.5, 31.9, 31.7, 31.3, 22.1, 22.0, 13.8; MS (EI)  $m/z$  (%) 267 ( $\text{M}^+$ , 14.93), 83 (100); IR (neat)  $\nu = 2955, 2923, 2871, 2804, 1598, 1489, 1459, 1442, 1355, 1320, 1255, 1138, 1109, 1069$   $\text{cm}^{-1}$ ; HRMS calcd for  $\text{C}_{19}\text{H}_{25}\text{N}$  ( $\text{M}^+$ ): 267.1987. Found: 267.1990.

(16) (*E*)-1-(4-methyl-4-hydroxy-2-pentenyl)-2-(phenylethynyl)pyrrolidine (**3da**)

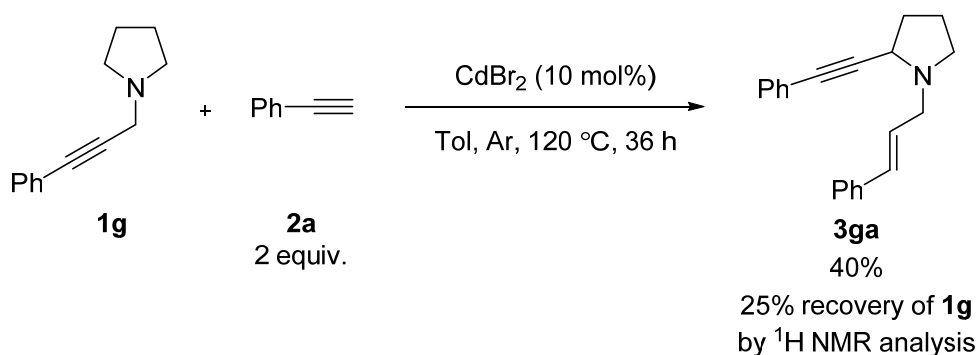
(lwl-9-70)



Following **Typical Procedure I**, the reaction of  $\text{CdBr}_2$  (27.2 mg, 0.1 mmol), **1d**

(167.0 mg, 1.0 mmol), phenylacetylene **2a** (204.5 mg, 2.0 mmol), and MTBE (6.0 mL) afforded **3da** (166.8 mg, 62%) (4% recovery of **1d** as determined by  $^1\text{H}$  NMR analysis of the crude product using  $\text{CH}_2\text{Br}_2$  as internal standard) (eluent: petroleum ether/ acetone = 20/1 to 10/1) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.46-7.39 (m, 2 H, ArH), 7.34-7.26 (m, 3 H, ArH), 5.91-5.74 (m, 2 H,  $2\times=\text{CH}$ ), 3.62-3.46 (m, 2 H, NCH and one proton of  $\text{CH}_2$ ), 3.08 (dd,  $J = 13.0, 6.6$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.87 (dd,  $J = 13.6, 8.4$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.51 (dd,  $J = 16.0, 8.0$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.26-2.12 (m, 1 H, one proton of  $\text{CH}_2$ ), 2.09-1.75 (m, 4 H, OH and  $3\times$ one proton of  $\text{CH}_2$ ), 1.32 (s, 6 H,  $2\times\text{CH}_3$ );  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  141.0, 131.6, 128.2, 127.9, 123.9, 123.2, 88.6, 54.7, 70.5, 54.9, 54.7, 51.8, 31.7, 29.61, 29.59, 22.0; MS (ESI)  $m/z$  270 ( $[\text{M}+\text{H}]^+$ ); IR (neat)  $\nu = 3371, 2970, 2876, 2805, 1598, 1489, 1460, 1443, 1358, 1326, 1233, 1148, 1070$   $\text{cm}^{-1}$ ; HRMS calcd for  $\text{C}_{18}\text{H}_{24}\text{ON}$  ( $[\text{M}+\text{H}]^+$ ): 270.1852. Found: 270.1851.

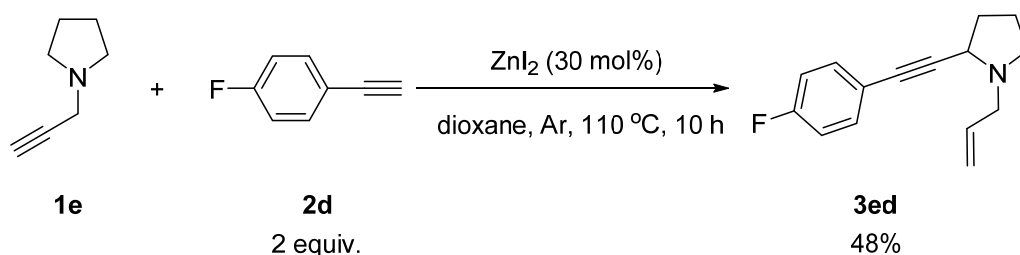
(17) (*E*)-1-cinnamyl-2-(phenylethynyl)pyrrolidine (**3ga**) (cyf-2-103)



Following **Typical Procedure I**, the reaction of  $\text{CdBr}_2$  (27.7 mg, 0.1 mmol), **1g** (185.4 mg, 1.0 mmol), phenylacetylene **2a** (211.9 mg, 2.0 mmol), and toluene (6.0 mL) afforded **3ga** (115.0 mg, 40%) (25% recovery of **1g** as determined by  $^1\text{H}$  NMR analysis of the crude product using  $\text{CH}_2\text{Br}_2$  as internal standard) (eluent: petroleum ether/ acetone = 40/1) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.48-7.40 (m, 2 H, ArH), 7.40-7.34 (m, 2 H, ArH), 7.32-7.23 (m, 5 H, ArH), 7.23-7.16 (m, 1 H, ArH), 6.59 (d,  $J = 16.0$  Hz, 1 H,  $=\text{CH}$ ), 6.38 (ddd,  $J = 16.0, 7.4, 6.2$  Hz, 1 H,  $=\text{CH}$ ), 3.69 (ddd,  $J = 13.6, 6.4, 1.1$  Hz, 1 H, NCH), 3.62 (dd,  $J = 7.4, 5.8$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 3.24 (dd,  $J = 13.4, 7.4$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.91 (td,  $J = 8.8, 4.9$  Hz,

