Supporting Information

Selective C–H Olefination of Indolines (C5) and Tetrahydroquinolines (C6) by Pd/S, O-Ligand Catalysis

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1. General Information

Chromatography: Silicycle Silica Flash P60 size 40-63 µm (230-400 mesh), TLC: Merck silica gel 60 (0.25mm). Visualization of the chromatogram was performed by UV and KMnO₄ solution. Mass spectra were recorded on AccuTOF GC v 4g, JMS-T100GCV mass spectrometers. ¹H, ¹³C and ³¹P were recorded on Bruker 500 AMX, 400 and Bruker DRX 300 using CDCl₃ as solvent. Chemical shift values are reported in ppm with the solvent resonance as the internal standard (CDCl₃: δ 7.26 for ¹H, δ 77.16 for ¹³C). Data are reported as follows: chemical shifts, multiplicity (s = singlet, d = doublet, dd = doublet of doublets, ddd = doublet of doublets of doublets, t = triplet, bs = broad singlet, m = multiplet, td = triplet of doublets, dt = doublet of triplets), coupling constants (Hz), and integration. Infrared spectra were recorded on a Bruker IFS 28 FT-spectrophotometer. ATR technique was used in IR spectroscopy. All reagents and solvents were used as received unless it was specified. Pd(OAc)₂ was purchased from Strem. S,O-ligand (3-methyl-2-(phenylthio)butanoic acid) was prepared following the procedure reported in the literature.¹

2. Synthesis of indoline and quinoline substrates

Substrates 1a, 1b, 1c, 1d, 1e, 1f, 1g, 1i, 1m, 1n, 3a, 3b, 3c, 3d, 3e, 3i were prepared following the general procedure reported in literature:²

In a flame-dried schlenk flask under N₂, (substituted)indole or quinoline (1.0 equiv.) was added, followed by paraformaldehyde (5.0 – 10.0 equiv.) and acetic acid (0.2 M). At 0 °C, NaCNBH₃ (2.0 – 10.0 equiv.) was then added portionwise. The reaction was then left to stir at room temperature overnight and was quenched at 0 °C by slowly adding cold NaOH aqueous solution (10 M) until the reaction was basic. The mixture was extracted with DCM three times and the combined organic extracts were washed with brine, dried with MgSO₄ and concentrated in vacuo. The product was purified by flash column chromatography.

1-Methylinodline (1a)³

1a was prepared following the general procedure starting from indole (1.11 g, 9.33 mmol) using 5.0 equivalents of paraformaldehyde and 2.0 equivalents of NaCNBH₃ as a colorless liquid (0.80 g, 64%) after purification by flash column chromatography (20:1, PE/Et₂O) and its ¹H NMR data matched with those reported in the literature.³ ¹H NMR (400 MHz) δ 7.11 – 7.07 (m, 2H), 6.68 (t, J = 7.4 Hz, 1H), 6.50 (d, J = 8.0 Hz, 1H), 3.29 (t, J = 8.2 Hz, 2H), 2.95 (t, J = 8.1 Hz, 2H), 2.76 (s, 3H).
4-Fluoro-1-methylindoline (1b)

1b was prepared following the general procedure starting from 4-fluoroindole (1.01 g, 7.48 mmol) using 5.0 equivalents of paraformaldehyde and 5.0 equivalents of NaCNBH₃ as a pale yellow liquid (0.58 g, 51%) after purification by flash column chromatography (20:1, PE/Et₂O). ¹H NMR (400 MHz) δ 7.06 – 7.00 (m, 1H), 6.37 (t, J = 8.5 Hz, 1H), 6.25 (d, J = 7.8 Hz, 1H), 3.37 (t, J = 8.3 Hz, 2H), 2.99 (t, J = 8.3 Hz, 2H), 2.76 (d, J = 1.5 Hz, 3H). ¹³C NMR (75 MHz) δ 159.6 (d, J₇CF = 243.4 Hz), 156.2 (d, J₇CF = 9.2 Hz), 129.2 (d, J₇CF = 8.7 Hz), 115.3 (d, J₇CF = 21.5 Hz), 105.1 (d, J₇CF = 21.3 Hz), 103.0 (d, J₇CF = 2.4 Hz), 56.2, 36.1, 25.1. IR: ν 2952, 2853, 2811, 1629, 1479, 1467, 1291, 1273, 1211, 1132, 959, 945, 755, 702 cm⁻¹. HRMS (ESI) calculated for C₉H₁₁FN [M⁺H⁺]: 152.0876; found: 152.0871.

6-Fluoro-1-methylindoline (1c)

1c was prepared following the general procedure starting from 6-fluoroindole (2.03 g, 15.0 mmol) using 5.0 equivalents of paraformaldehyde and 5.0 equivalents of NaCNBH₃ as a pale yellow liquid (1.18 g, 52%) after purification by flash column chromatography (20:1, PE/Et₂O) and its ¹H NMR data matched with those reported in the literature. ¹H NMR (400 MHz) δ 6.96 – 6.92 (m, 1H), 6.31 (d, J₆Fdd, J = 9.9, 8.0, 2.2 Hz, 1H), 6.15 (dd, J = 10.3, 2.1 Hz, 1H), 3.35 (t, J = 8.2 Hz, 2H), 2.90 (t, J = 8.2 Hz, 2H), 2.74 (s, 3H).

6-Fluoro-1-methylindoline (1d)

1d was prepared following the general procedure starting from 6-fluoroindole (2.03 g, 15.0 mmol) using 5.0 equivalents of paraformaldehyde and 5.0 equivalents of NaCNBH₃ as a pale yellow liquid (1.05 g, 46%) after purification by flash column chromatography (20:1, PE/Et₂O). ¹H NMR (300 MHz) δ 6.94 – 6.79 (m, 2H), 6.66 (d, J₆Fddd, J = 8.2, 7.2, 4.3 Hz, 1H), 3.35 (t, J = 8.3 Hz, 2H), 3.10 – 2.97 (m, 5H). ¹³C NMR (100 MHz) δ 149.9 (d, J₇CF = 240.6 Hz), 139.8 (d, J₇CF = 8.5 Hz), 134.4 (d, J₇CF = 5.4 Hz), 120.3 (d, J₇CF = 2.9 Hz), 119.2 (d, J₇CF = 6.2 Hz), 115.2 (d, J₇CF = 19.7 Hz), 57.4, 38.8 (d, J₇CF = 7.3 Hz), 29.7 (d, J₇CF = 1.9 Hz). IR: ν 2955, 2848, 2807, 1621, 1487, 1463, 1275, 1232, 1188, 1103, 1005, 752, 715 cm⁻¹. HRMS (ESI) calculated for C₉H₁₁FN [M⁺H⁺]: 152.0876; found: 152.0868.

4-Chloro-1-methylindoline (1e)

1e was prepared following the general procedure starting from 4-chloroindole (0.71 g, 4.70 mmol) using 7.0 equivalents of paraformaldehyde and 7.0 equivalents of NaCNBH₃ as a pale yellow liquid (0.63 g, 80%) after purification by flash column chromatography (20:1, PE/Et₂O). ¹H NMR (400 MHz) δ 7.00 (t, J = 7.9 Hz, 1H), 6.63 (d, J = 8.0 Hz, 1H), 6.33 (d, J = 7.8 Hz, 1H), 3.36 (t, J = 8.3 Hz, 2H), 2.99 (t, J = 8.3 Hz, 2H), 2.76 (s, 3H). ¹³C NMR (75 MHz) δ 154.7, 130.4, 128.9, 128.2, 117.6, 105.1, 55.4, 36.0, 28.0. IR: ν 2949, 2846, 2808, 1601, 1449, 1270, 1105, 752 cm⁻¹. HRMS (ESI) calculated for C₉H₁₁ClN [M⁺H⁺]: 168.0580; found: 168.0575.

7-Chloro-1-methylindoline (1f)

1f was prepared following the general procedure starting from 4-chloroindole (1.30 g, 8.47 mmol) using 7.0 equivalents of paraformaldehyde and 7.0 equivalents of NaCNBH₃ as a pale yellow liquid (0.95 g, 67%) after purification by flash column chromatography (20:1, PE/Et₂O). ¹H NMR (400 MHz) δ 7.01 (d, J = 7.9 Hz, 1H), 6.65 (d, J = 8.0 Hz, 1H), 6.33 (d, J = 7.8 Hz, 1H), 3.36 (t, J = 8.3 Hz, 2H), 2.99 (t, J = 8.3 Hz, 2H), 2.76 (s, 3H), 3.36 (t, J = 8.5 Hz, 2H). ¹³C NMR (100 MHz) δ 148.5, 133.8, 129.6, 122.9, 119.7, 115.6, 57.3, 39.1, 28.8. IR: ν 2951, 2847, 2807, 1602, 1451, 1415, 1264, 1091, 1053, 893, 750, 716 cm⁻¹. HRMS (ESI) calculated for C₉H₁₁ClN [M⁺H⁺]: 168.0580; found: 168.0575.
Methyl 1-methylindoline-7-carboxylate (1g)

1g was prepared following the general procedure starting from methyl indole-7-carboxylate (1.16 g, 6.62 mmol) using 5.0 equivalents of paraformaldehyde and 5.0 equivalents of NaCNBH₃ (Caution: the reaction was quenched by adding water followed by slow addition of K₂CO₃ till the the mixture was basic) as a pale yellow liquid (1.13 g, 89%) after purification by flash column chromatography (DCM). ¹H NMR (400 MHz) δ 7.47 (d, J = 8.0 Hz, 1H), 7.13 (d, J = 7.1 Hz, 1H), 6.65 (dd, J = 8.0, 7.0 Hz, 1H), 3.88 (s, 3H), 3.50 (t, J = 8.6 Hz, 2H), 2.99 (t, J = 8.7 Hz, 2H), 2.86 (s, 3H), 1.33 (d, J = 6.7 Hz, 3H). IR: ν 2949, 2841, 1705, 1411, 1287, 1229, 1189, 1130, 1099, 1057, 744 cm⁻¹. HRMS (ESI) calculated for C₁₇H₂₀NO₂ [M+H]⁺: 294.1289; found: 294.1288.

1,2-Dimethylindoline (1i)⁴

1i was prepared following the general procedure starting from 2-methylindole (2.01 g, 15.3 mmol) using 5.0 equivalents of paraformaldehyde and 5.0 equivalents of NaCNBH₃ as a colorless liquid (1.93 g, 85%) after purification by flash column chromatography (20:1, PE/EtO) and its ¹H NMR data matched with those reported in the literature.⁴ ¹H NMR (400 MHz) δ 7.10–7.04 (m, 2H), 6.67 (t, J = 7.3 Hz, 1H), 6.46 (d, J = 7.8 Hz, 1H), 3.45–3.36 (m, 1H), 3.12–3.06 (m, 1H), 2.72 (s, 3H), 2.64–2.57 (m, 1H), 1.32 (d, J = 6.1 Hz, 3H).

1,3-Dimethylindoline (1j)⁵

1j was prepared following the general procedure starting from 3-methylindole (2.62 g, 20.0 mmol) using 10.0 equivalents of paraformaldehyde and 5.0 equivalents of NaCNBH₃ as a colorless liquid (2.30 g, 78%) after purification by flash column chromatography (20:1, PE/EtO) and its ¹H NMR data matched with those reported in the literature.⁵ ¹H NMR (300 MHz) δ 7.17 – 7.03 (m, 2H), 6.71 (t, J = 7.3 Hz, 1H), 6.50 (d, J = 7.7 Hz, 1H), 3.53 (t, J = 8.4 Hz, 1H), 3.28 (h, J = 7.5 Hz, 1H), 2.80 (t, J = 8.5 Hz, 1H), 2.75 (s, 3H), 1.32 (d, J = 6.8 Hz, 3H).

(±)-9-Methyl-2,3,4,4a,9,9a-hexahydro-1H-carbazole [(±)-1m]⁶

(±)-1m was prepared following the general procedure starting from 2,3,4,9-tetrahydro-1H-carbazole (1.50 g, 8.8 mmol) using 5.0 equivalents of paraformaldehyde and 7.0 equivalents of NaCNBH₃ as a white solid (1.35 g, 82%) after purification by flash column chromatography (20:1, PE/EtO) and its ¹H NMR data matched with those reported in the literature.⁶ ¹H NMR (400 MHz) δ 7.16 – 7.01 (m, 2H), 6.71 (t, J = 7.4 Hz, 1H), 6.55 (d, J = 7.8 Hz, 1H), 3.23 (dt, J = 7.0, 4.5 Hz, 1H), 2.99 (dt, J = 9.3, 6.6 Hz, 1H), 2.71 (s, 3H), 1.93 – 1.70 (m, 2H), 1.68 – 1.25 (m, 6H).

(±)-4-Methyl-1,2,3,3a,4,8b-hexahydrocyclopenta[b]indole [(±)-1n]

(±)-1n was prepared following the general procedure starting from 1,2,3,4-tetrahydrocyclopenta[b]indole (1.51 g, 9.6 mmol) using 4.0 equivalents of paraformaldehyde and 6.5 equivalents of NaCNBH₃ as a white solid (1.36 g, 82%) after purification by flash column chromatography (20:1, PE/EtO). ¹H NMR (300 MHz) δ 7.08 – 6.96 (m, 2H), 6.58 (t, J = 7.3 Hz, 1H), 6.30 (d, J = 7.8 Hz, 1H), 4.00 (ddd, J = 8.3, 5.2, 2.1 Hz, 1H), 3.68 (td, J = 9.0, 3.2 Hz, 1H), 2.76 (s, 3H), 2.05 – 1.80 (m, 2H), 1.79 – 1.48 (m, 4H). ¹³C NMR (100 MHz) δ 153.0, 133.8, 127.6, 124.1, 116.6, 105.3, 71.7, 45.9, 34.9, 33.5, 32.5, 24.8. IR: ν 2950, 2864, 1695, 1594, 1505, 1254, 1211 cm⁻¹. HRMS (ESI) calculated for C₁₂H₁₈N [M+H]⁺: 174.1283; found: 174.1289.

S5
1-Methyl-1,2,3,4-tetrahydroquinoline (3a)\(^7\)

3a was prepared following the general procedure starting from 1,2,3,4-tetrahydroquinoline (3.73 g, 28.0 mmol) using 10.0 equivalents of paraformaldehyde and 5.0 equivalents of NaCNBH\(_3\) as a colorless liquid (2.95 g, 72%) after purification by flash column chromatography (1:1, DCM/cyclohexane) and its \(^1\)H NMR data matched with those reported in the literature.\(^7\) \(^1\)H NMR (400 MHz) \(\delta\) 7.08 (t, \(J = 7.8\) Hz, 1H), 6.96 (d, \(J = 7.4\) Hz, 1H), 6.62 (t, \(J = 7.4\) Hz, 2H), 3.23 (t, \(J = 5.7\) Hz, 2H), 2.89 (s, 3H), 2.78 (t, \(J = 6.6\) Hz, 2H), 1.99 (p, \(J = 6.2\) Hz, 2H).

1,5-Dimethyl-1,2,3,4-tetrahydroquinoline (3b)

3b was prepared following the general procedure starting from 5-methylquinoline (0.43 g, 3.0 mmol) using 10.0 equivalents of paraformaldehyde and 10.0 equivalents of NaCNBH\(_3\) as a colorless liquid (0.24 g, 50%) after purification by flash column chromatography (1:1, DCM/cyclohexane). \(^1\)H NMR (400 MHz) \(\delta\) 7.17 (t, \(J = 7.9\) Hz, 1H), 6.70 (t, \(J = 8.0\) Hz, 2H), 3.33 (t, \(J = 5.6\) Hz, 2H), 3.04 (s, 3H), 2.82 (t, \(J = 6.8\) Hz, 2H), 2.36 (s, 3H), 2.26 – 2.09 (m, 2H) ppm. \(^13\)C NMR (75 MHz) \(\delta\) 147.2, 136.3, 126.3, 121.4, 118.6, 109.4, 51.0, 39.9, 24.7, 22.6, 19.9. IR: \(\nu\) 2931, 2862, 1585, 1487, 1320, 1205, 899, 761, 710 cm\(^{-1}\). HRMS (ESI) calculated for C\(_{11}\)H\(_{15}\)N\(^+\) [M]+: 161.1204, found: 161.1207.

1,7-Dimethyl-1,2,3,4-tetrahydroquinoline (3c)\(^8\)

3c was prepared following the general procedure starting from 7-methylquinoline (0.43 g, 3.0 mmol) using 10.0 equivalents of paraformaldehyde and 10.0 equivalents of NaCNBH\(_3\) as a colorless liquid (0.34 g, 71%) after purification by flash column chromatography (1:4, DCM/cyclohexane) and its \(^1\)H NMR data matched with those reported in the literature.\(^8\) \(^1\)H NMR (400 MHz) \(\delta\) 6.83 (d, \(J = 7.3\) Hz, 1H), 6.44 (d, \(J = 8.3\) Hz, 2H), 3.20 (t, \(J = 8\) Hz, 2H), 2.88 (s, 3H), 2.73 (t, \(J = 6.5\) Hz, 2H), 2.28 (s, 3H), 2.02 – 1.91 (m, 2H).