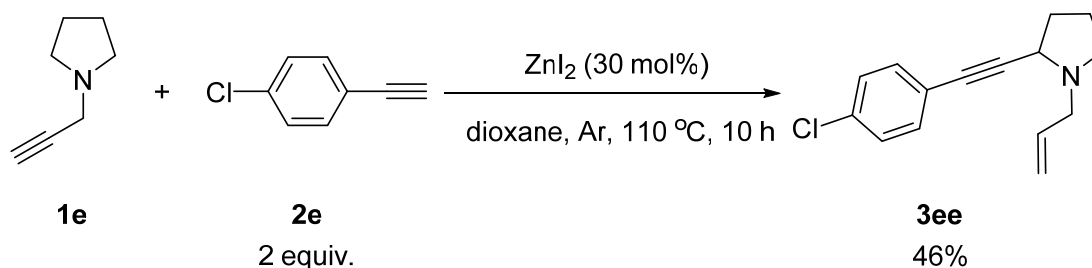






Following **Typical Procedure III**, the reaction of  $\text{ZnI}_2$  (95.8 mg, 0.3 mmol), **1e** (109.2 mg, 1.0 mmol), 4-fluorophenylacetylene **2d** (240.2 mg, 2.0 mmol), and dioxane (6.0 mL) afforded **3ed** (110.6 mg, 48%) (eluent: petroleum ether/ ethyl acetate/ dichloromethane = 100/1/5) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.46-7.36 (m, 2 H, ArH), 6.98 (t,  $J = 8.6$  Hz, 2 H, ArH), 6.03-5.90 (m, 1 H, =CH), 5.25 (dd,  $J = 16.8, 1.2$  Hz, 1 H, one proton of = $\text{CH}_2$ ), 5.13 (d,  $J = 10.0$  Hz, 1 H, one proton of = $\text{CH}_2$ ), 3.60-3.50 (m, 2 H, NCH and one proton of  $\text{NCH}_2$ ), 3.04 (dd,  $J = 12.8, 7.2$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.86 (td,  $J = 8.9, 4.9$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.49 (td,  $J = 8.8, 6.4$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.24-2.12 (m, 1 H, one proton of  $\text{CH}_2$ ), 2.07-1.87 (m, 2 H,  $\text{CH}_2$ ), 1.87-1.75 (m, 1 H, one proton of  $\text{CH}_2$ );  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  162.2 (d,  $J = 247.6$  Hz), 135.6, 133.5 (d,  $J = 8.2$  Hz), 119.3 (d,  $J = 2.9$  Hz), 117.2, 115.4 (d,  $J = 21.6$  Hz), 88.3 (d,  $J = 1.5$  Hz), 83.4, 56.3, 54.7, 51.7, 31.7, 22.0;  $^{19}\text{F}$  NMR (376 MHz,  $\text{CDCl}_3$ )  $\delta$  -112.1; MS (EI)  $m/z$  (%) 229 ( $\text{M}^+$ , 43.68), 228 (100); IR (neat)  $\nu = 3077, 2977, 2912, 2877, 2806, 1643, 1601, 1506, 1460, 1444, 1419, 1357, 1321, 1231, 1156, 1110, 1092$   $\text{cm}^{-1}$ ; HRMS calcd for  $\text{C}_{15}\text{H}_{16}\text{NF}$  ( $\text{M}^+$ ): 229.1267. Found: 229.1266.

(4) 1-Allyl-2-((4-chlorophenyl)ethynyl)pyrrolidine (**3ee**) (lwl-8-56)



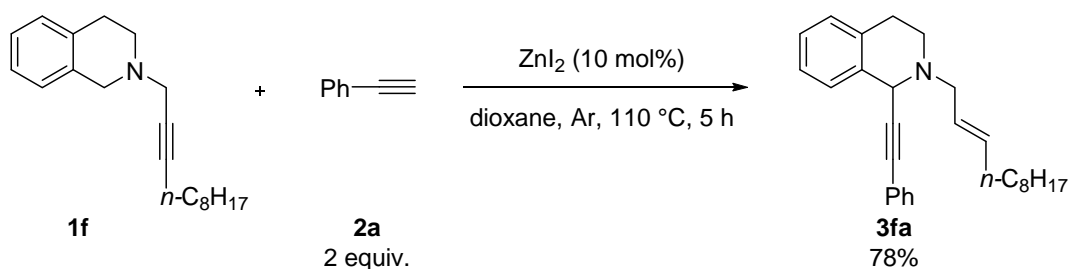
Following **Typical Procedure III**, the reaction of  $\text{ZnI}_2$  (95.8 mg, 0.3 mmol), **1e** (109.2 mg, 1.0 mmol), 4-chlorophenylacetylene **2e** (273.2 mg, 2.0 mmol), and

dioxane (6.0 mL) afforded **3ee** (113.2 mg, 46%) (eluent: petroleum ether/ ethyl acetate/ dichloromethane = 100/1/5) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.35 (d,  $J = 8.4$  Hz, 2 H, ArH), 7.26 (d,  $J = 8.4$  Hz, 2 H, ArH), 6.03-5.90 (m, 1 H, =CH), 5.25 (dd,  $J = 17.2, 1.2$  Hz, 1 H, one proton of = $\text{CH}_2$ ), 5.13 (d,  $J = 10.0$  Hz, 1 H, one proton of = $\text{CH}_2$ ), 3.61-3.50 (m, 2 H, NCH and one proton of  $\text{NCH}_2$ ), 3.04 (dd,  $J = 13.2, 7.6$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.86 (td,  $J = 8.7, 4.9$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.49 (td,  $J = 8.8, 6.4$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.24-2.13 (m, 1 H, one proton of  $\text{NCH}_2$ ), 2.07-1.87 (m, 2 H,  $\text{CH}_2$ ), 1.87-1.75 (m, 1 H, one proton of  $\text{CH}_2$ );  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  135.5, 133.8, 132.8, 128.5, 121.7, 117.3, 89.7, 83.4, 56.3, 54.7, 51.7, 31.6, 22.0; MS (EI)  $m/z$  (%) 247 ( $\text{M}^+(\text{Cl}^{37})$ , 13.82), 245 ( $\text{M}^+(\text{Cl}^{35})$ , 42.31), 244 (100); IR (neat)  $\nu = 3078, 2977, 2957, 2914, 2876, 2805, 1643, 1490, 1460, 1443, 1419, 1398, 1356, 1319, 1255, 1181, 1141, 1092, 1014$   $\text{cm}^{-1}$ ; HRMS calcd for  $\text{C}_{15}\text{H}_{16}\text{NCl}$  ( $\text{M}^+(\text{Cl}^{35})$ ): 245.0971. Found: 245.0979.

#### 4. The $\text{ZnI}_2$ -catalyzed reaction of 1-propargylic 1,2,3,4-tetrahydroisoquinoline with terminal alkynes

(1) (*E*)-1-(phenylethynyl)-2-(2-undecenyl)-1,2,3,4-tetrahydroisoquinoline (**3fa**)

(cyf-1-136)

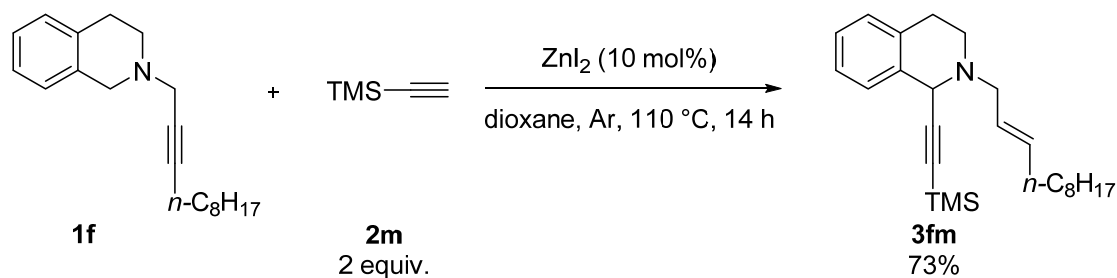


**Typical Procedure IV:** To a dry Schlenk tube with a polytetrafluoroethylene plug was added  $\text{ZnI}_2$  (32.3 mg, 0.1 mmol). Then the catalyst was dried with heating under vacuum. After cooling to room temperature, **2a** (211.0 mg, 2.0 mmol), dioxane (3 mL), **1f** (283.0 mg, 1.0 mmol), and dioxane (3 mL) were added sequentially under Ar atmosphere. Then the Schenk tube was stirred at 110 °C for 5 hours. After the completion of the reaction as monitored by TLC, the crude reaction mixture was