1,2,2,4,7-Pentamethyl-1,2,3,4-tetrahydroquinoline (3d)

3d was prepared following the general procedure starting from 2,2,4,7-tetramethyl-1,2,3,4-tetrahydroquinoline (3.50 g, 18.5 mmol) using 10.0 equivalents of paraformaldehyde and 5.0 equivalents of NaCNBH\(_3\) as a colorless liquid (3.05 g, 81%) after purification by flash column chromatography (1:1, DCM/cyclohexane). \(^1\)H NMR (400 MHz) \(\delta\) 7.17 (d, \(J = 7.6\) Hz, 1H), 6.64 (dd, \(J = 7.6\), 1.5 Hz, 1H), 6.56 (d, \(J = 1.7\) Hz, 1H), 3.01 – 2.91 (m, 4H), 2.45 (s, 3H), 1.90 (dd, \(J = 12.9\), 4.6 Hz, 1H), 1.66 (t, \(J = 12.7\) Hz, 1H), 1.47 (d, \(J = 6.7\) Hz, 3H), 1.42 (s, 3H), 1.33 (s, 3H). \(^13\)C NMR (75 MHz) \(\delta\) 146.0, 136.4, 125.8, 125.1, 116.4, 112.0, 54.0, 47.2, 31.5, 29.1, 27.2, 24.4, 21.7, 19.8. IR: \(\nu\) 2964, 2924, 1609, 1505, 1479, 1458, 1331, 1131, 793, 596 cm\(^{-1}\). HRMS (ESI) calculated for C\(_{18}\)H\(_{21}\)N\(^+\) [M]+: 203.1674; found: 203.1682.

7-Chloro-1-methyl-1,2,3,4-tetrahydroquinoline (3e)

3e was prepared following the general procedure starting from 7-chloroquinoline (0.50 g, 3.0 mmol) using 10.0 equivalents of paraformaldehyde and 10.0 equivalents of NaCNBH\(_3\) as a colorless liquid (0.31 g, 56%) after purification by flash column chromatography (1:4, DCM/cyclohexane). \(^1\)H NMR (400 MHz) \(\delta\) 6.83 (d, \(J = 7.8\) Hz, 1H), 6.59 – 6.47 (m, 2H), 3.26 – 3.17 (m, 2H), 2.87 (s, 3H), 2.70 (t, \(J = 6.4\) Hz, 2H), 1.95 (dd, \(J = 6.6\), 5.3 Hz, 2H). \(^13\)C NMR (75 MHz) \(\delta\) 147.6, 132.5, 129.6, 121.1, 115.6, 110.5,
50.9, 39.0, 27.4, 22.2. IR: v 2931, 2839, 1600, 1503, 1310, 828 cm⁻¹. HRMS (ESI) calculated for C₁₀H₁₂ClN⁺ [M+H]⁺: 182.0737; found: 182.0738.

8-Chloro-1-methyl-1,2,3,4-tetrahydroquinoline (3i)

![Chemical Structure](image)

3i was prepared following the general procedure starting from 8-chloroquinoline (0.50 g, 3.0 mmol) using 10.0 equivalents of paraformaldehyde and 10.0 equivalents of NaCNBH₃ as a colorless liquid (0.27 g, 56%) after purification by flash column chromatography (1:1, DCM/cyclohexane). ¹H NMR (400 MHz) δ 7.17 (d, J = 7.9 Hz, 1H), 6.94 (d, J = 7.7 Hz, 1H), 6.82 (t, J = 7.7 Hz, 1H), 3.19 – 3.08 (m, 2H), 2.90 (s, 3H), 2.79 (t, J = 6.7 Hz, 2H), 1.84 (dt, J = 10.0, 6.5 Hz, 2H). ¹³C NMR (75 MHz) δ 145.8, 131.1, 128.1, 127.3, 121.9, 51.9, 42.7, 27.8, 17.1. IR: v 2935, 2861, 1466, 1321, 1171, 1097, 904, 759 cm⁻¹. HRMS (ESI) calculated for C₁₀H₁₂ClN⁺ [M]⁺: 181.0658; found: 181.0653.

Tert-butyl indoline-1-carboxylate⁹,¹⁰

![Chemical Structure](image)

Tert-butyl indoline-1-carboxylate was prepared following the procedure described in the literature.⁹ Indoline (1.1 mL, 10.0 mmol, 1.0 equiv.) was added to a solution of NaHCO₃ (1.68 g, 20.0 mmol, 2.0 equiv.) in water (16 mL) and stirred vigorously for 10 min. The reaction mixture was cooled to 0 °C. A solution of di tert-butyl dicarbonate (2.18 g, 10.0 mmol, 1.0 equiv.) in dioxane (16 mL) was added dropwise. After stirring the reaction mixture for 1 hour at 0 °C, the ice bath was removed and the reaction was stirred overnight at room temperature. After the reaction reached full conversion as determined by TLC, the aqueous solution was washed with ethyl acetate and the organic layer was extracted with saturated NaHCO₃. The organic layer was dried over Na₂SO₄, filtered and concentrated in vacuo to afford the product as a colorless liquid (1.95 g, 89%). Its ¹H NMR data matched with those reported in the literature.¹⁰ ¹H NMR (300 MHz) δ 8.01 – 7.33 (m, 1H), 7.18 – 7.13 (m, 2H), 6.92 (t, J = 7.4 Hz, 1H), 3.97 (t, J = 8.7 Hz, 2H), 3.09 (t, J = 8.7 Hz, 2H), 1.57 (s, 9H).

1-Benzylindoline¹¹,¹²

![Chemical Structure](image)

1-Benzylindoline was prepared following the procedure as described in literature.¹¹ In a two-necked round-bottom flask, indoline (0.56 mL, 5.0 mmol, 1.0 equiv.) was added to a solution of NaHCO₃ (0.52 g, 6.2 mmol, 1.24 equiv.) in water (2 mL). The reaction was heated to 90 °C. At this temperature, benzyl chloride (0.60 mL, 5.2 mmol, 1.04 equiv.) was added dropwise over a period of 5 minutes (Caution, the addition results in formation of bubbles). The reaction mixture was then stirred overnight at 90 °C. After the reaction was completed, toluene was added to the reaction mixture at 80 °C and stirred vigorously. Then the reaction was left standing still good liquid separation was seen and the organic layer was removed using a Pasteur pipette. The aqueous layer was extracted using toluene. The organic extracts were combined, dried over Na₂SO₄ and concentrated in vacuo to yield the product as a colorless oil (1.04 g, 99%). Its ¹H NMR data matched with those reported in the literature.¹² ¹H NMR (400 MHz) δ 7.48 – 7.37 (m, 4H), 7.35 – 7.32 (m, 1H), 7.17 (d, J = 7.2 Hz, 1H), 7.13 (t, J = 7.7 Hz, 1H), 6.74 (t, J = 7.4 Hz, 1H), 6.58 (d, J = 7.8 Hz, 1H), 4.32 (s, 2H), 3.37 (t, J = 8.3 Hz, 2H), 3.04 (t, J = 8.3 Hz, 2H).

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7-Benzoyl-1-methylindoline (1h) was prepared using the following synthetic sequence:

**Step A**: In a flame-dried schlenk flask, indoline (3.0 g, 25.2 mmol, 1.0 equiv.) in anhydrous toluene (20 mL) was added slowly to a solution of boron trichloride (1 M in heptane, 28 mL, 1.1 equiv.) in dry toluene (28 ml) at 0 °C. The mixture was then heated to reflux for one hour before it was cooled to room temperature. Dry benzonitrile (13.8 mL, 133.8 mmol, 5.3 equiv.) was added to the reaction mixture followed by aluminium trichloride (4.5 g, 33.7 mmol, 1.3 equiv.). The mixture was refluxed overnight allowing to cool down to room temperature. The mixture was thereafter basified to pH 8 with sodium hydroxide solution. The mixture was then extracted with DCM three times. The combined organic extracts were washed with brine, dried with MgSO₄, filtered, concentrated and purified by flash column chromatography (8:1 n-pentane/EtO) to afford 1h as a yellow liquid which was used for the next step without further purification. **1H NMR** (400 MHz) δ 7.79 – 7.87 (m, 2H), 7.59 – 7.53 (m, 1H), 7.46 (dd, J = 8.3, 6.9 Hz, 2H), 7.16 (dd, J = 7.1, 1.4 Hz, 1H), 7.09 (dd, J = 8.0, 1.2 Hz, 1H), 6.61 (t, J = 7.5 Hz, 1H), 3.52 (t, J = 8.5 Hz, 2H), 3.04 (t, J = 8.5 Hz, 2H), 2.63 (s, 3H). **13C NMR** (100 MHz) δ 196.4, 152.8, 138.6, 132.7, 132.7, 130.3, 129.6, 128.4, 126.6, 119.7, 116.2, 57.0, 39.2, 28.3. **IR**: ν 2922, 1650, 1447, 1265, 713 cm⁻¹. **HRMS** (ESI) calculated for C₁₅H₁₈NO⁺ [M+H]⁺: 238.1232; found: 238.1277.

1,3,3-Trimethylindoline (1k) was prepared using the following synthetic sequence:

**Step A**: 2-Oxindole (3.00 g, 22.5 mmol, 1.0 equiv.) was dissolved in anhydrous THF (75 mL) and cooled to 0 °C. NaH (3.60 g, 60% in mineral oil, 90 mmol, 4.0 equiv.) was then added slowly followed by dropwise addition of MeI (4.9 mL, 78.75 mmol, 3.5 equiv.). The reaction was warmed up to room temperature and was left stirring overnight. Upon completion, the reaction was quenched with saturated solution of NH₄Cl and extracted with EtOAc three times. The extracts were washed with brine, dried over MgSO₄, filtered and concentrated to dryness to yield 1,3,3’-trimethyloxindole as a yellow liquid which was used for the next step without further purification. **1H NMR** (400 MHz) δ 7.29 (d, J = 8.1 Hz, 1H), 7.23 (d, J = 7.3 Hz, 1H), 7.09 (t, J = 7.5 Hz, 1H), 6.87 (d, J = 7.8 Hz, 1H), 3.24 (s, 3H), 1.39 (s, 6H). The 1H NMR data matched with those reported in the literature.
Step B: In a flame-dried schlenk flask, the obtained crude 1,3,3’-trimethyloxindole was dissolved in anhydrous THF (20 mL), LiAlH₄ (2.56 g, 67.5 mmol, 3 equiv.) was then added slowly at 0 °C under N₂. The reaction was then heated to reflux overnight. After cooling to room temperature, the reaction was quenched with a saturated solution of Na-K tartrate. The reaction was then extracted with EtOAc three times. The combined organic extracts were washed with brine, dried with MgSO₄, filtrated and concentrated in vacuo. The product was purified by flash column chromatography (20:1, PE/Et₂O) to yield 1k as a colorless oil (3.50 g, 96% over 2 steps).

1H NMR (400 MHz) δ 7.12 (t, J = 7.7 Hz, 1H), 7.04 (d, J = 7.2 Hz, 1H), 6.73 (t, J = 7.3 Hz, 1H), 6.51 (d, J = 7.8 Hz, 1H), 3.09 (s, 2H), 2.78 (s, 3H), 1.33 (s, 6H). The 1H NMR data matched those reported in the literarture.15

1'-Methylspiro[cyclohexane-1,3'-indoline] (II) was prepared using the following synthetic sequence:

Step A:15 To a solution of cyclohexanecarboxaldehyde (0.729 g, 6.5 mmol, 1.0 equiv.) in acetic acid (0.703 g, 6.5 mmol, 1.0 equiv.). The reaction was then heated at 80 °C for 3 h. After cooling the reaction to room temperature, NaBH(OAc)₃ (1.844 g, 8.7 mmol, 1.3 equiv.) was then added portionwise and the reaction was stirred for additional 30 min. The reaction mixture was concentrated in vacuo to dryness, diluted with EtOAc and washed with saturated aqueous solution of Na₂CO₃. The organic layer was dried over MgSO₄, concentrated and purified by flash column chromatography (4:1 PE/EtOAc) to afford spiro[cyclohexane-1,3'-indoline] as a yellow liquid (0.573 g, 47%).

1H NMR (400 MHz) δ 7.11 – 6.99 (m, 2H), 6.75 (t, J = 7.4 Hz, 1H), 6.65 (d, J = 7.7 Hz, 1H), 3.43 (s, 2H), 1.81 – 1.65 (m, 5H), 1.65 – 1.53 (m, 2H), 1.38 (m, 3H). The 1H NMR data matched with those reported in the literature.16

Step B: In a flame-dried schlenk flask, spiro[cyclohexane-1,3'-indoline] (0.573 g, 3.1 mmol, 1.0 equiv.) was dissolved in 20 mL anhydrous THF under N₂ and was cooled to 0 °C. NaH (0.184 g, 60% in mineral oil, 4.6 mmol) was added slowly and the reaction was stirred for 30 min at room temperature followed by the dropwise addition of MeI (0.658 g, 4.6 mmol, 1.5 equiv.) at 0 °C. The reaction was then warmed up to room temperature, and stirred for 4 h. Upon completion determined by TLC, water was slowly added, and the reaction was extracted with EtOAc three times. The combined organic extracts were dried over MgSO₄, filtrated, concentrated in vacuo and purified by flash column chromatography (15:1 to 4:1 PE/EtOAc) to afford II as pink liquid (0.311 g, 50%).

1H NMR (400 MHz) δ 7.23 (t, J = 7.6 Hz, 1H), 7.16 (d, J = 7.2 Hz, 1H), 6.83 (t, J = 7.4 Hz, 1H), 6.61 (d, J = 7.8 Hz, 1H), 3.32 (s, 2H), 2.89 (s, 3H), 1.92 – 1.80 (m, 5H), 1.80 – 1.66 (m, 2H), 1.62 – 1.39 (m, 3H). 13C NMR (100 MHz) δ 152.2, 139.2, 127.6, 122.1, 117.7, 107.2, 65.6, 44.7, 36.3, 35.9, 25.9, 23.3. IR: ν 2923, 2854, 1698, 1597, 1507, 1449, 1255, 1147, 1092, 801 cm⁻¹. HRMS (ESI) calculated for C₁₄H₁₉N⁺ [M+H]⁺: 202.1596; found: 202.1593.
(±)-3a,8-Dimethyl-1-tosyl-1,2,3,3a,8,8a-hexahydropyrrolo[2,3-b]indole ([±)-10] was prepared using the following synthetic sequence.\(^{17}\)

**Step A:** In a flame-dried schlenk flask was added 2-pyrrolidone (3.0 mL, 38.9 mmol, 1.0 equiv.) and anhydrous THF (50 mL) at –78 °C under N\(_2\) followed by dropwise addition of n-BuLi (1.6 M in hexanes, 25.6 mL, 41.0 mmol, 1.05 equiv.) over a period of 6 mins. The mixture was then stirred at –78 °C for 1.5 h before a solution of TsCl (7.95 g, 40.88 mmol, 1.05 equiv.) in anhydrous THF (15 mL) was added over a period of 20 mins. The reaction was left stirring at –78 °C for another 20 mins and then warmed up to room temperature. After stirring it for 1 h, the reaction was quenched by slowly adding saturated aqueous solution of NH\(_4\)Cl (30 mL) and extracted with EtOAc three times. The combined organic extracts were washed with brine, dried with MgSO\(_4\), filtrated and concentrated in vacuo. The product was purified by recrystallization from n-hexane to yield N-Ts-2-pyrrolidone as a yellow solid (8.1 g, 87%). \(^{1}H\) NMR (400 MHz) δ 7.93 (d, J = 8.6 Hz, 2H), 7.34 (d, J = 8.1 Hz, 2H), 3.98 – 3.91 (m, 1H), 3.73 – 3.64 (m, 1H), 2.43 (s, 3H), 2.30 – 2.20 (m, 1H), 1.77 – 1.63 (m, 1H), 1.14 (d, J = 7.0 Hz, 3H). The \(^{1}H\) NMR data matched with those reported in the literature.\(^{17}\)

**Step B:** In a flame-dried schlenk flask, to a solution of N-Ts-2-pyrrolidone (4.0 g, 16.7 mmol, 1.0 equiv.) in anhydrous THF (80 mL) at –78 °C, NaHMDS (2.0 M in THF, 8.8 mL, 17.6 mmol, 1.05 equiv.) was added dropwise over a period of 10 mins. The reaction was stirred for another 1 h at –78 °C before MeI (1.56 mL, 25.0 mmol, 1.5 equiv.) was added dropwise over a period of 2 mins. After stirring it for 1.5 h, the reaction was quenched by slowly adding saturated aqueous solution of NH\(_4\)Cl (60 mL) and extracted with EtOAc three times. The combined organic extracts were washed with brine, dried with MgSO\(_4\), filtrated and concentrated in vacuo. The product was purified by flash column chromatography (4:1 – 2:1 PE/EtOAc) to afford the product 3-methyl-N-tosyl-2-pyrrolidone as a yellow solid (3.6 g, 85%). \(^{1}H\) NMR (300 MHz) δ 7.92 (d, J = 8.6 Hz, 2H), 7.33 (d, J = 8.1 Hz, 2H), 3.90 (t, J = 7.0 Hz, 2H), 2.44 (s, 3H), 2.43 (t, J = 8.1 Hz, 2H), 2.11 – 2.03 (m, 2H). The \(^{1}H\) NMR data matched with those reported in the literature.\(^{17}\)

**Step C:** In a flame-dried schlenk flask, 3-methyl-N-tosyl-2-pyrrolidone (3.3 g, 13 mmol, 1.0 equiv.) was dissolved in anhydrous DCM (50 mL) at –78 °C under N\(_2\). DIBALH (1.0 M in THF, 39 mL, 3.0 equiv.) was then added to the solution slowly. After stirring it at –78 °C for 2 h, the reaction was quenched by slowly adding a saturated aqueous solution of NH\(_4\)Cl (100 mL) at –78 °C. After warming up to room temperature, the resulting mixture was transferred to a 1 L Erlenmeyer flask containing a saturated aqueous solution of Na-K tartrate (200 mL) and EtOAc (100 mL) and was stirred for 2 h at room temperature. The reaction was then extracted with EtOAc and combined organic extracts were washed with brine, dried with MgSO\(_4\), filtrated and concentrated in vacuo. The product was purified by flash column chromatography (2:1:1 PE/DCM/Et\(_2\)O) to afford the product 3-methyl-1-tosylpyrrolidin-2-ol as a clear viscous oil (2.8 g, 85%, as a mixture of diastereoisomers 43A:57B). \(^{1}H\) NMR (400 MHz) δ 7.92 (d, J = 8.4 Hz, 2H), 7.28 (d, J = 8.1 Hz, 2H), 3.88 – 3.81 (m, 1H), 3.73 – 3.64 (m, 1H), 2.43 (s, 3H), 2.30 – 2.20 (m, 1H), 1.77 – 1.63 (m, 1H), 1.14 (d, J = 7.0 Hz, 3H). The \(^{1}H\) NMR data matched with those reported in the literature.\(^{17}\)
MHZ) δ 7.75(B) [7.74 (A)] (d, J = 8.2 Hz, 2H), 7.32 (B) [7.31(A)] (d, J = 8.2 Hz, 2H), 4.97(B) [5.21(A)] (t, J = 2.3 Hz, 1H), 3.58 – 3.50(B+A) (m, 1H), 3.20(B) [3.03(A)] (dt, J = 9.6, 7.3 Hz, 1H), 3.05 (B) [2.74(A)] (d, J = 2.6 Hz, 1H), 2.43(B+A) (s, 3H), 2.22 – 2.13 (B+A) (m, 1H), 1.88 – 1.78 (B+A) (m, 1H), 1.42 – 1.37 (B+A) (m, 1H), 0.71 (B) [1.09(A)] (d, J = 6.9 Hz, 3H).

The 1H NMR data matched with those reported in the literature.\textsuperscript{17}

**Step D:** In a round bottom flask was added N-methyl hydrazine (1.05 g, 8.6 mmol, 1.0 equiv.), 3-methyl-1-toslypyrrolidin-2-ol (2.2 g, 8.6 mmol, 1.0 equiv.) and AcOH (40 mL). The reaction was then stirred at room temperature for 40 h. Water (100 mL) was then added and the reaction was basified with K₂CO₃. The reaction was then extracted with EtOAc three times and the combined organic extracts were washed with brine, dried with MgSO₄, filtered, and concentrated in vacuo. The product was purified by flash column chromatography (6:1 – 4:1 PE /Et₂O) to afford (±)-1o as a yellow solid (2.05 g, 70%).

(±)-3a,8-Dimethyl-3,3a,8a-tetrahydro-2H-furo[2,3-b]indole [±-1p] was prepared using the following synthetic sequence.\textsuperscript{17}

**Step A:** In a flame-dried schlenk flask, α-Methyl-γ-butyrolactone (1.42 mL, 14.98 mmol, 1.0 equiv.) was dissolved in DCM (20 mL) at –78 ºC under N₂. DIBALH (16.5 mL, 1.0 M in hexanes, 1.1 equiv.) was then added dropwise over a period of 30 mins via a syringe pump. The reaction was then stirred for another 0.5 h and was then quenched with EtOAc. The resulting mixture was then poured into a saturated aqueous solution of Na-K tartrate and was left stirring for 2 h. The mixture was then extracted with DCM three times. The combined organic extracts were washed with brine, dried with MgSO₄, filtered and concentrated in vacuo yielding the crude 3-methyltetrahydrofuran-2-ol which was used for the next step without purification.

**Step B:** In a round bottom flask was added crude 3-methyltetrahydrofuran-2-ol and N-methyl hydrazine (1.83 g, 15.0 mmol, 1.0 equiv.) and AcOH (60 mL). The reaction was then stirred at 60 ºC for 2.5 h. After cooling the reaction to room temperature, water (100 mL) was then added and the reaction was basified with K₂CO₃. The reaction was then extracted with EtOAc three times and the combined organic extracts were washed with brine, dried with MgSO₄, filtered, and concentrated in vacuo. The product was purified by flash column chromatography (4:1 PE /Et₂O to afford (±)-1p as an orange oil (0.83 g, 29% over 2 steps).

\[1\] H NMR (300 MHz) δ 7.10 (t, J = 7.7 Hz, 1H), 7.05 (d, J = 7.3 Hz, 1H), 6.68 (t, J = 7.4 Hz, 1H), 6.37 (d, J = 7.7 Hz, 1H), 5.07 (s, 1H), 3.95 (dd, J = 8.7, 7.0, 1.8 Hz, 1H), 3.65 – 3.30 (m, 1H), 2.92 (s, 3H), 2.14 (ddd, J = 11.9, 5.4, 1.8 Hz, 1H), 2.10 – 1.98 (m, 1H), 1.46 (s, 3H). The 1H NMR data matched with those reported in the literature.\textsuperscript{17}
(±)-5-Methyl-2-tosyl-2,3,4,4a,5,9b-hexahydro-1H-pyrido[4,3-b]indole  [(±)-1q] was prepared using the following synthetic sequence.

**Step A:** In a round bottom flask, piperidine-4,4-diol hydrochloride (3.07 g, 20 mmol, 1.0 equiv.) was mixed with H₂O (20 mL). K₂CO₃ (6.64 g, 48 mmol, 2.4 equiv.) was then added portionwise followed by DCM (20 mL). A solution of para-toluenesulfon chloride (4.01 g, 21 mmol, 1.05 equiv.) in DCM (10 mL) was then added over a period of 10 minutes. The reaction mixture was allowed to stir at room temperature for 16 hours. The organic and aqueous phases were separated and the aqueous phase was then extracted with CH₂Cl₂ two times. The combined organic extracts were washed with saturated aqueous solution of NaHCO₃, brine, dried over MgSO₄, filtered and concentrated in vacuo to provide 1-tosylpiperidin-4-one as a white solid (5.01 g, 99%) that was used without further purification. ^1H NMR (400 MHz) δ 7.67 (d, J = 8.1 Hz, 2H), 7.34 (d, J = 8.0 Hz, 2H), 3.38 (t, J = 6.2 Hz, 4H), 2.53 (t, J = 6.2 Hz, 4H), 2.43 (s, 3H). The ^1H NMR data matched with those reported in the literature. ^18

**Step B:** In a round bottom flask, 1-tosylpiperidin-4-one (4.80 g, 19.0 mmol, 1.0 equiv.) was added and the reaction was stirred at 70 °C for 1 h. The reaction mixture was then diluted with H₂O (200 mL). The yellow precipitate was suspended in water, filtrated, dissolved in DCM and washed with brine. The organic layer was dried over MgSO₄, filtered, concentrated in vacuo, and purified by flash column chromatography (30:1 DCM/MeOH) to afford 2-tosyl-2,3,4,5-tetrahydro-1H-pyrido[4,3-b]indole as a pale yellow solid (3.31 g, 60%). ^1H NMR (300 MHz) δ 7.79 (bs, 1H), 7.75 (d, J = 8.3 Hz, 2H), 7.39 (d, J = 7.7 Hz, 1H), 7.32 – 7.27 (m, 3H), 7.18 – 7.06 (m, 2H), 4.39 (s, 2H), 3.55 – 3.50 (m, 2H), 2.89 (dt, J = 8.0, 3.1 Hz, 1H), 2.41 (s, 1H). The ^1H NMR data matched with those reported in the literature. ^19

**Step C:** In a flame-dried Schlenk flask, DMF (20 mL) was mixed with pre-washed NaH (0.26 g, 6.9 mmol, 1.0 equiv.) at 0 °C, followed by the addition of 2-tosyl-2,3,4,5-tetrahydro-1H-pyrido[4,3-b]indole (1.80 g, 5.5 mmol, 1.0 equiv.). After stirring at room temperature for 0.5 h, methyl iodide (0.86 g, 6.05 mmol, 1.1 equiv.) was added dropwise at 0 °C. The reaction was then warmed up to room temperature and stirred for 1 h. Upon completion, the reaction was quenched with water, and extracted with EtOAc three times. The combined organic extracts were washed with water three times and brine twice, dried over Na₂SO₄, filtered and concentrated in vacuo to afford 5-methyl-2-tosyl-2,3,4,5-tetrahydro-1H-pyrido[4,3-b]indole as a yellow solid (1.74 g, 96%) which could be used for the next step without further purification. ^1H NMR (400 MHz) δ 7.79 (d, J = 8.0 Hz, 2H), 7.42 (d, J = 7.8 Hz, 1H), 7.33 (d, J = 8.0 Hz, 2H), 7.28 (d, J = 6.4 Hz, 1H), 7.21 (ddd, J = 8.2, 7.0, 1.2 Hz, 1H), 7.15 – 7.06 (m, 1H), 4.41 (d, J = 1.6 Hz, 2H), 3.61 (s, 3H), 3.57 (t, J = 5.7 Hz, 2H), 2.89 (t, J = 5.8 Hz, 2H), 2.44 (s, 3H).

**Step D:** 5-methyl-2-tosyl-2,3,4,5-tetrahydro-1H-pyrido[4,3-b]indole (1.02 g, 3.0 mmol, 1.0 equiv.) was dissolved in TFA (20 mL) and cooled to 0 °C. NaBH₄ (0.26 g, 6.9 mmol, 2.3 equiv.) was added portionwise over a period of 15 min. The reaction was then warmed up to room temperature and stirred for 2 h. Upon completion, the reaction was diluted with water and stirred for 1 h. The yellow precipitate was suspended in water, filtrated, dissolved in DCM and washed with brine. The organic layer was dried over MgSO₄, filtered, concentrated in vacuo to provide 5-methyl-2-tosyl-2,3,4,5-tetrahydro-1H-pyrido[4,3-b]indole as a pale yellow solid (1.17 g, 85%). ^1H NMR (400 MHz) δ 7.67 (d, J = 8.1 Hz, 2H), 7.31 (d, J = 8.2 Hz, 2H), 7.18 – 7.10 (m, 2H), 4.40 (d, J = 1.6 Hz, 2H), 3.61 (s, 3H), 3.57 (t, J = 5.7 Hz, 2H), 2.89 (t, J = 5.8 Hz, 2H), 2.44 (s, 3H). The ^1H NMR data matched with those reported in the literature. ^20

**References:**

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19. Green, R. B.; Meehan, P. G. Tetrahedron Lett. 1988, 29, 1717.
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neutralized with NaHCO₃. The reaction was extracted with EtOAc three times. The combined organic extracts were washed with brine, dried over MgSO₄, concentrated in vacuo and purified by flash column chromatography (4:1 PE/EtOAc) to afford (±)-1q (0.88g, 86%) as pale yellow solid.

\[
{^1}H\ \text{NMR} \ (300 \text{ MHz}) \ \delta \ 7.59 \ (d, \ J = 8.3 \text{ Hz}, 2\text{H}), 7.25 \ (d, \ J = 8.3 \text{ Hz}, 2\text{H}), 7.15 - 7.09 \ (m, 2\text{H}), 6.76 - 6.71 \ (m, 1\text{H}), 6.53 \ (d, \ J = 6.6 \text{ Hz}, 1\text{H}), 3.72 \ (dd, \ J = 11.8, 6.4, 2.1 \text{ Hz}, 1\text{H}), 3.65 - 3.58 \ (m, 1\text{H}), 3.34 - 3.27 \ (m, 1\text{H}), 3.26 - 3.21 \ (m, 1\text{H}), 2.61 \ (s, 3\text{H}), 2.55 \ (td, \ J = 11.0, 4.9 \text{ Hz}, 1\text{H}), 2.38 \ (s, 3\text{H}), 2.13 - 1.99 \ (m, 3\text{H}); \ {^{13}}C\ \text{NMR} \ (75 \text{ MHz}) \ \delta \ 153.1, 143.6, 133.5, 130.7, 129.9, 128.5, 127.7, 124.0, 119.1, 109.1, 64.2, 48.1, 42.0, 40.2, 33.8, 24.8, 21.6. \ \text{IR:} \ \nu \ 2927, 2853, 1608, 1481, 1254, 1164, 951, 744, 728 \text{ cm}^{-1}. \ \text{HRMS (ESI)} \ \text{calculated for} \ C_{19}H_{22}N_2O_2S^+ \ [M+H]^+: \ 343.1480; \ \text{found:} \ 343.1490.
\]

1-Methyl-2,3-dihydroquinolin-4(1H)-one (3f)\textsuperscript{20}

2,3-dihydroquinolin-4(1H)-one (1.0 g, 6.7 mmol) was added to a mixture of acetone with potassium carbonate (2.7 g, 20 mmol, 3.0 equiv.) and methyl iodide (1.7 mL, 27 mmol, 4.0 equiv.). The reaction mixture was heated at 80°C for 16 hours. After cooling down, DCM and brine were added and the water layer was extracted with DCM three times. The organic extracts were dried over MgSO₄, filtrated and evaporated in vacuo. The product was purified by flash column chromatography (1:1 cyclohexane/DCM) to afford the pure product as a yellow liquid (0.54 g, 50%). \( {^1}H \text{ NMR} \ (400 \text{ MHz}) \ \delta \ 7.91 \ (d, \ J = 8.0 \text{ Hz}, 1\text{H}), 7.41 \ (t, \ J = 8.0 \text{ Hz}, 1\text{H}), 6.77 - 6.70 \ (m, 2\text{H}), 3.47 \ (t, \ J = 8.0 \text{ Hz}, 2\text{H}), 2.99 \ (s, 3\text{H}), 2.74 \ (t, \ J = 8.0 \text{ Hz}, 2\text{H}). \) The \( {^1}H \text{ NMR data matched with those reported in the literature.} \)

2',3',3a',5'-Tetrahydro-1'H-spiro[indene-2,4'-pyrrolo[1,2-a]quinoline]-1,3-dione (3g)\textsuperscript{21}

3g was prepared following the reported procedure and its \( {^1}H \text{ NMR matched with those reported in the literature.} \) \( {^1}H \text{ NMR} \ (400 \text{ MHz}) \ \delta \ 8.04 - 7.97 \ (m, 1\text{H}), 7.89 - 7.79 \ (m, 3\text{H}), 7.22 - 7.15 \ (m, 1\text{H}), 7.01 \ (d, \ J = 7.3 \text{ Hz}, 1\text{H}), 6.66 - 6.58 \ (m, 2\text{H}), 3.89 \ (dd, \ J = 10.2, 5.5 \text{ Hz}, 1\text{H}), 3.59 \ (td, \ J = 8.3, 7.4, 2.9 \text{ Hz}, 1\text{H}), 3.35 - 3.25 \ (m, 2\text{H}), 2.81 \ (d, \ J = 16.1 \text{ Hz}, 1\text{H}), 2.02 - 1.89 \ (m, 2\text{H}), 1.88 - 1.82 \ (m, 1\text{H}), 1.35 - 1.22 \ (m, 1\text{H}). \)

1',2',3',4',4a',6'-Hexahydrospiro[indene-2,5'-pyrido[1,2-a]quinoline]-1,3-dione (3h)\textsuperscript{21}

3h was prepared following the reported procedure and its \( {^1}H \text{ NMR matched with those reported in the literature.} \) \( {^1}H \text{ NMR} \ (400 \text{ MHz}) \ \delta \ 8.03 - 7.97 \ (m, 1\text{H}), 7.97 - 7.91 \ (m, 1\text{H}), 7.84 \ (dd, \ J = 5.7, 3.1 \text{ Hz}, 2\text{H}), 7.21 - 7.14 \ (m, 1\text{H}), 6.98 \ (d, \ J = 8.4 \text{ Hz}, 1\text{H}), 6.93 \ (d, \ J = 7.4 \text{ Hz}, 1\text{H}), 6.70 \ (t, \ J = 7.3 \text{ Hz}, 1\text{H}), 4.20 - 4.10 \ (m, 1\text{H}), 3.37 \ (d, \ J = 11.7 \text{ Hz}, 1\text{H}), 3.25 \ (d, \ J = 16.1 \text{ Hz}, 1\text{H}), 2.86 - 2.71 \ (m, 2\text{H}), 1.77 - 1.67 \ (m, 2\text{H}), 1.67 - 1.59 \ (m, 1\text{H}), 1.51 - 1.42 \ (m, 1\text{H}), 1.34 \ (tdd, \ J = 12.1, 7.1, 4.2 \text{ Hz}, 1\text{H}), 1.16 \ (qd, \ J = 12.3, 3.5 \text{ Hz}, 1\text{H}). \)
3i was prepared using the following synthetic sequence:

\[
\begin{align*}
\text{Cl} & \quad \text{NaCNBH}_3 \text{(5.0 equiv.)} \\
\text{AcOH (0.2 M), } 0 \, ^\circ \text{C} - \text{r.t.} & \quad \text{I}_2 \text{(cat. amount)} \\
\text{Inseparable mixture 4:1} & \quad \text{HBpin} \\
\text{DCM, r.t.} & \quad \text{Cl}
\end{align*}
\]