diluted with 5 mL of dichloromethane and filtered through a short column of silica gel (eluent: 50 mL of Et<sub>2</sub>O). After evaporation, the residue was purified by column chromatography on silica gel to afford **3fa** (301.4 mg, 78%) (eluent: petroleum ether/ diethyl ether/ dicholoromethane = 40/1/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.44-7.37 (m, 2 H, ArH), 7.34-7.23 (m, 4 H, ArH), 7.21-7.09 (m, 3 H, ArH), 5.76 (dt, *J* = 15.2, 6.8 Hz, 1 H, =CH), 5.57 (td, *J* = 15.2, 6.8 Hz, 1 H, =CH), 4.88 (s, 1 H, NCH), 3.40-3.29 (m, 2 H, CH<sub>2</sub>), 3.08-2.96 (m, 2 H, CH<sub>2</sub>), 2.89-2.77 (m, 2 H, CH<sub>2</sub>), 2.08 (q, *J* = 6.8 Hz, 2 H, CH<sub>2</sub>), 1.46-1.20 (m, 12 H, 6×CH<sub>2</sub>), 0.88 (t, *J* = 6.6 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 135.40, 135.33, 134.0, 131.7, 129.0, 128.1, 127.9, 127.8, 126.9, 126.2, 125.8, 123.2, 87.4, 86.6, 57.6, 54.3, 45.4, 32.4, 31.9, 29.5, 29.3, 29.22, 29.17, 28.8, 22.7, 14.1; MS (EI) *m/z* (%) 385 (M<sup>+</sup>, 9.93), 145 (100); IR (neat) *ν* = 2954, 2922, 2852, 2820, 1598, 1489, 1454, 1356, 1321, 1286, 1261, 1189, 1133, 1099, 1070, 1050, 1028, 1007 cm<sup>-1</sup>; HRMS calcd for C<sub>28</sub>H<sub>35</sub>N (M<sup>+</sup>): 385.2770. Found: 385.2772.

(2) (*E*)-1-((trimethylsilyl)ethynyl)-2-(2-undecenyl)-1,2,3,4-tetrahydroisoquinoline

(**3fm**) (cyf-1-137B)



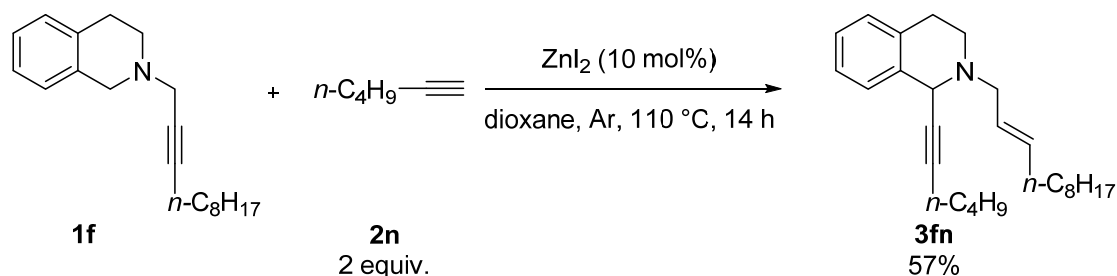
Following **Typical Procedure IV**, the reaction of ZnI<sub>2</sub> (32.4 mg, 0.1 mmol), trimethylsilylacetylene **2m** (200.9 mg, 2.0 mmol), **1f** (283.7 mg, 1.0 mmol), and dioxane (6.0 mL) afforded **3fm** (277.3 mg, 73%) (eluent: petroleum ether/ diethyl ether/ dicholoromethane = 30/1/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.27-7.19 (m, 1 H, ArH), 7.19-7.04 (m, 3 H, ArH), 5.72 (td, *J* = 15.8, 6.8 Hz, 1 H, =CH), 5.53 (td, *J* = 15.2, 6.8 Hz, 1 H, =CH), 4.65 (s, 1 H, NCH), 3.33-3.19 (m, 2 H, CH<sub>2</sub>), 3.02-2.88 (m, 2 H, CH<sub>2</sub>), 2.83-2.70 (m, 2 H, CH<sub>2</sub>), 2.07 (q, *J* = 7.1 Hz, 2 H, CH<sub>2</sub>), 1.46-1.18 (m, 12 H, 6×CH<sub>2</sub>), 0.89 (t, *J* = 6.8 Hz, 3 H, CH<sub>3</sub>), 0.15 (m, 9 H,



3×SiCH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 135.3, 135.1, 133.9, 128.9, 127.8, 126.8, 126.1, 125.7, 103.4, 90.6, 57.4, 54.4, 45.3, 32.4, 31.9, 29.5, 29.3, 29.22, 29.15, 28.7, 22.7, 14.1, 0.2; MS (EI) *m/z* (%) 381 ([M]<sup>+</sup>, 29.89), 228 (100); IR (neat) *v* = 2956, 2922, 2853, 2821, 2156, 1494, 1454, 1356, 1321, 1286, 1261, 1189, 1133, 1099, 1076, 1070 cm<sup>-1</sup>; HRMS calcd for C<sub>25</sub>H<sub>39</sub>NSi (M<sup>+</sup>): 381.2852. Found: 381.2844.

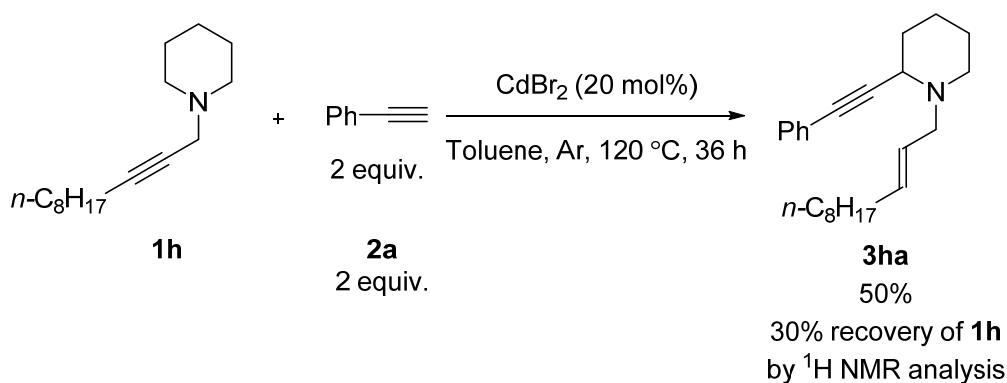
(3) (*E*)-1-(1-hexynyl)-2-(2-undecenyl)-1,2,3,4-tetrahydroisoquinoline (3fn)

(cyf-1-137A)