**8-chloro-1,2,3,4-tetrahydroquinoline (3j)** was prepared using the following synthetic sequence.

In a flame-dried schlenk flask under N\(_2\), 8-chloroquinoline (2.45 g, 15.0 mmol, 1.0 equiv.) was dissolved in AcOH (75 mL). NaCNBH\(_3\) (4.71 g, 75.0 mmol, 5.0 equiv.) was then added slowly at 0 °C. The reaction was then stirred overnight at room temperature. Cold 10 M NaOH aqueous solution was then added slowly while cooling the flask with ice-water bath until the mixture was basic. The reaction was then extracted with DCM three times. The combined organic extracts were washed with brine, dried with MgSO\(_4\), filtrated and concentrated in vacuo. A column flash chromatography was performed (20:1, n-hexane:Et\(_2\)O) yielding a mixture of 8-chloro-1,2,3,4-tetrahydroquinoline and 8-chloro-1,4-dihydroquinoline (cal. 4:1 ratio) which were not separable by column chromatography. The mixture was further reduced following the procedure reported in the literature. The crude sample was dissolved in DCM followed by addition of I\(_2\) (0.2 g) and HBpin (2.0 mL) under N\(_2\). After stirring it overnight at room temperature, the reaction was quenched with water and extracted with DCM three times. The combined organic extracts were washed with brine, dried with MgSO\(_4\), filtrated and concentrated in vacuo. The product was purified by column flash chromatography (20:1, n-hexane:Et\(_2\)O) giving 3i as a colorless oil (2.35 g, 94%). Its \(^1\)H NMR data matched with those reported in the literature. \(^1\)H NMR (300 MHz) δ 7.09 (dt, \(J = 7.9, 0.9\) Hz, 1H), 6.88 (dq, \(J = 7.4, 1.1\) Hz, 1H), 6.53 (t, \(J = 7.7\) Hz, 1H), 4.45 (bs, 1H), 3.47 – 3.37 (m, 2H), 2.04 – 1.89 (m, 2H).

**8-Acetyl-1,2,3,4-tetrahydroquinoline (3k)**

3k was prepared following the procedure reported in the literature: In a flame-dried schlenk flask, 1,2,3,4-tetrahydroquinoline (250 mg, 1.88 mmol, 1.0 equiv.) was added to a solution of boron trichloride (1 M in heptane, 2.1 mL, 1.1 equiv.) in dry toluene (2 mL) at 0 °C. Dry acetonitrile (196 μL, 3.76 mmol, 2.0 equiv.) was added to the reaction mixture followed by aluminium trichloride (280 mg, 2.1 mmol, 1.1 equiv.). The mixture was refluxed overnight and allowed to cool down to room temperature. The reaction was quenched with hydrochloric acid (1M, 6 ml) and the mixture was thereafter basified to PH = 8 with sodium hydroxide solution. The mixture was then extracted with DCM three times. The combined organic extracts were washed with brine, dried with MgSO\(_4\), filtrated and evaporated in vacuo. The product was purified by flash column chromatography (5:1 cyclohexane/EtOAc) to afford the pure product as a yellow solid (106 mg, 32%). \(^1\)H NMR (400 MHz) δ 9.00 (s, 1H), 7.53 (d, \(J = 8.2\) Hz, 1H), 7.02 (d, \(J = 7.1\) Hz, 1H), 6.43 (t, \(J = 7.6\) Hz, 1H), 3.48 – 3.34 (m, 2H), 2.76 (t, \(J = 6.4\) Hz, 2H), 2.04 – 1.89 (m, 2H).
2.54 (s, 3H), 1.92 – 1.86 (m, 2H). \( ^{13}C\) NMR (100 MHz) \( \delta \) 200.5, 148.5, 133.9, 130.5, 122.7, 116.2, 113.0, 41.0, 28.0, 27.9, 20.6. IR: \( \nu \) 3320, 2934, 1631, 1572, 1511, 1360, 1237, 940, 732, 660 cm\(^{-1}\). HRMS (ESI) calculated for \( C_{11}H_{13}NO^{+} \) [M]: 175.0997; found: 175.1000.

3. Reaction optimization for the C5 C-H olefination of indolines

Table S1. Protecting group screening

| Entry | R   | \(^1^H\) NMR yield\(^b\) | Starting material\(^b\) |
|-------|-----|--------------------------|-------------------------|
| 1     | H   | 0%\(^c\)                 | 0%                      |
| 2     | Me  | 38%                      | 0%                      |
| 3     | Boc | 24%\(^d\) \(\text{a few other isomers were also observed. However, it was difficult to quantify them.}\) | 31%                     |
| 4     | Benzyl | 27%\(^e\) | 10%                     |
| 5\(^f\) | Me  | 0%\(^g\) \(39\% \text{ oxidized product (N-methylindole) was detected.}\) | 0%                      |

\(^a\)Reaction conditions: \( \text{1} \) (0.25 mmol, 1.0 equiv.), ethyl acrylate (40.8 μL, 0.375 mmol, 1.5 equiv.), Pd(OAc)\(_2\) (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO\(_3\)Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), DCE (1,2-dichloroethane) (1.25 mL), 80 °C, 16 h.
\(^b\)The yield was determined by \(^1^H\) NMR analysis of crude reaction samples using CH\(_2\)Br\(_2\) as internal standard. \(^c\)39\% \text{ N-olefinated product was observed.} \(^d\)Mixture of isomers (6:1, para:others). \(^e\)A few other isomers were also observed. However, it was difficult to quantify them. \(^f\)Without S,O-ligand. \(^g\)39\% oxidized product (N-methylindole) was detected.

Table S2. Reaction concentration screening

| Entry | X     | The amount of DCE (mL) | \(^1^H\) NMR yield\(^b\) |
|-------|-------|------------------------|--------------------------|
| 1     | 0.20  | 1.25                   | 38%                      |
| 2     | 0.10  | 2.50                   | 36%                      |
| 3     | 0.17  | 1.50                   | 37%                      |
| 4     | 0.83  | 0.30                   | 31%                      |

\(^a\)Reaction conditions: \( \text{1a} \) (33.3 mg, 0.25 mmol, 1.0 equiv.), ethyl acrylate (40.8 μL, 0.375 mmol, 1.5 equiv.), Pd(OAc)\(_2\) (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO\(_3\)Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), DCE, 80 °C, 16 h. \(^b\)The yield was determined by \(^1^H\) NMR analysis of crude reaction samples using CH\(_2\)Br\(_2\) as internal standard.
### Table S3. Reaction temperature screening

| Entry | Temperature (°C) | \(^1\)H NMR yield\(^b\) |
|-------|------------------|-------------------------|
| 1     | 80               | 38%                     |
| 2     | 60               | 51%                     |
| 3     | 40               | 34%                     |
| 4     | 100              | 24%                     |

\( ^a\)Reaction conditions: 1a (33.3 mg, 0.25 mmol, 1.0 equiv.), ethyl acrylate (40.8 μL, 0.375 mmol, 1.5 equiv.), Pd(OAc)\(_2\) (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO\(_3\)Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), DCE (0.2 M), temperature, 16 h. \( ^b\)The yield was determined by \(^1\)H NMR analysis of crude reaction samples using CH\(_2\)Br\(_2\) as internal standard.

### Table S4. Reaction solvent screening

| Entry | Solvent            | \(^1\)H NMR yield\(^b\) |
|-------|--------------------|-------------------------|
| 1     | DCE                | 51%                     |
| 2     | \( \tau \)-AmylOH  | < 10%                   |
| 3     | hexafluoroisopropanol | 0%                      |
| 4     | \( N,N \)-dimethylformamide | 0%                      |
| 5     | acetonitrile       | 14%                     |
| 6     | ethyl acetate      | 12%                     |
| 7     | 1,4-dioxane        | < 10%                   |
| 8     | dichloromethane    | 23%                     |
| 9     | hexafluorobenzene  | traces                  |

\( ^a\)Reaction conditions: 1a (33.3 mg, 0.25 mmol, 1.0 equiv.), ethyl acrylate (40.8 μL, 0.375 mmol, 1.5 equiv.), Pd(OAc)\(_2\) (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO\(_3\)Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), solvent (0.2 M), 60 °C, 16 h. \( ^b\)The yield was determined by \(^1\)H NMR analysis of crude reaction samples using CH\(_2\)Br\(_2\) as internal standard.
Table S5. Reaction oxidant screening

\[ \text{1a} + \text{COOEt} \quad \text{1.5 equiv.} \quad \text{Pd(OAc)}_2 (10 \text{ mol\%}) \quad \text{S,O-ligand (10 mol\%)} \quad \text{oxidant (1.0 equiv.)} \quad \text{DCE (0.2 M), 60 °C, 16 h} \quad \text{2a} \]

| Entry | Oxidant | \[^{1}H \text{NMR yield}^b| \%
|-------|---------|----------------|
| 1     | 'BuOOH (80%, w/w% in water) | < 10%
| 2     | H$_2$O$_2$ (35%, w/w% in water) | < 10%
| 3     | oxone | 0%
| 4     | K$_2$S$_2$O$_8$ | 0%
| 5     | CuSO$_4$ | < 10%
| 6     | PhI(OAc)$_2$ | 0%
| 7     | AgOAc | < 10%
| 8     | BQ | 13%
| 9     | O$_2$ @ 1 atm | < 10%
| 10    | O$_2$ @ 6 atm | 39%
| 11    | O$_2$ @ 10 atm | 44%
| 12    | PhCO$_3$Bu | 51%
| 13$^c$ | PhCO$_3$Bu | 35%
| 14$^d$ | PhCO$_3$Bu | 21%

$^a$Reaction conditions: 1a (33.3 mg, 0.25 mmol, 1.0 equiv.), ethyl acrylate (40.8 μL, 0.375 mmol, 1.5 equiv.), Pd(OAc)$_2$ (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), oxidant (0.25 mmol, 1.0 equiv.), DCE (0.2 M), 60 °C, 16 h. $^b$The yield was determined by $^1$H NMR analysis of crude reaction samples using CH$_2$Br$_2$ as internal standard. $^c$2.0 equivalents of PhCO$_3$Bu was used. $^d$3.0 equivalents of PhCO$_3$Bu was used.

Table S6. Screening of reaction time and temperature

\[ \text{1a} + \text{COOEt} \quad \text{1.5 equiv.} \quad \text{Pd(OAc)}_2 (10 \text{ mol\%}) \quad \text{S,O-ligand (10 mol\%)} \quad \text{PhCO$_3$Bu (1.0 equiv.)} \quad \text{DCE (0.2 M), temp., time} \quad \text{2a} \]

| Entry | Reaction time (h) | \[^{1}H \text{NMR yield}^b| \%
|-------|------------------|----------------|
| 1     | 2 | 31% | 50%
| 2     | 4 | 41% | 46%
| 3     | 6 | 46% | 39%
| 4     | 16 | 51% | 38%
| 5     | 24 | 41% | - |

$^a$Reaction conditions: 1a (33.3 mg, 0.25 mmol, 1.0 equiv.), ethyl acrylate (40.8 μL, 0.375 mmol, 1.5 equiv.), Pd(OAc)$_2$ (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO$_3$Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), DCE (0.2 M), temperature, time. $^b$The yield was determined by $^1$H NMR analysis of crude reaction samples using CH$_2$Br$_2$ as internal standard. $^c$Reaction temperature: 60 °C. $^d$Reaction temperature: 80 °C.
**Table S7. Evaluation of the ratio between N-methylindoline and ethyl acrylate**

| Entry | Ratio (1a/ethyl acrylate) | $^1$H NMR yield $^b$ |
|-------|----------------------------|----------------------|
| 1     | 1.0 : 1.0                  | 45%                  |
| 2     | 1.2 : 1.0                  | 47%                  |
| 3     | 1.5 : 1.0                  | 50%                  |
| 4     | 2.0 : 1.0                  | 58%                  |
| 5     | 1.0 : 1.5                  | 51%                  |
| 6     | 1.0 : 3.0                  | 43%                  |

$^a$Reaction conditions: 1a (X mmol)/ethyl acrylate (Y mmol) (0.25 mmol scale relative to the limiting reagent), Pd(OAc)$_2$ (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO$_3$Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), DCE (0.2 M), 60 °C, 16 h. $^b$The yield was determined by $^1$H NMR analysis of crude reaction samples using CH$_2$Br$_2$ as internal standard.

4. **General procedure for Pd-catalyzed C5 C-H olefination of indolines**

In a pressure tube containing a suitable stirring bar was added indoline (0.50 mmol, 2.0 equiv.), Pd(OAc)$_2$ (5.6 mg, 0.025 mmol, 10 mol%), PhCO$_3$Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), ethyl acrylate (27.2 μL, 0.25 mmol, 1.0 equiv.), S,O-ligand stock solution in DCE (250 μL, 0.1 M, 0.025 mmol, 10 mol%) and 1.0 mL of DCE. The tube was put in a pre-heated oil bath at 60 °C and was stirred for 16 h. After cooling to room temperature, the reaction was filtrated through celite and rinsed with DCM. The filtrate was then washed with a saturated solution of Na$_2$CO$_3$, dried with MgSO$_4$, filtrated and concentrated in vacuo. The product was then purified by flash column chromatography.
Scheme S1. Substrate scope of indolines

Yields for the reactions without ligand were determined by analysis of crude $^1$H NMR by using CH$_2$Br$_2$ as internal standard (n.d., not determined).

A mixture of DCE and HFB (1:4, v/v) was...
used as solvent. The reaction was performed at 80 °C. The reaction time was 8 h. A mixture of DCE and HFB (1:1, v/v) was used as solvent. 1H equiv. of indoline substrate and 2.0 equiv. of ethyl acrylate were used.

*(E)-Ethyl 3-(1-methyl-5-indoliny1)acrylate (2a)*

Substrate 1a (66.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure and the product was purified by flash chromatography (5:1, n-hexane/Et2O) to give 2a as a yellow oil (33.5 mg, 58%) with greater than 20:1 regioselectivity (para:others). 1H NMR (400 MHz, Chloroform-d) δ 7.60 (d, J = 15.8 Hz, 1H), 7.30 – 7.21 (m, 2H), 6.38 (d, J = 8.0 Hz, 1H), 6.19 (d, J = 15.8 Hz, 1H), 4.23 (q, J = 7.1 Hz, 2H), 3.42 (t, J = 8.3 Hz, 2H), 2.97 (t, J = 8.3 Hz, 2H), 2.81 (s, 3H), 1.32 (t, J = 7.2 Hz, 3H). 13C NMR (75 MHz, Chloroform-d) δ 168.1, 155.3, 145.6, 130.9, 130.2, 123.9, 123.5, 112.3, 106.0, 60.2, 55.5, 35.1, 28.2, 14.6. IR: ν 2978, 2926, 2854, 1700, 1602, 1505, 1475, 1389, 1280, 1163, 849 cm⁻¹. HRMS (ESI) calculated for C₁₄H₁₃NO₂ [M⁺]: 231.1259; found: 231.1252.

A parallel reaction without ligand was also performed, and less than 10% of product was observed (para: others). A parallel reaction without ligand was also performed, and less than 10% of product was observed (para: others).

*(E)-Ethyl 3-(4-fluoro-1-methyl-5-indoliny1)acrylate (2b)*

Substrate 1b (75.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure and the product was purified by flash chromatography (5:1, n-pentane/Et2O) to give 2b as a yellow solid (47.2 mg, 76%) with greater than 20:1 regioselectivity (para:others). 1H NMR (400 MHz) δ 7.68 (d, J = 16.0 Hz, 1H), 7.27 – 7.23 (m, 1H), 6.30 (d, J = 16.0 Hz, 1H), 6.17 (d, J = 8.2 Hz, 1H), 4.23 (q, J = 7.1 Hz, 2H), 3.48 (t, J = 8.5 Hz, 2H), 3.01 (t, J = 8.5 Hz, 2H), 2.80 (s, 3H), 1.32 (t, J = 7.1 Hz, 3H). 13C NMR (100 MHz) δ 168.1, 158.5 (d, JCF = 250.7 Hz), 157.4 (d, JCF = 10.5 Hz), 138.9, 130.9 (d, JCF = 4.1 Hz), 115.2 (d, JCF = 21.7 Hz), 114.8 (d, JCF = 7.6 Hz), 112.4 (d, JCF = 12.0 Hz), 102.4 (d, JCF = 2.2 Hz), 60.2, 55.7, 34.8, 24.5, 14.5. IR: ν 2977, 2852, 1698, 1606, 1519, 1469, 1253, 1166, 988, 816 cm⁻¹. HRMS (ESI) calculated for C₁₄H₁₄FNO₂ [M⁺]: 250.1243; found: 250.1289.

A parallel reaction without ligand was also performed, and less than 10% of product was observed by 1H NMR analysis (para: others, not determined) with CH₂Br₂ as internal standard.

*(E)-Ethyl 3-(6-fluoro-1-methyl-5-indoliny1)acrylate (2c)*

Substrate 1c (75.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure with a mixture of DCE and HFB (1:4, v/v) as solvent and the product was purified by flash chromatography (5:1 to 4:1, n-pentane/Et₂O) to give 2c as a yellow solid (42.5 mg, 68%) with greater than 20:1 regioselectivity (para: others). 1H NMR (400 MHz) δ 7.75 (d, J = 16.1 Hz, 1H), 7.15 (d, J = 7.3 Hz, 1H), 6.21 (d, J = 15.9 Hz, 1H), 6.04 (d, J = 11.7 Hz, 1H), 4.23 (q, J = 7.2 Hz, 2H), 3.46 (t, J = 8.4 Hz, 2H), 2.93 (t, J = 8.2 Hz, 2H), 2.79 (s, 3H), 1.31 (t, J = 7.1 Hz, 3H). 13C NMR (100 MHz) δ 168.0, 163.2 (d, JCF = 251.0 Hz), 156.4 (d, JCF = 13.0 Hz), 138.1 (d, JCF = 4.1 Hz), 126.1 (d, JCF = 1.9 Hz), 123.1 (d, JCF = 5.1 Hz), 113.8 (d, JCF = 5.7 Hz), 110.3 (d, JCF = 12.7 Hz), 93.7 (d, JCF = 27.8 Hz), 60.2, 55.6, 34.6, 27.5, 14.5. IR: ν 2851, 1692, 1587, 1518, 1410, 1163, 849 cm⁻¹. HRMS (ESI) calculated for C₁₄H₁₄FNO₂ [M⁺]: 249.1172; found: 249.1172.
A parallel reaction without ligand was also performed, and 11% of product was observed (32.0 mg, 51%) with greater than 20:1 regioselectivity (para : others). $^1$H NMR (300 MHz) δ 7.52 (d, $J = 15.8$ Hz, 1H), 7.03 (s, 1H), 6.98 (d, $J = 13.1$ Hz, 1H), 6.18 (d, $J = 15.8$ Hz, 1H), 4.23 (q, $J = 7.1$ Hz, 2H), 3.40 (t, $J = 8.5$ Hz, 2H), 3.00 (t, $J = 2.0$ Hz, 5H), 1.32 (t, $J = 7.1$ Hz, 3H), $^{13}$C NMR (100 MHz) δ 167.7, 149.0, 148.2, 134.7, 134.3, 128.3, 128.2, 121.1, 114.7, 104.6, 102.6, 60.3, 54.9, 34.9, 28.1, 14.5, 14.1. IR: v 2923, 2851, 1700, 1605, 1159, 847, 592 cm$^{-1}$. HRMS (ESI) calculated for C$_{14}$H$_17$FNO$_2$: [M+H]$^+$: 266.0948; found: 266.0990.

A parallel reaction without ligand was also performed, and less than 10% of product was observed (para:others, not observed) by $^1$H NMR analysis with CH$_2$Br$_2$ as internal standard.

(E)-Ethyl 3-(4-chloro-1-methyl-5-indoliny)acrylate (2e)

Substrate 1e (83.8 mg, 0.5 mmol, 2.0 equiv.) was olefination following the general procedure and the product was purified by flash column chromatography (5:1, n-pentane/Et$_2$O) to give 2e as a yellow solid (46.0 mg, 69%) with greater than 20:1 regioselectivity (para : others). $^1$H NMR (300 MHz) δ 8.02 (d, $J = 15.9$ Hz, 1H), 7.43 (d, $J = 8.3$ Hz, 1H), 6.28 (d, $J = 8.4$ Hz, 1H), 6.23 (d, $J = 15.8$ Hz, 1H), 4.24 (q, $J = 7.1$ Hz, 2H), 3.48 (t, $J = 8.5$ Hz, 2H), 3.00 (t, $J = 2.0$ Hz, 5H), 1.32 (t, $J = 7.1$ Hz, 3H), $^{13}$C NMR (100 MHz) δ 167.7, 155.6, 141.0, 131.7, 128.6, 128.3, 121.1, 114.7, 104.6, 60.3, 54.9, 34.9, 28.1, 14.5, 14.1. IR: v 2921, 2851, 1688, 1587, 1223, 1156, 981, 804 cm$^{-1}$. HRMS (ESI) calculated for C$_{14}$H$_{17}$ClNO$_2$: [M+H]$^+$: 266.0948; found: 266.0990.

A parallel reaction without ligand was also performed, and traces of product was observed by $^1$H NMR analysis with CH$_2$Br$_2$ as internal standard.

(E)-Ethyl 3-(7-chloro-1-methyl-5-indoliny)acrylate (2f)

Substrate 1f (83.8 mg, 0.5 mmol, 2.0 equiv.) was olefination following the general procedure and the product was purified by flash column chromatography (5:1, n-pentane/Et$_2$O) to give 2f as a yellow solid (37.0 mg, 56%) with greater than 20:1 regioselectivity (para : others, not determined). HRMS (ESI) calculated for C$_{14}$H$_{17}$ClNO$_2$: [M+H]$^+$: 266.0948; found: 266.0997.

A parallel reaction without ligand was also performed, and 11% of product was observed (para:others, not determined) by $^1$H NMR analysis with CH$_2$Br$_2$ as internal standard.

S21
(E)-Methyl 5-(3-ethoxy-3-oxoprop-1-en-1-yl)-1-methylindoline-7-carboxylate (2g)

Substrate 1g (95.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure and the product was purified by flash column chromatography (3:1, n-pentane/EtO) to give 2g as a yellow solid (39.0 mg, 54%) with greater than 20:1 regioselectivity (C5:C4:C6). 1H NMR (400 MHz) δ 7.64 (s, 1H), 7.58 (d, J = 15.8 Hz, 1H), 7.32 (s, 1H), 6.22 (d, J = 15.8 Hz, 1H), 4.25 (q, J = 7.1 Hz, 2H), 3.90 (s, 3H), 3.63 (t, J = 8.6 Hz, 2H), 3.03 (t, J = 8.6 Hz, 2H), 2.94 (s, 3H), 1.33 (t, J = 7.1 Hz, 3H). 13C NMR (100 MHz) δ 167.7, 167.1, 155.2, 145.5, 144.4, 133.9, 132.4, 125.1, 123.3, 113.6, 110.9, 60.3, 57.0, 52.0, 39.1, 27.6, 14.51. IR: ν 2984, 1697, 1608, 1411, 1258, 1155, 1084, 856 cm⁻¹. HRMS (ESI) calculated for C₁₅H₁₀NO₃⁺ [M-MeO]+: 258.1130; found: 258.1139.

A parallel reaction without ligand was also performed, and 15% of C5-olefinated product was observed together with around 10% other isomers by 1H NMR analysis with CH₂Br₂ as internal standard.

(E)-Ethyl 3-(7-benzoyl-1-methyl-5-indolyl)acrylate (2h)

Substrate 1h (118.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure using a solvent mixture of DCE and HFB (1:4, v/v) and the product was purified by flash column chromatography (3:1, n-hexane/EtO) to give 2h as a yellow solid (64.0 mg, 76%) with 15:1 regioselectivity (para : others). 1H NMR (300 MHz) δ 7.91 (d, J = 8.1 Hz, 2H), 7.64 – 7.59 (m, 1H), 7.55 – 7.48 (m, 3H), 7.37 (s, 1H), 7.24 (s, 1H), 6.16 (d, J = 15.8 Hz, 1H), 4.22 (q, J = 7.1 Hz, 2H), 3.68 (t, J = 8.6 Hz, 2H), 3.10 (t, J = 8.6 Hz, 2H), 2.71 (s, 3H), 1.31 (t, J = 7.1 Hz, 3H). 13C NMR (75 MHz) δ 195.5, 167.7, 154.2, 144.5, 138.2, 133.7, 133.0, 132.6, 130.3, 128.6, 124.4, 122.4, 118.3, 113.2, 60.2, 56.6, 38.5, 27.6, 14.5. IR: ν 2979, 1707, 1448, 1264, 1174, 719 cm⁻¹. HRMS (ESI) calculated for C₂₁H₂₂NO₃⁺ [M+H]⁺: 336.1600; found: 336.1801.

A parallel reaction without ligand was also performed, and 35% of product was observed with regioselectivity of 5:1 (para : others) by 1H NMR analysis with CH₂Br₂ as internal standard.

(E)-Ethyl 3-(1,2-dimethyl-5-indolyl)acrylate (2i)

Substrate 1i (73.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure with a mixture of DCE and HFB (1:4, v/v) as solvent at 80 °C for 8 h and the product was purified by flash column chromatography (5:1, n-pentane/EtO) to give 2i as a yellow liquid (36.2 mg, 59%) with greater than 20:1 regioselectivity (para : others). 1H NMR (400 MHz) δ 7.60 (d, J = 15.8 Hz, 1H), 7.24 – 7.22 (m, 2H), 6.34 (d, J = 6.4 Hz, 1H), 6.18 (d, J = 15.8 Hz, 1H), 4.23 (q, J = 7.1 Hz, 2H), 3.65 – 3.54 (m, 1H), 3.13 (dd, J = 15.6, 8.5 Hz, 1H), 2.76 (s, 3H), 2.60 (dd, J = 15.7, 9.1 Hz, 1H), 1.34 – 1.30 (dd, J = 7.5, 6.7 Hz, 6H). 13C NMR (100 MHz) δ 168.1, 155.2, 145.7, 130.3, 129.8, 124.0, 123.3, 112.2, 105.9, 62.2, 60.1, 36.8, 32.6, 19.1, 14.6. IR: ν 2964, 2926, 1699, 1601, 1500, 1163, 807 cm⁻¹. HRMS (ESI) calculated for C₁₅H₂₀NO₂⁺ [M+H]⁺: 246.1494; found: 246.1526.

A parallel reaction without ligand was also performed, and traces of product was observed by 1H NMR analysis with CH₂Br₂ as internal standard.
(E)-Ethyl 3-(1,3-dimethyl-5-indoliny1)acrylate (2j)

Substrate 1j (73.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure and the product was purified by flash column chromatography (4:1, n-hexane/EtO) to give 2j as a yellow liquid (46.3 mg, 76%) with 14:1 regioselectivity (para : others). ¹H NMR (300 MHz) δ 7.62 (d, J = 15.9 Hz, 1H), 7.29 – 7.24 (m, 2H), 6.38 (d, J = 8.6 Hz, 1H), 6.21 (d, J = 15.8 Hz, 1H), 4.24 (q, J = 7.1 Hz, 2H), 3.61 (t, J = 8.0 Hz, 1H), 2.83 (s, 3H). HRMS (ESI) calculated for C_{15}H_{20}NO^+: [M+H]^+: 246.1498; found: 246.1498.

A parallel reaction without ligand was also performed, and 16% of product was observed by ¹H NMR analysis with 1:1 regioselectivity (para : others) with CH₂Br₂ as internal standard.

(E)-Ethyl 3-(1,3,3-trimethyl-5-indoliny1)acrylate (2k)

Substrate 1k (80.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure and the product was purified by flash column chromatography (8:1, n-hexane/EtO) to give 2k as a yellow liquid (46.8 mg, 72%) with greater than 20:1 regioselectivity (para : others). ¹H NMR (400 MHz): δ 7.64 (d, J = 15.8 Hz, 1H), 7.25 (d, J = 8.4 Hz, 1H), 7.22 (s, 1H), 6.41 (d, J = 8.1 Hz, 1H), 6.24 (d, J = 15.8 Hz, 1H), 4.25 (q, J = 7.2 Hz, 2H), 3.20 (s, 6H). HRMS (ESI) calculated for C_{16}H_{22}NO^+: [M+H]^+: 260.1606, measured: 260.1651.

A parallel reaction without ligand was also performed, and 18% of product was observed with regioselectivity of 15:1 (para : others) by ¹H NMR analysis with CH₂Br₂ as internal standard.

(E)-Ethyl 3-(1'-methylspiro[cyclohexane-1,3'-indolin]-5'-yl)acrylate (2l)

Substrate 1l (100.7 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure and the product was purified by flash column chromatography (7:1, n-hexane/EtO) to give 2l as a yellow solid (51.0 mg, 67%) with greater than 20:1 regioselectivity (para : others). ¹H NMR (300 MHz) δ 7.62 (d, J = 15.8 Hz, 1H), 7.4 (d, J = 8.0 Hz, 1H), 7.21 (s, 1H), 6.36 (d, J = 8.0 Hz, 1H), 6.21 (d, J = 15.8 Hz, 1H), 4.24 (q, J = 7.1 Hz, 2H), 3.30 (s, 2H), 2.82 (s, 3H), 1.76 – 1.30 (m, 13 H). ¹³C NMR (75 MHz) δ 168.1, 154.1, 145.8, 139.8, 130.6, 123.8, 121.4, 112.0, 105.9, 65.3, 60.1, 44.5, 36.7, 34.7, 25.8, 23.2, 14.6. IR: ν 2953, 2952, 2855, 1708, 1618, 1463, 1415, 1257, 1172 cm⁻¹. HRMS (ESI) calculated for C_{16}H_{20}NO^+: 300.1694, measured: 300.1947.

A parallel reaction without ligand was also performed, and 13% of product was observed (para : others, not determined) by ¹H NMR analysis with CH₂Br₂ as internal standard.
(E)-Ethyl 3-[(±)-9-methyl-2,3,4a,9,9a-hexahydro-1H-carbazol-6-yl]acrylate [(±)-2m]

Substrate (±)-1m (93.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure using a mixture of DCE ad HFB (1:1, v/v) as solvent and the product was purified by flash column chromatography (6:1, n-hexane/EtO) to give (±)-2m as a yellow solid (34.0 mg, 48%) with greater than 20:1 regioselectivity (para : others). \( ^{1}H \) NMR (400 MHz) \( \delta \) 7.65 (d, \( J = 15.8 \) Hz, 1H), 7.29 – 7.27 (m, 2H), 6.46 (d, \( J = 8.5 \) Hz, 1H), 6.24 (d, \( J = 15.8 \) Hz, 1H), 4.26 (q, \( J = 7.1 \) Hz, 2H), 3.40 (q, \( J = 5.3 \) Hz, 1H), 3.06 (q, \( J = 7.1 \) Hz, 1H), 2.77 (s, 3H), 1.83 – 1.65 (m, 3H), 1.59 – 1.31 (m, 8H). \( ^{13}C \) NMR (100 MHz) \( \delta \) 168.1, 154.9, 145.8, 135.3, 130.1, 124.4, 121.9, 112.4, 107.2, 66.0, 60.1, 40.1, 32.3, 28.2, 25.1, 23.1, 21.1, 14.6. IR: \( \nu \) 2975, 2933, 2852, 1705, 1605, 1486, 1300, 1155, 1030, 816 cm\(^{-1}\). HRMS (ESI) calculated for C\(_{18}\)H\(_{23}\)NO\(_2\) [M+H]\(^+\): 286.1807; measured: 286.1783.

A parallel reaction without ligand was also performed, and no product was observed.

(E)-Ethyl 3-[(±)-4-methyl-1,2,3,3a,4,8b-hexahydrocyclopenta[b]indol-7-yl]acrylate [(±)-2n]

Substrate (±)-1n (86.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure and the product was purified by flash column chromatography (7:1, n-hexane/EtO) to give (±)-2n as a yellow solid (48.0 mg, 68%) with greater than 20:1 regioselectivity (para : others). \( ^{1}H \) NMR (300 MHz) \( \delta \) 7.59 (d, \( J = 15.8 \) Hz, 1H), 7.20 (d, \( J = 7.7 \) Hz, 2H), 6.23 – 6.10 (m, 2H), 4.23 (q, \( J = 7.1 \) Hz, 2H), 4.13 (ddd, \( J = 8.0, 6.0, 1.7 \) Hz, 1H), 3.69 (td, \( J = 8.8, 2.7 \) Hz, 1H), 2.81 (s, 3H), 2.06 – 1.82 (m, 2H), 1.80 – 1.56 (m, 3H), 1.56 – 1.41 (m, 1H), 1.32 (t, \( J = 7.1 \) Hz, 3H). \( ^{13}C \) NMR (100 MHz) \( \delta \) 168.3, 154.8, 145.8, 134.5, 130.8, 123.3, 122.9, 111.1, 104.0, 71.3, 60.0, 45.2, 35.2, 32.3, 32.1, 24.5, 14.6. IR: \( \nu \) 2949, 2864, 1695, 1594, 1504, 1145 cm\(^{-1}\). HRMS (ESI) calculated for C\(_{17}\)H\(_{23}\)NO\(_2\) [M+H]\(^+\): 272.1651; found: 272.1815.