Following **Typical Procedure IV**, the reaction of ZnI<sub>2</sub> (32.2 mg, 0.1 mmol), 1-hexyne **2n** (169.8 mg, 2.0 mmol), **1f** (283.3 mg, 1.0 mmol), and dioxane (6.0 mL) afforded **3fn** (208.8 mg, 57%) (eluent: petroleum ether/ diethyl ether/ dichloromethane = 40/1/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.28-7.19 (m, 1 H, ArH), 7.17-7.04 (m, 3 H, ArH), 5.71 (td, *J* = 15.2, 6.8 Hz, 1 H, =CH), 5.54 (td, *J* = 16.0, 6.8 Hz, 1 H, =CH), 4.62 (s, 1 H, NCH), 3.25 (qd, *J* = 13.5, 6.7 Hz, 2 H, CH<sub>2</sub>), 3.01-2.88 (m, 2 H, CH<sub>2</sub>), 2.85-2.69 (m, 2 H, CH<sub>2</sub>), 2.20 (td, *J* = 6.8, 1.6 Hz, 2 H, CH<sub>2</sub>), 2.06 (q, *J* = 6.8 Hz, 2 H, CH<sub>2</sub>), 1.53-1.20 (m, 16 H, 8×CH<sub>2</sub>), 0.93-0.83 (m, 6 H, 2×CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 136.2, 135.0, 133.7, 128.9, 127.6, 126.6, 126.3, 125.6, 86.8, 77.6, 57.4, 54.0, 45.2, 32.4, 31.9, 31.0, 29.5, 29.3, 29.23, 29.16, 28.8, 22.7, 22.0, 18.5, 14.1, 13.6; MS (EI) *m/z* (%) 365 ([M]<sup>+</sup>, 22.97), 212 (100); IR (neat) *v* = 2955, 2923, 2853, 1658, 1493, 1456, 1357, 1323, 1288, 1260, 1192, 1132, 1113, 1075, 1050 cm<sup>-1</sup>; HRMS calcd for C<sub>26</sub>H<sub>39</sub>N (M<sup>+</sup>): 365.3083. Found: 365.3081.

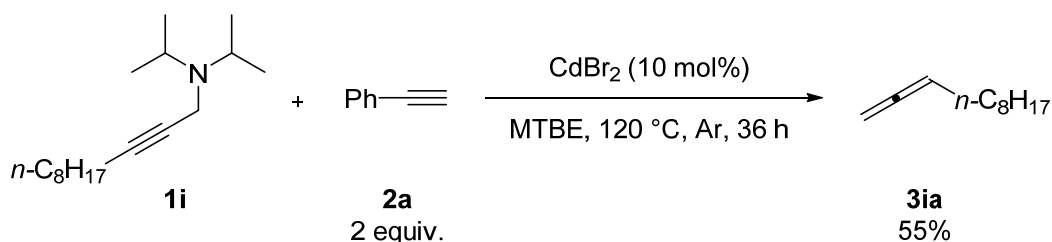
**5. The CdBr<sub>2</sub>-catalyzed reaction of 1-(2-Undecynyl) piperidine with phenylacetylene. (*E*)-2-(Phenylethynyl)-1-(2-undecenyl)piperidine (3ha)**  
(cyf-2-112)



Following **Typical Procedure I**, the reaction of  $\text{CdBr}_2$  (55.4 mg, 0.2 mmol), **1h** (235.2 mg, 1.0 mmol), phenylacetylene **2a** (212.6 mg, 2.0 mmol), and toluene (6.0 mL) afforded **3ha** (168.8 mg, 50%) (30% recovery of **1h** as determined by  $^1\text{H}$  NMR analysis of the crude product using  $\text{CH}_2\text{Br}_2$  as internal standard) (eluent: petroleum ether/ ethyl acetate = 50/1) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.49-7.41 (m, 2 H, ArH), 7.34-7.27 (m, 3 H, ArH), 5.66 (dt,  $J = 15.6, 7.4$  Hz, 1 H, =CH), 5.49 (dt,  $J = 15.2, 6.8$  Hz, 1 H, =CH), 3.82 (s, 1 H, NCH), 3.17 (dd,  $J = 12.8, 5.8$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 3.08 (dd,  $J = 13.2, 7.4$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.62-2.46 (m, 2 H,  $\text{NCH}_2$ ), 2.03 (q,  $J = 6.9$  Hz, 2 H,  $\text{CH}_2$ ), 1.91-1.80 (m, 2 H,  $\text{CH}_2$ ), 1.78-1.50 (m, 4 H,  $2 \times \text{CH}_2$ ), 1.44-1.18 (m, 12 H,  $6 \times \text{CH}_2$ ), 0.88 (t,  $J = 6.8$  Hz, 3 H,  $\text{CH}_3$ );  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  134.9, 131.7, 128.2, 127.8, 126.2, 123.5, 87.2, 86.4, 58.6, 51.7, 49.1, 32.4, 31.8, 31.4, 29.4, 29.3, 29.2, 29.1, 25.7, 22.6, 20.9, 14.1; MS (EI)  $m/z$  (%) 337 ( $\text{M}^+$ , 8.77), 184 (100); IR (neat)  $\nu = 2922, 2852, 2814, 1598, 1489, 1441, 1377, 1351, 1319, 1292, 1260, 1201, 1123, 1068, 1041, 1027$   $\text{cm}^{-1}$ ; HRMS calcd for  $\text{C}_{24}\text{H}_{35}\text{N}$  ( $\text{M}^+$ ): 337.2770. Found: 337.2760.

## 6. The $\text{CdBr}_2$ -catalyzed reaction of propargylic amine **1i** with terminal alkyne.

1,2-Undecadiene (**3ia**) (cyf-2-92)<sup>4</sup>

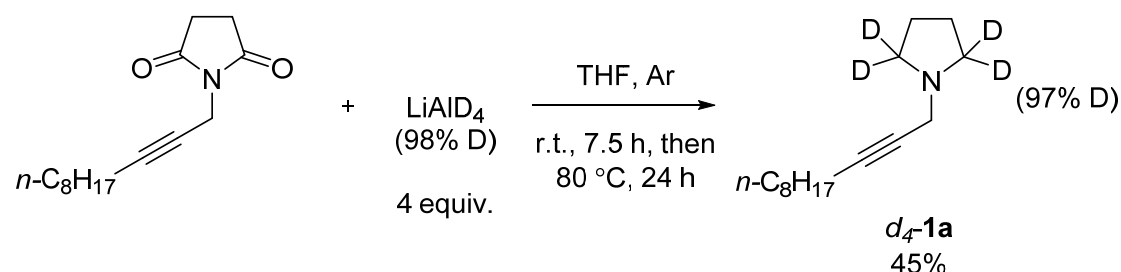


Following **Typical Procedure I**, the reaction of  $\text{CdBr}_2$  (27.6 mg, 0.1 mmol), **1i**

(251.7 mg, 1.0 mmol), phenylacetylene **2a** (208.1 mg, 2.0 mmol), and MTBE (6.0 mL) afforded **3ia** (83.8 mg, 55%) (eluent: petroleum ether) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  5.01 (quint,  $J = 6.8$  Hz, 1 H, =CH), 4.64 (dt,  $J = 6.4, 3.2$  Hz, 2 H, =CH<sub>2</sub>), 2.03-1.94 (m, 2 H, CH<sub>2</sub>), 1.45-1.19 (m, 12 H, 6 $\times$ CH<sub>2</sub>), 0.88 (t,  $J = 6.8$  Hz, 3 H, CH<sub>3</sub>);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  208.5, 90.1, 74.5, 31.9, 29.4, 29.3, 29.14, 29.10, 28.3, 22.7, 14.1; MS (EI)  $m/z$  (%) 152 ( $\text{M}^+$ , 1.0), 54 (100); IR (neat)  $\nu = 2957, 2923, 2854, 1957, 1463, 1378, 1260, 1096, 1016$   $\text{cm}^{-1}$ .

## 7. Mechanistic studies

(1) 1-(2-Undecynyl)pyrrolidine-2,2,5,5- $d_4$  ( $d_4$ -**1a**) (cyf-1-060)

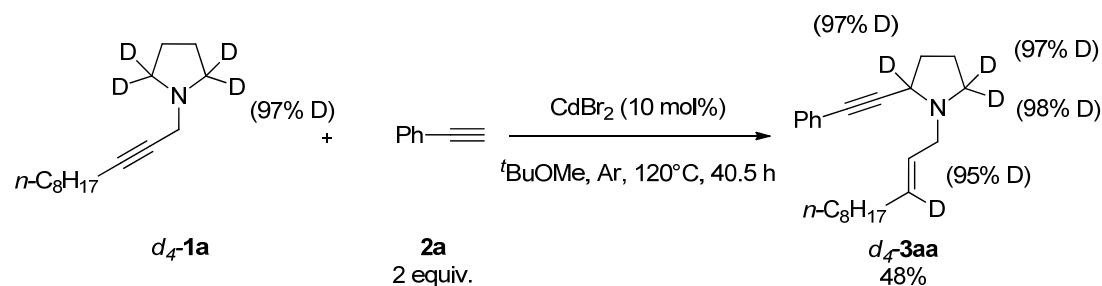


To a flame-dried Schlenk tube were added  $\text{LiAlD}_4$  (168.5 mg, 4.0 mmol) and 4 mL of THF under Ar atmosphere. The reaction mixture was cooled to 0 °C with an ice bath and 1-(2-undecynyl)pyrrolidine-2,5-dione (249.5 mg, 1.0 mmol) was then added. After being stirred for 7.5 hours at room temperature, the reaction mixture was stirred at 80 °C with a pre-heated oil bath for 24 hours. After being cooled to room temperature, 6 mL of a saturated aqueous solution of  $\text{Na}_2\text{SO}_4$  was added. After filtration, extraction with EtOAc (3 $\times$ 10 mL), and evaporation, the residue was purified by chromatography on silica gel to afford  $d_4$ -**1a** (100.6 mg, 45%, 97% deuteration) (eluent: petroleum ether/ acetone = 30/1) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  3.39-3.33 (m, 2 H, CH<sub>2</sub>), 2.22-2.14 (m, 2 H, CH<sub>2</sub>), 1.78 (s, 4 H, 2 $\times$ CH<sub>2</sub>), 1.49 (quint,  $J = 7.1$  Hz, 2 H, CH<sub>2</sub>), 1.43-1.18 (m, 10 H, 5 $\times$ CH<sub>2</sub>), 0.88 (t,  $J = 6.6$  Hz, 3 H, CH<sub>3</sub>);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  84.3, 75.5, 51.6 (quint,  $J_{\text{C-D}} = 20.3$  Hz), 43.3, 31.7, 29.1, 29.0, 28.8, 28.76, 28.73, 23.4, 22.5, 18.6, 13.9; MS (EI)  $m/z$  (%) 225 ( $[\text{M}]^+$ , 34.66), 224 (100); IR (neat)  $\nu = 2955, 2924, 2873, 2854, 2771, 2199, 2056, 1464, 1433, 1359, 1326, 1260, 1214, 1125, 1068, 1017$   $\text{cm}^{-1}$ ; HRMS calcd for  $\text{C}_{15}\text{NH}_{23}\text{D}_4$

(M<sup>+</sup>): 225.2395. Found: 225.2393.

The following signals are discernible for **1a**: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 2.57 (s, 4 H, 2×CH<sub>2</sub>). <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 52.2.

(2) (*E*)-2-(Phenylethynyl)-1-(3-deuterio-2-undecenyl)-2,5,5-trideuteriopyrrolidine (*d*<sub>4</sub>-**3aa**) (cyf-1-089)

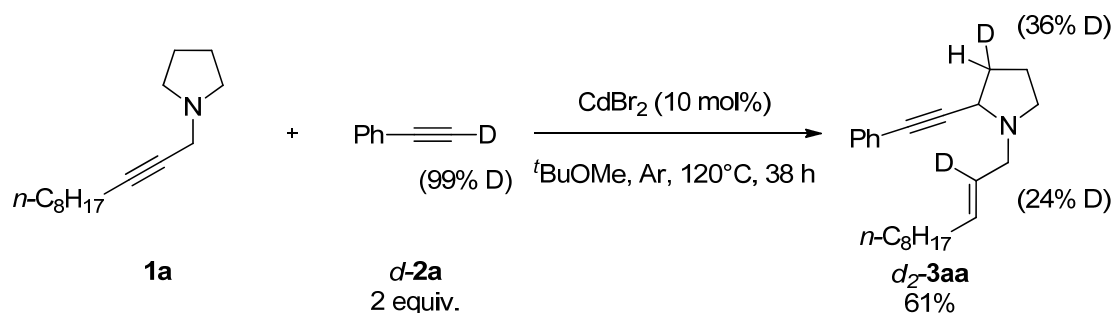


To a dry Schlenk tube with a polytetrafluoroethylene plug was added CdBr<sub>2</sub> (8.3 mg, 0.03 mmol). Then the catalyst was dried under vacuum with heating. *d*<sub>4</sub>-**1a** (67.8 mg, 0.3 mmol), MTBE (1 mL), phenylacetylene **2a** (63.4 mg, 0.6 mmol), and MTBE (1 mL) were then added sequentially under Ar atmosphere. The resulting mixture was stirred at 120 °C for 40.5 h. After the completion of the reaction as monitored by TLC, the crude reaction mixture was filtrated through a short column of silica gel eluted with Et<sub>2</sub>O (50 mL). After evaporation, the residue was purified by column chromatography on silica gel to afford *d*<sub>4</sub>-**3aa** (46.9 mg, 48%, greater than 95% of incorporation) (eluent: petroleum ether/ acetone = 100/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.47-7.39 (m, 2 H, ArH), 7.36-7.25 (m, 3 H, ArH), 5.57 (t, *J* = 6.6 Hz, 1 H, =CH), 3.47 (dd, *J* = 12.6, 6.2 Hz, 1 H, one proton of NCH<sub>2</sub>), 3.03 (dd, *J* = 12.8, 7.6 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.23-2.12 (m, 1 H, one proton of CH<sub>2</sub>), 2.07-1.86 (m, 4 H, CH<sub>2</sub> and 2×one proton of CH<sub>2</sub>), 1.86-1.75 (m, 1 H, one proton of CH<sub>2</sub>), 1.41-1.20 (m, 12 H, 6×CH<sub>2</sub>), 0.88 (t, *J* = 6.6 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 133.8 (t, *J*<sub>C-D</sub> = 22.6 Hz), 131.7, 128.2, 127.8, 126.6, 123.4, 88.7, 84.6, 55.2, 54.1 (t, *J*<sub>C-D</sub> = 21.8 Hz), 50.8 (quint, *J*<sub>C-D</sub> = 20.9 Hz), 32.2, 31.9, 31.6, 29.4, 29.3, 29.2, 29.1, 22.7, 21.8, 14.1; MS (EI) *m/z* (%) 327 ([M]<sup>+</sup>, 5.10), 213 (100); IR (neat) *ν* = 3056, 2954, 2853, 2195, 2060, 1598, 1573, 1489, 1463, 1443, 1363, 1311, 1285, 1259, 1203, 1117, 1068, 1027 cm<sup>-1</sup>; HRMS calcd for C<sub>23</sub>H<sub>29</sub>D<sub>4</sub>N (M<sup>+</sup>): 327.2864. Found:

327.2858.