A parallel reaction without ligand was also performed, and traces of product was observed.

(E)-Ethyl 3-[(±)-3a,8-dimethyl-1-tosyl-1,2,3,3a,8a-hexahydropyrrolo[2,3-b]indol-5-yl]acrylate [(±)-2o]

Substrate (±)-1o (171.2 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure and the product was purified by flash column chromatography (2:1, n-hexane/EtO) to give (±)-2o as a yellow solid (94.5 mg, 86%) with 15:1 regioselectivity (para : others). \( ^{1}H \) NMR (400 MHz) \( \delta \) 7.77 (d, \( J = 8.0 \) Hz, 2H), 7.57 (d, \( J = 15.8 \) Hz, 1H), 7.35 (d, \( J = 8.0 \) Hz, 2H), 7.27 (d, \( J = 6.0 \) Hz, 1H), 7.12 (s, 1H), 6.34 (d, \( J = 8.2 \) Hz, 1H), 6.17 (d, \( J = 15.8 \) Hz, 1H), 5.16 (s, 1H), 4.21 (q, \( J = 7.1 \) Hz, 2H), 3.56 (ddd, \( J = 12.3, 7.3, 2.3 \) Hz, 1H), 3.09 – 3.02 (m, 1H), 3.03 (s, 3H), 2.45 (s, 3H), 1.90 (dd, \( J = 12.5, 5.7, 2.3 \) Hz, 1H), 1.40 – 1.34 (m, 1H), 1.30 (t, \( J = 7.2 \) Hz, 3H), 1.13 (s, 3H). \( ^{13}C \) NMR (100 MHz) \( \delta \) 167.8, 152.1, 145.2, 144.0, 136.6, 134.1, 131.1, 130.0, 127.3, 124.2, 121.4, 112.7, 105.4, 90.9, 60.2, 52.9, 48.4, 39.7, 30.9, 24.7, 21.7, 14.5. IR: \( \nu \) 2851, 1692, 1591, 1410, 1214, 1163, 991, 849 cm\(^{-1}\). HRMS (ESI) calculated for C\(_{24}\)H\(_{29}\)NO\(_2\)S\(_2\) [M+H]\(^+\): 441.1848; found: 441.1875.

The reaction using (±)-1o as the limiting reagent was also performed [reaction conditions: (±)-1o (85.6 mg, 0.25 mmol, 1.0 equiv.), ethyl acrylate (54.4 μL, 0.50 mmol, 2.0 equiv.), Pd(OAc)$_2$ (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO$_2$Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), DCE (0.2 M), 60 °C, 16 h] and the product was obtained in 75% isolated yield after purification by flash column chromatography.
A parallel reaction without ligand was also performed, and 46% of product was observed (para: others, not determined) by $^1$H NMR analysis with $\text{CH}_2\text{Br}_2$ as internal standard.

(E)-Ethyl 3-[(±)-3a,8-dimethyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indol-5-yl]acrylate [(±)-2p]

Substrate (±)-1p (94.6 mg, 0.5 mmol, 2.0 equiv.) was olefined following the general procedure and the product was purified by flash column chromatography (4:1, n-hexane/EtO) to give (±)-2p as a yellow solid (44.5 mg, 62% with greater than 20:1 regioselectivity (para:others).

$^1$H NMR (300 MHz) δ 7.64 (d, $J = 15.8$ Hz, 1H), 7.32 – 7.25 (m, 2H), 6.34 (d, $J = 8.7$ Hz, 1H), 6.23 (d, $J = 15.8$ Hz, 1H), 5.14 (s, 1H), 4.26 (q, $J = 7.1$ Hz, 2H), 3.99 (ddd, $J = 8.7, 6.7, 1.8$ Hz, 1H), 3.46 (ddd, $J = 10.8, 8.8, 5.5$ Hz, 1H), 2.97 (s, 3H), 2.20 – 2.00 (m, 2H), 1.49 (s, 3H), 1.34 (s, $J = 7.1$ Hz, 3H). $^{13}$C NMR (75 MHz) δ 168.0, 152.5, 145.5, 135.5, 130.9, 124.0, 121.9, 112.4, 105.0, 104.4, 67.4, 60.2, 52.1, 41.9, 30.6, 24.9, 14.5. IR: v 2926, 1697, 1598, 547 cm$^{-1}$. HRMS (ESI) calculated for C$_{15}$H$_{16}$NO$_2$ $^+\text{[M+H]}^+$: 242.1181; found: 242.1224.

The reaction using (±)-1p as the limiting reagent was also performed [reaction conditions: (±)-1p (47.3 mg, 0.25 mmol, 1.0 equiv.), ethyl acrylate (54.4 µL, 0.50 mmol, 2.0 equiv.), Pd(OAc)$_2$ (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO$_2$Bu (46.6 µL, 0.25 mmol, 1.0 equiv.), DCE (0.2 M), 60°C, 16 h] and the product was obtained in 65% isolated yield after purification by flash column chromatography.

A parallel reaction without ligand was also performed, and 30% of product was observed with regioselectivity of greater than 20:1 (para: others) by $^1$H NMR analysis with CH$_2$Br$_2$ as internal standard.

(E)-(±)-5-Methyl-2-tosyl-2,3,4,4a,5,9b-hexahydro-1H-pyrrolo[4,3-b]indol-8-yl)acrylate [(±)-2q]

Substrate (±)-1q (171.2 mg, 0.5 mmol, 2.0 equiv.) was olefined following the general procedure and the product was purified by flash column chromatography (5:1:1, n-hexane/DCM/EtOAc) to give (±)-2q as a yellow solid (78.1 mg, 71%) with greater than 20:1 regioselectivity (para:others).

$^1$H NMR (400 MHz) δ 7.61 – 7.57 (m, 3H), 7.29 – 7.24 (m, 4H), 6.46 (d, $J = 8.5$ Hz, 1H), 6.22 (d, $J = 15.8$ Hz, 1H), 4.24 (q, $J = 7.2$ Hz, 2H), 3.68 (ddd, $J = 11.9$, 6.4, 1.9 Hz, 1H), 3.61 – 3.56 (m, 1H), 3.39 – 3.29 (m, 2H), 2.66 (s, 3H), 2.56 (dt, $J = 11.7, 7.7$ Hz, 1H), 2.38 (s, 3H), 2.15 – 2.04 (m, 3H), 1.32 (t, $J = 7.1$ Hz, 3H). $^{13}$C NMR (75 MHz) δ 167.8, 154.9, 144.9, 143.7, 133.4, 131.2, 130.5, 129.9, 127.7, 125.7, 123.1, 113.9, 108.4, 63.8, 60.3, 47.7, 41.8, 39.8, 32.9, 24.7, 21.6, 14.5. IR: v 2927, 2863, 1697, 1630, 1493, 1162, 725, 547 cm$^{-1}$. HRMS (ESI) calculated for C$_{25}$H$_{28}$N$_2$O$_3$ $^+\text{[M+H]}^+$: 441.1848; found: 441.1892.

The reaction using (±)-1q as the limiting reagent was also performed [reaction conditions: (±)-1q (85.6 mg, 0.25 mmol, 1.0 equiv.), ethyl acrylate (54.4 µL, 0.50 mmol, 2.0 equiv.), Pd(OAc)$_2$ (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO$_2$Bu (46.6 µL, 0.25 mmol, 1.0 equiv.), DCE (0.2 M), 60°C, 16 h] and the product was obtained in 54% isolated yield after purification by flash column chromatography.

A parallel reaction without ligand was also performed, and 18% of product was observed (para: others, not determined) by $^1$H NMR analysis with CH$_2$Br$_2$ as internal standard.
Table S8. C–H Olefination of indolines containing electron-donating substituent on the benzene ring

| Entry | X         | solvent | \(^1\text{H} \text{NMR yield}\) 2\(^b\) |
|-------|-----------|---------|----------------------------------|
| 1     | 4-Me      | DCE     | 18%                              |
| 2     | 4-Me      | HFB     | 33%                              |
| 3     | 7-Me      | DCE     | 22%                              |
| 4     | 7-Me      | HFB     | 11%                              |
| 5\(^c\) | 7-Me     | DCE     | traces                           |
| 6\(^d\) | 7-Me     | DCE     | traces                           |
| 7\(^e\) | 7-Me     | DCE     | traces                           |
| 8     | 4-OMe     | DCE     | 23% + 13%                        |
| 9     | 4-OMe     | HFB     | 23% + < 10%                      |

\(^a\)Reaction conditions: 1 (0.50 mmol, 2.0 equiv.), ethyl acrylate (27.2 μL, 0.25 mmol, 1.0 equiv.), Pd(OAc)$_2$ (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO$_3$Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), solvent (0.2 M), 60 °C, 16 h. \(^b\)The yield was determined by \(^1\text{H} \text{NMR analysis of crude reaction samples using CH}_2\text{Br}_2 \text{as internal standard.}

\(^c\)1.0 equiv. of Cu(OAc)$_2$ was used as oxidant instead of PhCO$_3$Bu. \(^d\)1.0 equiv. of AgOAc was used as oxidant instead of PhCO$_3$Bu. \(^e\)O$_2$ (@ 1 atm) was used as oxidant instead of PhCO$_3$Bu.

5. Reaction optimization for the C6 C–H olefination of tetrahydroquinolines

Table S9. Protecting group screening

| Entry | R    | \(^1\text{H} \text{NMR yield}\) 2\(^b\) |
|-------|------|----------------------------------|
| 1     | H    | 0%                              |
| 2     | Me   | 55%                             |
| 3     | Boc  | 0%                              |
| 4     | Benzyl | 28%                         |
| 5\(^e\) | Me    | 11%                             |

\(^a\)Reaction conditions: 3 (0.25 mmol, 1.0 equiv.), ethyl acrylate (40.8 μL, 0.375 mmol, 1.5 equiv.), Pd(OAc)$_2$ (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO$_3$Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), DCE (1,2-dichloroethane) (1.25 mL), 80 °C, 16 h. \(^b\)The yield was determined by \(^1\text{H} \text{NMR analysis of crude reaction samples using CH}_2\text{Br}_2 \text{as internal standard.}

\(^e\)Without S,O-ligand.
Table S10. Reaction temperature screening

| Entry | Temperature (°C) | 1H NMR yield (%) |
|-------|-----------------|------------------|
| 1     | 80              | 55               |
| 2     | 100             | 26               |
| 3     | 60              | 64               |
| 4     | 40              | 72               |
| 5     | 23              | 61               |

Entry conditions: 3a (36.8 mg, 0.25 mmol, 1.0 equiv.), ethyl acrylate (40.8 μL, 0.375 mmol, 1.5 equiv.), Pd(OAc)₂ (5.6 mg, 0.025 mmol, 10 mol%), S,O- ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO₂Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), DCE (0.2 M), temp., 16 h. The yield was determined by 1H NMR analysis of crude reaction samples using CH₂Br₂ as internal standard.

Table S11. Reaction concentration screening

| Entry | X   | The amount of DCE (mL) | 1H NMR yield (%) |
|-------|-----|------------------------|------------------|
| 1     | 0.20| 1.25                   | 72               |
| 2     | 0.10| 2.50                   | 69               |
| 3     | 0.30| 0.83                   | 57               |

Entry conditions: 3a (36.8 mg, 0.25 mmol, 1.0 equiv.), ethyl acrylate (40.8 μL, 0.375 mmol, 1.5 equiv.), Pd(OAc)₂ (5.6 mg, 0.025 mmol, 10 mol%), S,O-ligand (5.2 mg, 0.025 mmol, 10 mol%), PhCO₂Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), DCE (0.2 M), 80 °C, 16 h. The yield was determined by 1H NMR analysis of crude reaction samples using CH₂Br₂ as internal standard.

6. General procedure for the performance of C6 C-H olefination of tetrahydroquinolines

In a pressure tube containing a suitable stirring bar was added quinoline (0.25 mmol, 1.0 equiv.), Pd(OAc)₂ (5.6 mg, 0.025 mmol, 10 mol%), PhCO₂Bu (46.6 μL, 0.25 mmol, 1.0 equiv.), ethyl acrylate (40.8 μL, 0.375 mmol, 1.5 equiv.), S,O-ligand stock solution in DCE (250 μL, 0.1 M, 0.025 mmol, 10 mol%) and 1.0 mL of DCE. The tube was put in a pre-heated oil bath at 40 °C and was stirred for 16 h. After cooling to room temperature, the reaction was filtrated through celite and rinsed with DCM. The filtrate was then washed with a saturated solution of Na₂CO₃, dried with MgSO₄, filtrated and concentrated in vacuo. The product was then purified by flash column chromatography.
Scheme S2. Substrate scope of tetrahydroquinolines

(Scheme) 

\[
\text{Pd(OAc)}_2 (10 \text{ mol\%}) \quad \text{S,O-ligand (10 mol\%)} \\
\text{PhCO}_2\text{Bu (1.0 equiv.)} \\
\text{DCE (0.2 M), 40 °C, 16 h} \\
\rightarrow \quad 4 \\
\text{With S,O-ligand} \\
\text{Without S,O-ligand}^a
\]

(a) Yields for the reactions without ligand were determined by analysis of crude $^1$H NMR by using CH$_2$Br$_2$ as internal standard (n.d., not determined). (b) Reaction was performed at 50 °C. (c) 1,4-dioxane was used as solvent. (d) Reaction was performed at 80 °C.

\((E)\)-Ethyl 3-(1-methyl-1,2,3,4-tetrahydroquinolin-6-yl)acrylate (4a)

Substrate 3a (36.8 mg, 0.25 mmol, 1.0 equiv.) was olefinated following the general procedure and the product was purified by flash column chromatography (DCM) to give 4a as a yellow liquid (45.0 mg, 73%) with greater than 20:1 regioselectivity (para : others).

$^1$H NMR (400 MHz) δ 7.58 (d, $J = 15.8$ Hz, 1H), 7.25 (dd, $J = 6.3, 2.2$ Hz, 1H), 7.14 (d, $J = 2.1$ Hz, 1H), 6.51 (d, $J = 8.5$ Hz, 1H), 6.18 (d, $J = 15.9$ Hz, 1H), 4.23 (q, $J = 7.1$ Hz, 2H), 3.34 – 3.25 (m, 2H), 2.94 (s, 3H), 2.75 (t, $J = 6.4$ Hz, 2H), 2.01 – 1.91 (m, 2H), 1.32 (t, $J = 7.1$ Hz, 3H).

$^{13}$C NMR (100 MHz) δ 168.2, 148.4, 145.5.
A parallel reaction without ligand was also performed, and 13% of product was observed (para:others, not determined) by \(^1\)H NMR analysis with CH\(_2\)Br\(_2\) as internal standard.

(\(E\))-Ethyl 3-(1,5-dimethyl-1,2,3,4-tetrahydro-6-quinolinyl)acrylate (4b)

Substrate 3b (40.3 mg, 0.25 mmol, 1.0 equiv.) was olefinated following the general procedure using 1,4-dioxane as solvent and the product was purified by flash column chromatography (1:1, DCM/cyclohexane) to give 4b as a yellow liquid (33.0 mg, 50%) with greater than 20:1 regioselectivity (para : others). \(^1\)H NMR (400 MHz) \(\delta\) 8.03 (d, \(J = 7.1\) Hz, 1H), 4.24 (q, \(J = 7.1\) Hz, 2H), 3.32 – 3.25 (m, 2H), 2.93 (s, 3H), 2.72 (t, \(J = 6.4\) Hz, 2H), 2.39 (s, 3H), 2.00 – 1.90 (m, 2H), 1.32 (t, \(J = 7.1\) Hz, 3H). \(^13\)C NMR (100 MHz) \(\delta\) 168.3, 147.9, 142.8, 138.0, 127.0, 120.6, 112.6, 112.0, 60.1, 51.3, 38.9, 27.5, 22.3, 20.1, 14.6. IR: \(\nu\) 2986, 2838, 1695, 1588, 1516, 1307, 1157, 978, 842 cm\(^{-1}\). HRMS (ESI) calculated for C\(_{16}\)H\(_{22}\)NO\(_2^+\) [M+H]\(^+\): 260.1651; found: 260.1655.

A parallel reaction without ligand was also performed, and no product was observed.

(\(E\))-Ethyl 3-(1,7-dimethyl-1,2,3,4-tetrahydro-6-quinolinyl)acrylate (4c)

Substrate 3c (40.3 mg, 0.25 mmol, 1.0 equiv.) was olefinated following the general procedure using 1,4-dioxane as solvent at 50 °C and the product was purified by flash column chromatography (1:1, DCM/cyclohexane) to give 4c as a yellow liquid (35.0 mg, 54%) with greater than 20:1 regioselectivity (para : others). \(^1\)H NMR (400 MHz) \(\delta\) 7.95 (d, \(J = 7.1\) Hz, 1H), 7.23 (s, 1H), 6.33 (s, 1H), 6.16 (d, \(J = 15.7\) Hz, 2H), 4.24 (q, \(J = 7.1\) Hz, 2H), 3.32 – 3.25 (m, 2H), 2.93 (s, 3H), 2.72 (t, \(J = 6.4\) Hz, 2H), 2.39 (s, 3H), 2.00 – 1.90 (m, 2H), 1.32 (t, \(J = 7.1\) Hz, 3H). \(^13\)C NMR (100 MHz) \(\delta\) 168.3, 148.2, 142.5, 138.0, 127.0, 120.6, 120.6, 112.6, 112.0, 60.1, 51.3, 38.9, 27.5, 22.3, 20.1, 14.6. IR: \(\nu\) 2986, 2838, 1695, 1588, 1516, 1307, 1157, 978, 842 cm\(^{-1}\). HRMS (ESI) calculated for C\(_{16}\)H\(_{22}\)NO\(_2^+\) [M+H]\(^+\): 260.1651; found: 260.1655.

A parallel reaction without ligand was also performed, and less than 10% of product was observed (para:others, not determined) by \(^1\)H NMR analysis with CH\(_2\)Br\(_2\) as internal standard.

(\(E\))-Ethyl 3-(1,2,2,4,7-pentamethyl-1,2,3,4-tetrahydro-6-quinolinyl)acrylate (4d)

Substrate 3d (50.8 mg, 0.25 mmol, 1.0 equiv.) was olefinated following the general procedure using 1,4-dioxane as solvent at 50 °C and the product was purified by flash column chromatography (1:1, DCM/cyclohexane) to give 4d as a yellow liquid (47.0 mg, 62%) with greater than 20:1 regioselectivity (para : others). \(^1\)H NMR (400 MHz) \(\delta\) 7.90 (d, \(J = 15.7\) Hz, 1H), 7.40 (s, 1H), 6.34 (s, 1H), 6.20 (d, \(J = 15.7\) Hz, 1H), 4.25 (q, \(J = 7.1\) Hz, 2H), 2.88 – 2.77 (m, 4H), 2.41 (s, 3H), 1.78 (dd, \(J = 13.1, 4.3\) Hz, 1H), 1.52 (t, \(J = 12.9\) Hz, 1H), 1.37 – 1.28 (m, 9H), 1.22 (s, 3H). \(^13\)C NMR (100 MHz) \(\delta\) 168.3, 147.9, 142.8, 137.9, 126.5, 123.6, 120.1, 112.5, 112.3, 60.1, 54.8, 46.6, 31.6, 29.2, 27.0, 25.1 20.1, 19.5, 14.6. IR: \(\nu\) 2966, 2929, 1699, 1591, 1504, 1237, 1154, 1113, 977, 808 cm\(^{-1}\). HRMS (ESI) calculated for C\(_{19}\)H\(_{26}\)NO\(_2^+\) [M+H]\(^+\): 302.2120; found: 302.2134.
A parallel reaction without ligand was also performed, and less than 10% of product was observed (para: others, not determined) by $^1$H NMR analysis with CH$_3$Br$_2$ as internal standard.

(E)-Ethyl 3-(7-chloro-1-methyl-1,2,3,4-tetrahydro-6-quinolinyl)acrylate (4e)

Substrate 3e (45.3 mg, 0.25 mmol, 1.0 equiv.) was olefinated following the general procedure and the product was purified by flash column chromatography (1:1, DCM/cyclohexane) to give 4e as a yellow solid (30.0 mg, 43%) with greater than 20:1 regioselectivity (para: others, not determined). $^1$H NMR (400 MHz) δ 8.01 (d, J = 15.9 Hz, 1H), 7.22 (s, 1H), 6.49 (s, 1H), 6.20 (d, J = 15.9 Hz, 1H), 4.24 (q, J = 7.1 Hz, 2H), 3.33 – 3.25 (m, 2H), 2.92 (s, 3H), 2.70 (t, J = 6.3 Hz, 2H), 1.99 – 1.89 (m, 2H), 1.32 (t, J = 7.1 Hz, 3H). $^{13}$C NMR (100 MHz) δ 167.7, 148.7, 140.9, 134.8, 127.2, 121.6, 119.1, 114.2, 110.5, 60.3, 50.9, 38.9, 27.5, 21.9, 14.5. IR: ν 2974, 2899, 1699, 1592, 1516, 1430, 1308, 1161, 1024, 981, 845 cm$^{-1}$. HRMS (ESI) calculated for C$_{15}$H$_{12}$ClNO$_2^+$ [M+H]$^+$: 280.1104; found: 280.1106.

A parallel reaction without ligand was also performed, and 12% of product was observed (para: others, not determined) by $^1$H NMR analysis with CH$_3$Br$_2$ as internal standard.

(E)-Ethyl 3-(1-methyl-4-oxo-1,2,3,4-tetrahydro-6-quinolinyl)acrylate (4f)

Substrate 3f (40.3 mg, 0.25 mmol, 1.0 equiv.) was olefinated following the general procedure at 50 °C and the product was purified by flash column chromatography (2.5:1, n-hexane/Et$_2$O) to give 4f as a yellow liquid (36.0 mg, 56%) with greater than 20:1 regioselectivity (para: others). $^1$H NMR (300 MHz) δ 8.01 (s, 1H), 7.64 – 7.51 (m, 2H), 6.71 (dd, J = 9.0, 2.3 Hz, 1H), 6.29 (d, J = 15.8 Hz, 2H), 4.23 (q, J = 7.2 Hz, 2H), 3.53 (t, J = 7.0 Hz, 2H), 3.04 (s, 3H), 2.80 – 2.66 (t, J = 6.6 Hz, 2H), 1.31 (t, J = 7.2 Hz, 3H). $^{13}$C NMR (75 MHz) δ 193.0, 167.5, 153.4, 144.0, 134.5, 128.7, 123.4, 119.5, 115.2, 113.8, 60.4, 51.1, 39.4, 37.9, 14.5. IR: ν 3052, 2922, 1677, 1592, 1515, 1324, 1156, 805 cm$^{-1}$. HRMS (ESI) calculated for C$_{15}$H$_{10}$NO$_2^+$ [M+H]$^+$: 260.1287, measured: 260.1251.

A parallel reaction without ligand was also performed, and 24% of product was observed (para: others, not determined) by $^1$H NMR analysis with CH$_3$Br$_2$ as internal standard.

(E)-Ethyl 3-(1,3-dioxo-1',2',3',3a',5'-hexahydro-1'H-spiro[indene-2,4'-pyrrolo[1,2-a]quinolin]-7'-yl)acrylate (4g)

Substrate 3g (75.8 mg, 0.25 mmol, 1.0 equiv.) was olefinated following the general procedure and the product was purified by flash column chromatography (3:1, n-hexane/EtOAc) to give 4g as a yellow solid (73.1 mg, 73%) with greater than 20:1 regioselectivity (para: others). $^1$H NMR (300 MHz) δ 8.06 – 7.96 (m, 1H), 7.90 – 7.80 (m, 3H), 7.58 (d, J = 15.8 Hz, 1H), 7.37 (dd, J = 8.5, 2.0 Hz, 1H), 7.19 (d, J = 1.7 Hz, 1H), 6.56 (d, J = 8.5 Hz, 1H), 6.16 (d, J = 15.8 Hz, 1H), 4.21 (q, J = 7.1 Hz, 2H), 3.90 (dd, J = 10.5, 5.3 Hz, 1H), 3.61 (td, J = 8.5, 2.6 Hz, 1H), 3.40 – 3.18 (m, 2H), 2.80 (d, J = 16.2 Hz, 1H), 2.06 – 1.91 (m, 2H), 1.89 – 1.80 (m, 1H), 1.36 – 1.27 (m, 4H). $^{13}$C NMR (75 MHz) δ 202.1, 199.5, 168.0, 145.8, 145.5, 142.4, 141.3, 136.2, 135.8, 129.0, 128.9, 123.4, 123.2, 122.0, 118.3, 112.2, 110.7, 61.2, 60.1, 51.1, 47.5, 34.2, 28.1, 23.8, 14.5. IR: ν 2974, 1700, 1598, 1507, 1251 cm$^{-1}$. HRMS (ESI) calculated for C$_{25}$H$_{23}$NO$_2^+$ [M+H]$^+$: 401.1627; found: 401.1666.
A parallel reaction without ligand was also performed, and 15% of product was observed (para:others, not determined) by $^1$H NMR analysis with CH$_2$Br$_2$ as internal standard.

(E)-Ethyl 3-(1,3-dioxo-1',2',3,3',4',4a',6'-octahydrospiro[indene-2,5'-pyrido[1,2-a]quinolin]-8'-yl)acrylate (4h)

Substrate 3h (79.3 mg, 0.25 mmol, 1.0 equiv.) was olefination following the general procedure and the product was purified by flash column chromatography (3:1, n-hexane/ EtOAc) to give 4h as a yellow solid (73.7 mg, 72%) with greater than 20:1 regioselectivity (para : others). $^1$H NMR (400 MHz) $\delta$ 8.01 – 7.97 (m, 1H), 7.94 – 7.91 (m, 1H), 7.85 (dd, $J$ = 5.6, 3.1 Hz, 2H), 7.55 (dd, $J$ = 8.7, 2.1 Hz, 1H), 7.09 (d, $J$ = 2.1 Hz, 1H), 6.92 (d, $J$ = 8.8 Hz, 1H), 6.18 (d, $J$ = 15.8 Hz, 1H), 4.23 – 4.14 (m, 3H), 3.45 (dd, $J$ = 11.7, 2.4 Hz, 1H), 3.18 (d, $J$ = 16.1 Hz, 1H), 2.87 (td, $J$ = 12.7, 2.6 Hz, 1H), 2.76 (d, $J$ = 16.1 Hz, 1H), 1.73 (d, $J$ = 12.3 Hz, 2H), 1.58 (qt, $J$ = 12.4, 3.4 Hz, 1H), 1.50 – 1.43 (m, 1H), 1.38 (ddd, $J$ = 16.3, 9.7, 3.5 Hz, 1H), 1.30 (t, $J$ = 7.1 Hz, 3H), 1.23 – 1.11 (m, 1H). $^{13}$C NMR (100 MHz) $\delta$ 201.8, 199.5, 167.8, 147.7, 144.8, 142.1, 141.2, 136.3, 135.8, 129.3, 128.4, 123.6, 123.5, 123.0, 113.5, 113.0, 60.1, 59.3, 54.9, 48.6, 32.9, 28.4, 24.9, 24.1, 14.5, 1R: ν 2976, 1701, 1596, 1518, 1255, 1156, 730 cm$^{-1}$. HRMS (ESI) calculated for C$_{26}$H$_{26}$NO$_5$ $\cdot$ [M+H]$^+$: 416.1862; found: 416.1899.

A parallel reaction without ligand was also performed, and less than 10% of product was observed (para:others, not determined) by $^1$H NMR analysis with CH$_2$Br$_2$ as internal standard.

(E)-Ethyl-3-(8-chloro-1,2,3,4-tetrahydro-6-quinolinyl)acrylate (4j)

Substrate 3j (41.9 mg, 0.25 mmol, 1.0 equiv.) was olefination following the general procedure and the product was purified by flash column chromatography (8:1, n-hexane/EtOAc) to give 4j as a yellow solid (21.0 mg, 32%) with greater than 20:1 regioselectivity (para : others). $^1$H NMR (400 MHz) $\delta$ 7.49 (d, $J$ = 15.8 Hz, 1H), 7.28 (d, $J$ = 1.9 Hz, 1H), 7.04 (d, $J$ = 1.9 Hz, 1H), 6.18 (d, $J$ = 15.9 Hz, 1H), 4.76 (bs, 1H), 4.23 (q, $J$ = 7.1 Hz, 2H), 3.48 – 3.37 (m, 2H), 2.77 (t, $J$ = 6.3 Hz, 2H), 1.99 – 1.88 (m, 2H), 1.31 (t, $J$ = 7.1 Hz, 3H). $^{13}$C NMR (100 MHz) $\delta$ 167.7, 144.3, 142.6, 128.0, 127.2, 122.8, 118.0, 113.7, 60.3, 41.9, 27.3, 21.3, 14.5. IR: ν 3418, 2929, 2850, 1699, 1599, 1518, 1230, 1162, 979, 720 cm$^{-1}$. HRMS (ESI) calculated for C$_{16}$H$_{16}$ClNO$_3$ $\cdot$ [M]$^+$: 265.0870; found: 265.0870.

A parallel reaction without ligand was also performed, and traces of product was observed.

(E)-Ethyl-3-(8-acetyl-1,2,3,4-tetrahydro-6-quinolinyl)acrylate (4k)

Substrate 3k (43.8 mg, 0.25 mmol, 1.0 equiv.) was olefination following the general procedure at 80 °C and the product was purified by flash column chromatography (4:1, n-hexane/EtOAc) to give 4k as a yellow solid (53.6 mg, 78%) with greater than 20:1 regioselectivity (para : others). $^1$H NMR (300 MHz) $\delta$ 9.39 (bs, 1H), 7.69 (s, 1H), 7.58 (d, $J$ = 15.8 Hz, 1H), 7.29 (s, 1H), 6.20 (d, $J$ = 15.8 Hz, 1H), 4.26 (q, $J$ = 7.1 Hz, 2H), 3.56 – 3.40 (m, 2H), 2.81 (t, $J$ = 6.2 Hz, 2H), 2.59 (s, 3H), 1.93 (p, $J$ = 6.1 Hz, 2H), 1.40 – 1.31 (m, 3H). $^{13}$C NMR (75 MHz) $\delta$ 200.6, 167.8, 150.2, 144.7, 133.0, 131.8, 123.6, 119.7, 116.0, 112.8, 60.3, 41.3, 28.0, 27.9, 20.4, 14.5. HRMS (ESI) calculated for C$_{16}$H$_{16}$NO$_5$ $\cdot$ [M]$^+$: 273.1365; found: 273.1365.

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A parallel reaction without ligand was also performed, and 10% of product was observed (para:others, not determined) by \(^1\)H NMR analysis with \(\text{CH}_2\text{Br}_2\) as internal standard.

7. General procedure for the evaluation of olefins

**General procedure A**: In a pressure tube containing a suitable stirring bar was added 1k (80.6 mg, 0.50 mmol, 2.0 equiv.), \(\text{Pd(OAc)}_2\) (5.6 mg, 0.025 mmol, 10 mol%), \(\text{PhCO}_3\text{Bu}\) (46.6 μL, 0.25 mmol, 1.0 equiv.), olefin (0.25 mmol, 1.0 equiv.), S,O-ligand stock solution in DCE (250 μL, 0.1 M, 0.025 mmol, 10 mol%) and 1.0 mL of DCE. The tube was put in a pre-heated oil bath at 60 °C and was stirred for 16 h. After cooling to room temperature, the reaction was filtrated through celite and rinsed with DCM. The filtrate was then washed with a saturated solution of \(\text{Na}_2\text{CO}_3\), dried with \(\text{MgSO}_4\), filtrated and concentrated \textit{in vacuo}. The product was then purified by flash column chromatography.

**General procedure B**: In a pressure tube containing a suitable stirring bar was added 3h (79.3 mg, 0.25 mmol, 1.0 equiv.), \(\text{Pd(OAc)}_2\) (5.6 mg, 0.025 mmol, 10 mol%), \(\text{PhCO}_3\text{Bu}\) (46.6 μL, 0.25 mmol, 1.0 equiv.), olefin (0.50 mmol, 2.0 equiv.), S,O-ligand stock solution in DCE (250 μL, 0.1 M, 0.025 mmol, 10 mol%) and 1.0 mL of DCE. The tube was put in a pre-heated oil bath at 40 °C and was stirred for 16 h. After cooling to room temperature, the reaction was filtrated through celite and rinsed with DCM. The filtrate was then washed with a saturated solution of \(\text{Na}_2\text{CO}_3\), dried with \(\text{MgSO}_4\), filtrated and concentrated \textit{in vacuo}. The product was then purified by flash column chromatography.

**Scheme S3. Olefin scope**

![Scheme S3. Olefin scope](image-url)

**5a**, 72%, C5 : others > 20:1  
11%, C5 : others, n.d.

**5b**, 76%, C5 : others > 20:1  
13%, C5 : others, n.d.

**5c**, 76%, C5 : others > 20:1  
13%, C5 : others, n.d.

**5d**, 79%, **5d1** : **5d2** : **5d3** = 6 : 12 : 1, C5 : others > 20:1  
32%, **5d1** : **5d2** : **5d3** = 1 : 1 : 7, C5 : others, n.d.
Substrate 1k (80.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure A using methyl acrylate as olefin (22.5 μL, 0.25 mmol, 1.0 equiv.) and the product was purified by flash column chromatography (8:1, n-hexane/Et₂O) to give 5a as a yellow liquid (44.3 mg, 72%) with greater than 20:1 regioselectivity (para : others). ¹H NMR (300 MHz) δ 7.63 (d, J = 15.8 Hz, 1H), 7.25 (d, J = 8.0 Hz, 1H), 7.19 (s, 1H), 6.39 (d, J = 8.0 Hz, 1H), 6.22 (d, J = 15.8 Hz, 1H), 3.77 (s, 3H), 3.18 (s, 2H), 2.81 (s, 3H), 1.31 (s, 6H). ¹³C NMR (75 MHz) δ 168.5, 154.0, 146.0, 139.9, 130.4, 123.9, 120.9, 111.7, 106.2, 69.8, 51.5, 40.1, 34.8, 27.8. IR: ν 2953, 1711, 1601, 1466, 1159, 809 cm⁻¹. HRMS (ESI) calculated for C₁₅H₂₀NO₂⁺ [M+H]⁺: 246.1494; found: 246.1639.