The following signals are discernible for (**3aa**):  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  5.65 (dt,  $J = 15.6, 6.4$  Hz, 1 H, =CH), 3.58 (dd,  $J = 7.4, 5.8$  Hz, 1 H, NCH), 2.85 (dd,  $J = 9.2, 6.0$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.49 (dd,  $J = 8.2, 6.6$  Hz, 1 H, one proton of  $\text{NCH}_2$ ).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  134.1, 54.5.

(3) (*E*)-2-(phenylethynyl)-1-(2-deuterio-2-undecenyl)-3-deuteriopyrrolidine ( $d_2$ -**3aa**)  
(cyf-1-075)

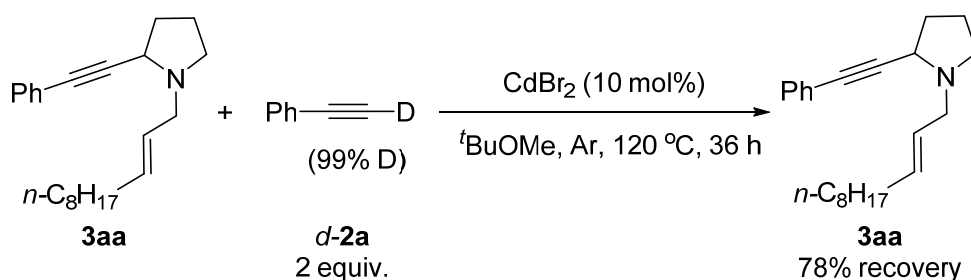


To a dry Schlenk tube with a polytetrafluoroethylene plug was added  $\text{CdBr}_2$  (27.7 mg, 0.1 mmol). Then the catalyst was dried under vacuum with heating. **1a** (222.0 mg, 1.0 mmol), MTBE (3 mL), deuterated phenylacetylene **d-2a** (207.0 mg, 2.0 mmol), and MTBE (3 mL) were then added sequentially under Ar atmosphere. The resulting mixture was stirred at 120 °C for 38 h. After the completion of the reaction as monitored by TLC, the crude reaction mixture was filtrated through a short column of silica gel eluted with  $\text{Et}_2\text{O}$  (50 mL). After evaporation, the residue was purified by column chromatography on silica gel to afford  $d_2$ -**3aa** (198.0 mg, 61%, D-incorporation: =CD:  $(1-0.76) \times 100\% = 24\%$ , CHD:  $(1-0.64) \times 100\% = 36\%$ ) (eluent: petroleum ether/ acetone = 200/1 (200 mL) to 100/1 (600 mL)) as a liquid:  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.50-7.39 (m, 2 H, ArH), 7.34-7.24 (m, 3 H, ArH), 5.67 (dt,  $J = 15.2, 6.2$  Hz, 1 H, =CH), 3.61-3.54 (m, 1 H, NCH), 3.52-3.45 (m, 1 H, one proton of  $\text{NCH}_2$ ), 3.02 (dd,  $J = 12.6, 7.0$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.88-2.80 (m, 1 H, one proton of  $\text{NCH}_2$ ), 2.51 (dd,  $J = 15.4, 8.6$  Hz, 1 H, one proton of  $\text{NCH}_2$ ), 2.09-1.87 (m, 4 H,  $\text{CH}_2$  and  $2 \times$  one proton of  $\text{CH}_2$ ), 1.86-1.74 (m, 1 H, one proton of  $\text{CH}_2$ ), 1.46-1.14 (m, 12 H,  $6 \times \text{CH}_2$ ), 0.88 (t,  $J = 6.6$  Hz, 3 H,  $\text{CH}_3$ );  $^{13}\text{C}$  NMR (100

MHz, CDCl<sub>3</sub>)  $\delta$  134.0, 131.6, 128.1, 127.8, 126.4 (t,  $J_{C-D}$  = 23.5 Hz), 123.4, 88.7, 84.5, 55.2, 54.45, 51.6, 32.27, 31.8, 31.2 (t,  $J_{C-D}$  = 19.9 Hz), 29.4, 29.25, 29.19, 29.1, 22.6, 21.9, 14.1; MS (EI)  $m/z$  (%) 325 ([M(C<sub>23</sub>H<sub>31</sub>D<sub>2</sub>N)]<sup>+</sup>, 13.27), 324 ([M(C<sub>23</sub>H<sub>32</sub>DN)]<sup>+</sup>, 32.36), 323 ([M(C<sub>23</sub>H<sub>33</sub>N)]<sup>+</sup>, 44.31), 211 (100); IR (neat)  $\nu$  = 3058, 3021, 2955, 2922, 2853, 2807, 1598, 1573, 1489, 1459, 1443, 1375, 1321, 1267, 1158, 1116, 1070, 1028 cm<sup>-1</sup>; HRMS calcd for C<sub>23</sub>H<sub>31</sub>D<sub>2</sub>N (M<sup>+</sup>): 325.2739. Found: 325.2747.

The following signals are discernible for (**3aa**): <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  5.58 (dt,  $J$  = 15.2, 6.6 Hz, 1 H, =CH), 1.86-1.74 (m, 1 H, one proton of CH<sub>2</sub>). <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>)  $\delta$  134.1, 126.7, 55.3, 54.51, 32.33, 31.7, 22.0.

(4) (*E*)-2-(Phenylethynyl)-1-(2-undecenyl)pyrrolidine (**3aa**) (cyf-1-101)

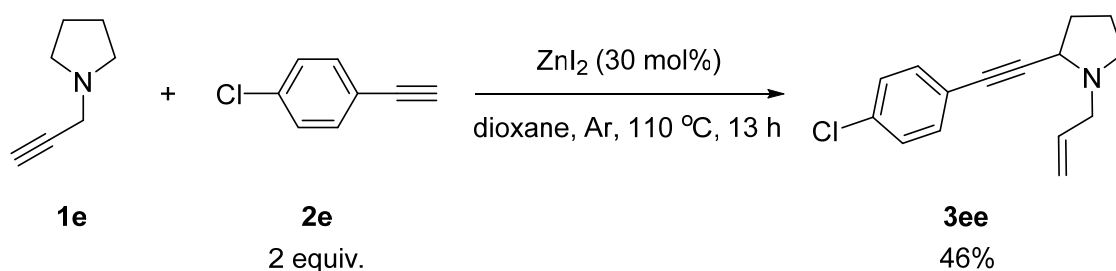


To a dry Schlenk tube with a polytetrafluoroethylene plug was added CdBr<sub>2</sub> (11.2 mg, 0.04 mmol). Then the catalyst was dried under vacuum with heating. After cooling to room temperature, deuterated phenylacetylene **d-2a** (83.5 mg, 0.8 mmol), MTBE (1.2 mL), **3aa** (128.9 mg, 0.4 mmol), and MTBE (1.2 mL) were added sequentially under Ar atmosphere. The resulting mixture was stirred at 120 °C for 36 h. The crude reaction mixture was diluted with 5 mL of DCM and filtrated through a short pad of silica gel eluted with DCM (30 mL). After evaporation, the residue was purified by chromatography on silica gel to afford **3aa** (101.3 mg, 78%) (eluent: petroleum ether/ acetone = 100/1 (200 mL) to 50/1 (200 mL)) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.47-7.39 (m, 2 H, ArH), 7.33-7.25 (m, 3 H, ArH), 5.67 (dt,  $J$  = 15.2, 6.2 Hz, 1 H, =CH), 5.58 (dt,  $J$  = 15.2, 6.4 Hz, 1 H, =CH), 3.56 (dd,  $J$  = 6.8, 5.6 Hz, 1 H, NCH), 3.49 (dd,  $J$  = 12.6, 5.4 Hz, 1 H, one proton of NCH<sub>2</sub>), 3.00 (dd,  $J$  = 12.8, 7.2 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.85 (td,  $J$  = 8.7, 5.2 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.55-2.45 (m, 1 H, one proton of NCH<sub>2</sub>), 2.24-2.12 (m, 1 H, one proton of

CH<sub>2</sub>), 2.08-1.87 (m, 4 H, CH<sub>2</sub> and 2×one proton of CH<sub>2</sub>), 1.87-1.75 (m, 1 H, one proton of CH<sub>2</sub>), 1.42-1.18 (m, 12 H, 6×CH<sub>2</sub>), 0.88 (t, *J* = 6.8 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 134.1, 131.6, 128.1, 127.8, 126.7, 123.4, 88.7, 84.5, 55.3, 54.5, 51.6, 32.3, 31.8, 31.7, 29.4, 29.24, 29.18, 29.1, 22.6, 22.0, 14.1.

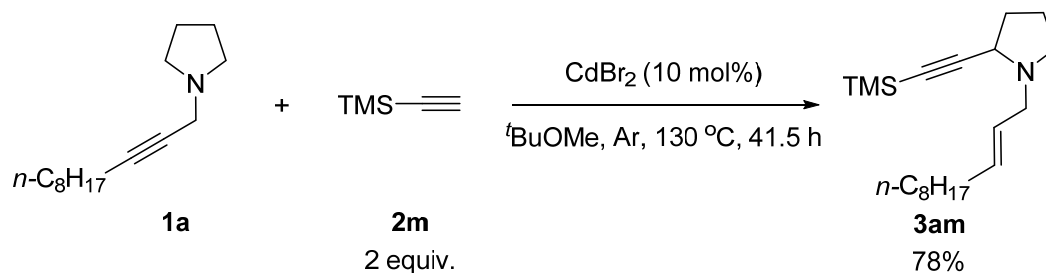
## 8. Gram-scale synthesis.

(1) 1-Allyl-2-((4-chlorophenyl)ethynyl)pyrrolidine (**3ee**) (cyf-1-051)



To a dry Schlenk tube with a polytetrafluoroethylene plug was added ZnI<sub>2</sub> (967.0 mg, 3.0 mmol). Then the catalyst was heated under vacuum until sublimation of ZnI<sub>2</sub>. After cooling to room temperature, 4-chlorophenylacetylene **2e** (2.7890 g, 20.0 mmol), **1e** (1.0920 g, 10.0 mmol) and dioxane (50 mL) were added sequentially under Ar atmosphere. Then the Schlenk tube was stirred at 110 °C for 13 h. After the completion of the reaction as monitored by TLC, the crude reaction mixture was filtrated through a short column of silica gel eluted with DCM (60 mL) and EtOAc (100 mL). After evaporation, the residue was purified by column chromatography on silica gel to afford **3ee** (1.1364 g, 46%) (eluent: petroleum ether/ acetone = 200/1 (500 mL) to 50/1 (1000 mL)) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.38-7.32 (m, 2 H, ArH), 7.29-7.23 (m, 2 H, ArH), 6.03-5.89 (m, 1 H, =CH), 5.25 (d, *J* = 17.2 Hz, 1 H, one proton of =CH<sub>2</sub>), 5.13 (d, *J* = 10.0 Hz, 1 H, one proton of =CH<sub>2</sub>), 3.59-3.51 (m, 2 H, NCH and one proton of NCH<sub>2</sub>), 3.04 (dd, *J* = 13.2, 7.6 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.85 (td, *J* = 8.7, 4.9 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.54-2.45 (m, 1 H, one proton of NCH<sub>2</sub>), 2.24-2.13 (m, 1 H, one proton of CH<sub>2</sub>), 2.07-1.87 (m, 2 H, 2×one proton of CH<sub>2</sub>), 1.87-1.75 (m, 1 H, one proton of CH<sub>2</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 135.4, 133.8, 132.8, 128.4, 121.7, 117.3, 89.6, 83.5, 56.2, 54.6, 51.6, 31.6, 22.0.

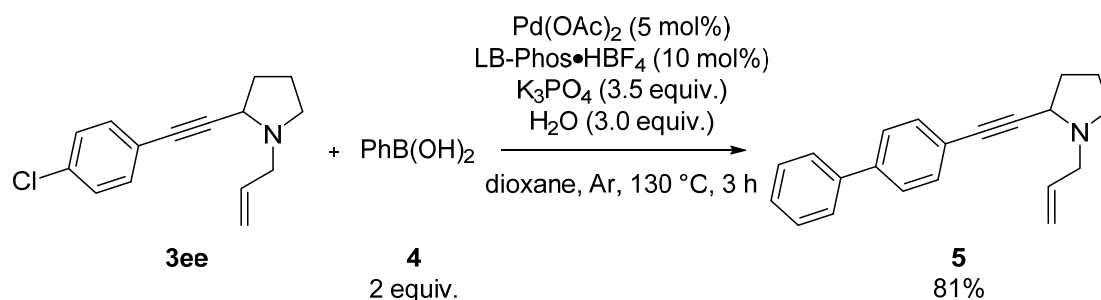
(2) (*E*)-2-((trimethylsilyl)ethynyl)-1-(2-undecenyl)pyrrolidine (**3am**) (cyf-1-069)



Following **Typical Procedure II**, the reaction of CdBr<sub>2</sub> (138.6 mg, 0.5 mmol), **1a** (1.1067 g, 5.0 mmol), trimethylsilylacetylene **2m** (1.0025 g, 10.0 mmol), and MTBE (30 mL) afforded **3am** (1.2437 g, 78%) (eluent: petroleum ether/ acetone = 200/1 to 100/1) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 5.63 (dt, *J* = 15.2, 6.4 Hz, 1 H, =CH), 5.54 (dt, *J* = 16.0, 6.6 Hz, 1 H, =CH), 3.42 (dd, *J* = 12.4, 6.0 Hz, 1 H, one proton of NCH<sub>2</sub>), 3.32 (dd, *J* = 7.4, 5.4 Hz, 1 H, NCH), 2.91 (dd, *J* = 12.6, 7.4 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.82-2.72 (m, 1 H, one proton of NCH<sub>2</sub>), 2.48-2.38 (m, 1 H, one proton of NCH<sub>2</sub>), 2.15-1.97 (m, 3 H, CH<sub>2</sub> and one proton of CH<sub>2</sub>), 1.96-1.67 (m, 3 H, CH<sub>2</sub> and one proton of CH<sub>2</sub>), 1.43-1.15 (m, 12 H, 6×CH<sub>2</sub>), 0.88 (t, *J* = 6.8 Hz, 3 H, CH<sub>3</sub>), 0.16 (s, 9 H, 3×SiCH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 134.0, 126.7, 105.4, 88.6, 55.2, 54.5, 51.5, 32.3, 31.9, 31.6, 29.4, 29.3, 29.2, 29.1, 22.6, 21.9, 14.1, 0.1.