A parallel reaction without ligand was also performed, and 11% of product was observed (para:others, not determined) by ¹H NMR analysis with CH₂Br₂ as internal standard.

Substrate 1k (80.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure A using phenyl acrylate (34.3 μL, 0.25 mmol, 1.0 equiv.) as olefin and the product was purified by flash column chromatography (8:1, n-hexane/Et₂O) to give 5b as a yellow solid (58.3 mg, 76%) with greater than 20:1 regioselectivity (para : others). ¹H NMR (400 MHz) δ 7.82 (d, J = 15.8 Hz, 1H), 7.42 – 7.38 (m, 2H), 7.32 (d, J = 8.1 Hz, 1H), 7.27 (s, 1H), 7.25 – 7.21 (m, 1H), 7.20 – 7.14 (m, 2H), 6.43 (s, 1H), 6.40 (d, J = 7.2 Hz, 1H), 3.23 (s, 2H), 2.84 (s, 3H), 1.34 (s, 6H). ¹³C NMR (100 MHz) δ 166.5, 154.3, 151.3, 147.7, 140.0, 131.0, 129.4, 125.5, 123.7, 121.9, 121.1, 110.9, 106.1, 69.8, 40.1, 34.7, 27.9. IR: ν 2955, 1715, 1593, 1062, 788 cm⁻¹. HRMS (ESI) calculated for C₂₀H₂₀NO₂⁺ [M+H⁺]: 308.1651; found: 308.1849.

A parallel reaction without ligand was also performed, and 13% of product was observed (para:others, not determined) by ¹H NMR analysis with CH₂Br₂ as internal standard.
(E)-Cyclohexyl 3-(1,3,3-trimethyl-5-indoliny1)acrylate (5c)

Substrate 1k (80.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure A using cyclohexyl acrylate (39.5 μL, 0.25 mmol, 1.0 equiv.) as olefin, and the product was purified by flash column chromatography (10:1, n-hexane/Et2O) to give 5c as a yellow liquid (59.5 mg, 76%) with greater than 20:1 regioselectivity (para:others). $^1$H NMR (400 MHz) δ 7.61 (d, J = 15.8 Hz, 1H), 7.24 (d, J = 8.1 Hz, 1H), 7.20 (s, 1H), 6.38 (d, J = 8.1 Hz, 1H), 6.21 (d, J = 15.8 Hz, 1H), 4.87 (ddt, J = 13.0, 9.0, 3.9 Hz, 1H), 3.18 (s, 2H), 2.81 (s, 3H), 1.92 (dt, J = 13.5, 4.0 Hz, 2H), 1.76 (td, J = 7.7, 7.1, 4.0 Hz, 2H), 1.59 – 1.35 (m, 6H), 1.30 (s, 6H). $^{13}$C NMR (100 MHz) δ 167.5, 153.9, 145.4, 139.9, 130.4, 124.2, 120.8, 112.9, 106.2, 72.3, 69.9, 40.1, 34.9, 32.0, 27.8, 25.7, 24.0. IR: ν 2935, 2858, 1698, 1601, 1505, 1162, 808 cm$^{-1}$. HRMS (ESI) calculated for C$_{20}$H$_{28}$NO$_{3}$+ [M+H]$^+$: 314.2120; found: 314.2431.

A parallel reaction without ligand was also performed, and 13% of product was observed (para:others, not determined) by $^1$H NMR analysis with CH$_2$Br$_2$ as internal standard.

(E)-3-[(1,3,3-Trimethyl-5-indoliny1)methylene]dihydrofuran-2(3H)-one (5d1). 3-[(1,3,3-trimethyl-5-indoliny1)methyl]furan-2(5H)-one (5d2). (Z)-3-[(1,3,3-trimethyl-5-indoliny1)methylene]dihydrofuran-2(3H)-one (5d3)

Substrate 1k (80.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure A using 3-methyleneidihydrofuran-2(3H)-one (21.8 μL, 0.25 mmol, 1.0 equiv.) as olefin and the product was purified by flash column chromatography (5:1, n-hexane/Et$_2$O) to give 5d as a yellow solid (31.4 mg, 55%, 5d1: 5d2: 5d3 = 6:12:1) with greater than 20:1 regioselectivity (para:others). $^1$H NMR (400 MHz) δ 7.50 (t, J = 2.8 Hz, 1H), 7.29 (dd, J = 8.2, 1.8 Hz, 1H), 7.13 (d, J = 1.8 Hz, 1H), 6.98 – 6.93 (m, 2H), 6.87 (d, J = 1.8 Hz, 1H), 6.46 – 6.42 (m, 1H), 4.75 – 4.73 (m, 2H), 4.43 (t, J = 7.4 Hz, 2H), 3.51 – 3.49 (m, 2H), 3.24 – 3.19 (m, 4H), 3.06 (s, 2H), 2.83 (s, 3H), 2.74 (s, 3H), 1.32 (s, 6H), 1.28 (s, 6H). HRMS (ESI) calculated for C$_{15}$H$_{20}$NO$_{2}$+ [M+H]$^+$: 258.1494; found: 258.1508.

A parallel reaction without ligand was also performed, and 32% of product was observed (5d1: 5d2: 5d3 = 1:1:7) (para:others, not determined) by $^1$H NMR analysis with CH$_2$Br$_2$ as internal standard.

(E)-4-(1,3,3-Trimethyl-5-indoliny1)but-3-en-2-one (5e)

Substrate 1k (80.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure A using but-3-en-2-one (20.2 μL, 0.25 mmol, 1.0 equiv.) as olefin and the product was purified by flash column chromatography (5:1, n-hexane/Et$_2$O) to give 5e as a yellow liquid (31.4 mg, 55%) with greater than 20:1 regioselectivity (para:others). $^1$H NMR (300 MHz) δ 7.46 (d, J = 16.1 Hz, 1H), 7.27 (d, J = 8.0 Hz, 1H), 7.22 (s, 1H), 6.54 (d, J = 16.1 Hz, 1H), 6.39 (d, J = 8.1 Hz, 1H), 3.20 (s, 2H), 2.82 (s, 3H), 2.33 (s, 3H), 1.51 (d, J = 0.9 Hz, 6H). $^{13}$C NMR (75 MHz) δ 198.6, 154.2, 145.0, 140.0, 130.9, 123.7, 122.1, 121.1, 106.2, 69.8, 40.1, 34.7, 27.9, 27.3. IR: ν 2957, 1658, 1598, 1254, 1187957, 804 cm$^{-1}$. HRMS (ESI) calculated for C$_{14}$H$_{20}$NO$_{2}$+ [M+H]$^+$: 230.1545; found: 230.1721.
A parallel reaction without ligand was also performed, and 16% of product was observed (para:others, not determined) by $^1$H NMR analysis with CH$_2$Br$_2$ as internal standard.

$(E)$-Dimethyl [2-(1,3,3-trimethyl-5-indolinyllvinyl)phosphonate (5f)

Substrate 1k (80.6 mg, 0.5 mmol, 2.0 equiv.) was olefinated following the general procedure A using dimethyl vinylphosphonate (28.8 μL, 0.25 mmol, 1.0 equiv.) as olefin and the product was purified by flash column chromatography (100:3, DCM/MeOH) to give 5f as a yellow solid (60.2 mg, 82%) with greater than 20:1 regioselectivity (para:others).

$^1$H NMR (400 MHz) δ 7.43 (dd, $J$ = 22.7, 17.3 Hz, 1H), 7.22 (dd, $J$ = 8.2 Hz, 1H), 7.17 (s, 1H), 6.38 (d, $J$ = 7.8 Hz, 1H), 5.89 (dd, $J$ = 17.7, 17.3 Hz, 1H), 3.76 (s, 3H), 3.73 (s, 3H), 3.18 (s, 2H), 2.80 (s, 3H), 1.30 (s, 6H). $^{13}$C NMR (100 MHz) δ 154.0, 150.7, 139.9, 130.1, 120.4, 106.1, 105.9, 103.9, 69.9, 52.4, 40.1, 34.9, 27.8. $^{31}$P NMR (162 MHz) δ 25.01. IR: v 2954, 1599, 1506, 1246, 1186, 1029, 862 cm$^{-1}$. HRMS (ESI) calculated for C$_{31}$H$_{29}$NO$_3$P$^+$/[M+H]$^+$: 415.2068; found: 415.2068.

A parallel reaction without ligand was also performed, and less than 10% of product was observed (para:others, not determined) by $^1$H NMR analysis with CH$_2$Br$_2$ as internal standard.

$(E)$-3-(1,3-Dioxo-1,1',2',3,3',4',4a',6'-octahydrospiro[indene-2,5'-pyrido[1,2-a]quinolin]-8'-yl)-N,N-dimethylacrylamide (5g)

Substrate 3h (79.3 mg, 0.25 mmol, 1.0 equiv.) was olefinated following the general procedure B using N,N-dimethylacrylamide (38.6 μL, 0.375 mmol, 1.5 equiv.) as the olefin and the product was purified by flash column chromatography (100:3, DCM/MeOH) to give 5g as a yellow liquid (70.1 mg, 68%) with greater than 20:1 regioselectivity (para:others).

$^1$H NMR (400 MHz) δ 8.03 – 7.99 (m, 1H), 7.97 – 7.93 (m, 1H), 7.89 – 7.85 (m, 2H), 7.57 (d, $J$ = 15.2 Hz, 1H), 7.37 (dd, $J$ = 8.7, 2.1 Hz, 1H), 7.13 (s, 1H), 6.94 (d, $J$ = 8.7 Hz, 1H), 6.67 (d, $J$ = 15.2 Hz, 1H), 4.18 (d, $J$ = 12.7 Hz, 1H), 3.46 (dd, $J$ = 11.7, 2.4 Hz, 1H), 3.22 (d, $J$ = 16.1 Hz, 1H), 3.14 (s, 3H), 3.05 (s, 3H), 2.88 (td, $J$ = 12.6, 2.6 Hz, 1H), 2.79 (d, $J$ = 16.1 Hz, 1H). $^{13}$C NMR (100 MHz) δ 201.9, 199.6, 167.5, 147.1, 142.6, 142.2, 141.3, 136.2, 135.8, 128.9, 128.1, 124.7, 123.5, 123.4, 120.3, 113.0, 112.9, 59.4, 55.0, 48.7, 37.5, 36.0, 33.0, 28.5, 25.0, 24.2. IR: ν 3429, 2931, 1702, 1641, 1589, 1390, 1254, 1132, 978, 729 cm$^{-1}$. HRMS (ESI) calculated for C$_{35}$H$_{27}$N$_2$O$_3$P$^+$/[M+H]$^+$: 415.2022, measured: 415.2068.

A parallel reaction without ligand was also performed, and traces of product was observed.

$(E)$-8'-[2-(Phenylsulfonyl)vinyl]-1',2',3,3',4',4a',6'-hexahydrospiro[indene-2,5'-pyrido[1,2-a]quinoline]-1,3-dione (5h)

Substrate 3h (79.3 mg, 0.25 mmol, 1.0 equiv.) was olefinated following the general procedure B using (vinylsulfonyl)benzene (63.1 mg, 0.375 mmol, 1.5 equiv.) as the olefin and the product was purified by flash column chromatography (2:1 to 1:1, n-hexane/EtOAc) to give 5h as a yellow solid (62.0 mg, 51%) with greater than 20:1 regioselectivity (para:others).

$^1$H NMR (400 MHz) δ 8.06 – 7.98 (m, 1H), 7.98 – 7.85 (m, 5H), 7.62 – 7.46 (m, 4H), 7.33 (dd, $J$ = 8.7, 2.2 Hz, 1H), 7.07 (s, 1H), 6.92 (d,
J = 8.7 Hz, 1H), 6.58 (d, J = 15.1 Hz, 1H), 4.18 (d, J = 13.1 Hz, 1H), 3.51 (dd, J = 11.7, 2.4 Hz, 1H), 3.17 (d, J = 15.9 Hz, 1H), 2.94 (td, J = 12.7, 2.5 Hz, 1H), 2.77 (d, J = 15.9 Hz, 1H), 1.76 (d, J = 13.3 Hz, 2H), 1.62 – 1.54 (m, 1H), 1.54 – 1.44 (m, 1H), 1.43 – 1.32 (m, 1H), 1.19 (qd, J = 12.3, 3.4 Hz, 1H). \(^1^3\)C NMR (100 MHz) δ 201.6, 199.5, 148.5, 143.4, 142.2, 141.9, 141.2, 136.4, 136.0, 133.0, 129.9, 129.3, 129.2, 127.4, 123.6, 123.6, 121.7, 121.2, 120.5, 112.9, 59.3, 54.8, 32.9, 28.4, 24.9, 24.1. IR: ν 2936, 2836, 1704, 1503, 1255, 958, 796, 726 cm\(^{-1}\). HRMS (ESI) calculated for C\(_{29}\)H\(_{36}\)NO\(_2\) [M+H]\(^+\): 484.1583, measured: 484.1608.

A parallel reaction without ligand was also performed, and less than 10% of product was observed (para:others, not determined) by \(^1^H\) NMR analysis with CH\(_2\)Br\(_2\) as internal standard.

**(E)**-8'-Styryl-1',2',3',4',4a',6'-hexahydrospiro[indene-2,5'-pyrido[1,2-a]quinoline]-1,3-dione (5i)

Substrate 3h (79.3 mg, 0.25 mmol, 1.0 equiv.) was olefinated following the general procedure B using styrene (43.0 μL, 0.375 mmol, 1.5 equiv.) as the olefin and the product was purified by flash column chromatography (10:1, n-hexane/EtOAc) to give 5i as a yellow liquid (47.8 mg, 51%) with greater than 20:1 regioselectivity (para : others). \(^1^H\) NMR (400 MHz) δ 8.03 – 7.99 (m, 1H), 7.98 – 7.93 (m, 1H), 7.88 – 7.83 (m, 2H), 7.45 (d, J = 7.2 Hz, 2H), 7.37 – 7.30 (m, 3H), 7.19 (t, J = 7.4 Hz, 1H), 7.11 (d, J = 2.1 Hz, 1H), 7.02 – 6.87 (m, 3H), 4.17 (dd, J = 13.0, 3.6 Hz, 1H), 3.41 (dd, J = 11.7, 2.4 Hz, 1H), 3.26 (d, J = 16.1 Hz, 1H), 2.89 – 2.75 (m, 2H), 1.78 – 1.69 (m, 2H), 1.62 – 1.57 (m, 1H), 1.51 – 1.44 (m, 1H), 1.42 – 1.31 (m, 1H). 1.17 (qd, J = 12.4, 3.6 Hz, 1H). \(^1^3\)C NMR (100 MHz) δ 202.3, 199.8, 145.6, 142.3, 141.4, 138.2, 136.2, 135.7, 128.7, 128.7, 127.5, 127.1, 126.9, 126.3, 126.2, 125.1, 123.5, 123.4, 120.5, 113.5, 59.7, 55.2, 49.0, 33.1, 28.7, 25.1, 24.3. IR: ν 2930, 1739, 1702, 1592, 1503, 1255, 986, 796, 726 cm\(^{-1}\). HRMS (ESI) calculated for C\(_{29}\)H\(_{36}\)NO\(_2\) [M+H]\(^+\): 420.1964, measured: 420.1981.

A parallel reaction without ligand was also performed, and less than 20% of product was observed (para:others, not determined) by \(^1^H\) NMR analysis with CH\(_2\)Br\(_2\) as internal standard.

### 8. Large scale reaction of Pd-catalyzed C5 C–H olefination of 1,3,3-trimethylindoline

In a 50 mL round bottom flask was added 1k (2.0 mmol, 1.0 equiv.), Pd(OAc)\(_2\) (89.8 mg, 0.4 mmol, 10 mol%), PhCO\(_2\)Bu (746 μL, 4.0 mmol, 1.0 equiv.), S,O-ligand stock solution (4.0 mL, 0.1 M in DCE, 0.4 mmol, 10 mol%), ethyl acrylate (426 μL, 4.0 mmol, 1.0 equiv.) and DCE (16.0 mL). The flask was then sealed with a septum and was placed into a pre-heated oil bath at 60 °C. The reaction was then stirred for 14 h. After cooling to room temperature, a saturated aqueous solution of Na\(_2\)CO\(_3\) was added to quench the benzoic acid side product. The mixture was extracted with DCM three times and the combined organic extracts were dried with MgSO\(_4\), filtrated and concentrated in vacuo. The product was purified by flash column chromatography (25:1 to 8:1, n-hexane/Et\(_2\)O) to obtain 2k as a viscous yellow liquid (654.5 mg, 63%) and the unreacted 1k was also recovered (480 mg, 37%).
9. $^1$H NMR, $^{13}$C NMR and $^{31}$P NMR spectra:
EtOOC
\[\text{2b}\]

EtOOC
\[\text{2b}\]
EtOOC-\text{Cl-}\text{N}

4e

EtOOC-\text{Cl-}\text{N}

4e
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