## 9. Synthetic applications

(1) 2-(4-phenylphenylethynyl)-1-allylpyrrolidine (**5**) (cyf-1-081)

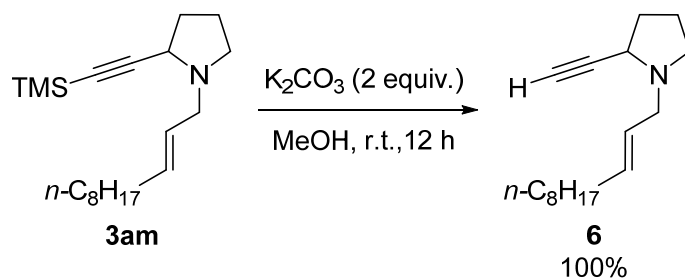


To a dry Schlenk tube with a polytetrafluoroethylene plug was added K<sub>3</sub>PO<sub>4</sub> (383.3 mg, 1.75 mmol). Then it was dried under vacuum with a heating gun. Pd(OAc)<sub>2</sub> (5.8 mg, 0.025 mmol), LB-Phos·HBF<sub>4</sub> (23.2 mg, 0.05 mmol), phenylboronic acid **4** (124.4 mg, 1 mmol), and dioxane (0.5 mL) were added



sequentially under Ar atmosphere. After being stirred for 5 min at room temperature, 1-allyl-2-((4-chlorophenyl)ethynyl)pyrrolidine **3ee** (123.0 mg, 0.5 mmol), dioxane (0.5 mL) and 27.0  $\mu$ L of H<sub>2</sub>O (27.0 mg, 1.5 mmol) were added. The resulting mixture was heated at 130 °C with a preheated oil bath. After 3 hours, it was allowed to cool to room temperature. The reaction mixture was diluted with 5 mL of dichloromethane and filtered through a short column of silica gel (eluent: 50 mL of Et<sub>2</sub>O). After evaporation, the residue was purified by column chromatography on silica gel to afford **5** (116.8 mg, 81%) (eluent: petroleum ether/ acetone = 200:1 (400 mL) to 100:1 (300 mL)) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.68-7.29 (m, 9 H, ArH), 6.07-5.90 (m, 1 H, =CH), 5.27 (d, *J* = 16.8 Hz, 1 H, one proton of =CH<sub>2</sub>), 5.14 (d, *J* = 10.0 Hz, 1 H, one proton of =CH<sub>2</sub>), 3.67-3.52 (m, 2 H, NCH and one proton of NCH<sub>2</sub>), 3.08 (dd, *J* = 12.8, 7.6 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.94-2.82 (m, 1 H, one proton of NCH<sub>2</sub>), 2.52 (q, *J* = 8.0 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.29-2.14 (m, 1 H, one proton of CH<sub>2</sub>), 2.11-1.76 (m, 3 H, 3 $\times$ one proton of CH<sub>2</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>)  $\delta$  140.6, 140.3, 135.6, 132.1, 128.8, 127.5, 126.94, 126.85, 122.2, 117.3, 89.2, 84.5, 56.3, 54.8, 51.7, 31.7, 22.0; MS (EI) *m/z* (%) 287 (M<sup>+</sup>, 61.40) 286 (100); IR (neat)  $\nu$  = 3076, 3030, 2975, 2955, 2910, 2875, 1643, 1600, 1518, 1485, 1459, 1444, 1418, 1403, 1354, 1318, 1284, 1259, 1180, 1159, 1140, 1108, 1077, 1007 cm<sup>-1</sup>; HRMS calcd for C<sub>21</sub>H<sub>21</sub>N (M<sup>+</sup>): 287.1674. Found: 287.1676.

(2) (*E*)-2-ethynyl-1-(2-undecenyl)pyrrolidine (**6**) (cyf-1-087)



To a round-bottom flask were added (*E*)-2-((trimethylsilyl)ethynyl)-1-(2-undecenyl)-pyrrolidine **3am** (63.9 mg, 0.2 mmol), MeOH (3 mL), and K<sub>2</sub>CO<sub>3</sub> (55.7 mg, 0.4 mmol) sequentially. The resulting mixture was allowed to stir at room temperature for 12 h. MeOH was then evaporated under





methanol = 30:1 to 15:1) to afford (5a*R*\*,6*R*\*,8b*S*\*)-6-octyl-1,2,3,5a,6,8b-hexahydrocyclopenta[*a*]pyrrolizin-7(5*H*)-one **8** (24.9 mg, 45%) as a liquid: <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 6.00 (s, 1 H, =CH), 4.17 (t, *J* = 8.0 Hz, 1 H, NCH), 3.33 (t, *J* = 6.6 Hz, 1 H, one proton of NCH<sub>2</sub>), 3.20 (dd, *J* = 11.6, 8.0 Hz, 1 H, one proton of NCH<sub>2</sub>), 2.98-2.88 (m, 1 H, CH), 2.78-2.63 (m, 2 H, 2×one proton of CH<sub>2</sub>), 2.32-2.21 (m, 1 H, one proton of CH<sub>2</sub>), 2.10-1.83 (m, 4 H, CH<sub>2</sub>, CH and one proton of CH<sub>2</sub>), 1.65-1.52 (m, 1 H, one proton of CH<sub>2</sub>), 1.46-1.19 (m, 13 H, 6×CH<sub>2</sub> and one proton of CH<sub>2</sub>), 0.88 (t, *J* = 6.6 Hz, 3 H, CH<sub>3</sub>); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 211.6, 187.8, 123.3, 57.6, 62.1, 56.5, 53.3, 47.9, 32.2, 31.8, 29.5, 29.4, 29.2, 28.7, 28.0, 27.8, 22.6, 14.1; MS (ESI) *m/z* 276 ([M+H]<sup>+</sup>); IR (neat) *ν* = 2923, 2855, 1700, 1457, 1373, 1258, 1084, 1017 cm<sup>-1</sup>; HRMS calcd for C<sub>18</sub>H<sub>30</sub>NO ([M+H]<sup>+</sup>): 276.2322. Found: 276.2318.

#### References:

1. Bieber, L. W.; Da Silva, M. F. *Tetrahedron Lett.* **2004**, *45*, 8281.
2. Biel, J. H.; DiPierro, F. *J. Am. Chem. Soc.* **1958**, *80*, 4609.
3. Bew, S. P.; Hiatt-Gipson, G. D.; Lovell, J. A.; Poullain, C. *Org. Lett.* **2012**, *14*, 456.
4. Kuang J.; Ma, S. *J. Org. Chem.* **2009**, *74*, 1763.