Supporting Information
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A Facile Route To Substituted Bidentate And Tridentate Ligands Capable Of Forming Six-membered Chelate Rings With Transition Metal Ions

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Supporting Information

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General information

Nuclear magnetic resonance (NMR) spectra were recorded in CDCl₃ at room temperature (r.t.) on a Bruker AV400 (400 MHz) spectrometer for ¹H NMR and at 100 and for ¹³C NMR, respectively. Chemical shifts are reported in part per million (ppm) relative to residual solvent protons (7.26 ppm for CDCl₃) and the carbon resonance (77.00 ppm for CDCl₃) of the solvent.

Accurate mass measurements were performed on a 6210 TOF mass spectrometer from Agilent technologies, coupled to a 1100 series LC system in positive electrospray mode. Appropriate [M+H]⁺ species were used for empirical formula determination, and exact masses were calculated using Analyst® QS Software from Applied Biosystems.

In a typical procedure, a 100 mL oven-dried round-bottomed flask was charged with (±) BINAP (3 mol% with respect to halogenated N-heterocycle) which was dissolved in dry toluene (5 mL) under an inert N₂-atmosphere at ~ 60 °C to give a clear colourless solution. To this solution was added Pd(OAc)₂ (2 mol% with respect to halogenated N-heterocycle) and the reaction mixture was stirred at ambient temperature under N₂-atmosphere to give a clear dark red solution. To this solution was added the halogenated N-heterocycle (1 mmol) and the reaction was heated to ~ 60 °C under N₂-atmosphere for 15-20 min, while a color change from dark-red to yellow could be observed. To the resulting clear yellow solution was added H-hpp (1.1 equiv with respect to starting halogenated N-heterocycle), followed by the addition of KOt-Bu (2.5 equiv. with respect to halogenated N-heterocycle) and the resulting brownish-red solution was heated at the temperature and time indicated in Table 1. After this time, the reaction mixture was cooled to room temperature and the solvent was evaporated to dryness. To the resulting brownish-green solid was added an aliquot of a mixture of toluene and diethyl-ether (10:60, v/v) and filtered. The pale yellow filtrate was evaporated to dryness. The desired product could be isolated as colorless to yellow solid by trituration with acetone (2 mL), followed by drying under vacuum to afford the yield as indicated in Table 1 in the main text.

For di-substitution reactions, with respect to 1 equiv. of the halogenated-N-heterocycle, 2 mol% of palladium, 3 mol% of BINAP, 2.2 equiv. of H-hpp and 5 equiv. of KOt-Bu were used.

3. Spectral data of compounds

1. 1-(5-nitropyridin-2-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine

![Chemical structure of 1-(5-nitropyridin-2-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine]

Yellow solid
\(^{1}\)H NMR (400 MHz, CDCl\(_3\)): \(\delta = 9.02\) (d, J = 4 Hz, 1H), \(8.13\) (dd, J = 12 Hz, 1H), \(7.86\) (d, J = 10 Hz, 1H), \(4.01\) (t, J = 6 Hz, 2H), \(3.44\) (t, J = 6 Hz, 2H), \(3.25\) (m, 4H), \(2.01\) (quintet, J = 6 Hz, 2H), \(1.90\) (quintet, J = 6 Hz, 2H) ppm. \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta = 159.0, 148.34, 144.28, 137.10, 130.70, 114.68, 48.19, 48.14, 43.46, 42.95, 23.29, 21.93\) ppm. MS (ESI-HRMS, CHCl\(_3\)): \(m/z\) [M+H]\(^+\) \(C_{12}H_{15}N_{3}O_{2}\) calcd for: 262.1304; found: 260.1348.

2. 1-(6-methylpyridin-2-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine

![Structure](image)

White solid

\(^{1}\)H NMR (400 MHz, CDCl\(_3\)): \(\delta = 7.28\) (d, J = 5.6 Hz, 1H), \(7.24\) (d, J = 8 Hz, 1H), \(6.53\) (d, J = 7.2 Hz, 1H), \(3.75\) (t, J = 6 Hz, 2H), \(3.27\) (t, J = 5.6 Hz, 2H), \(3.10\) (m, 4H), \(2.29\) (s, 3H), \(1.89\) (quintet, J = 6 Hz, 2H), \(1.76\) (quintet, J = 6 Hz, 2H) ppm. \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta = 155.45, 155.35, 149.51, 135.75, 115.68, 115.16, 48.16, 47.95, 43.24, 43.07, 23.85, 22.98, 22.07\) ppm. MS (ESI-HRMS, CHCl\(_3\)): \(m/z\) [M+H]\(^+\) \(C_{13}H_{18}N_{4}\) calcd for: 231.1610; found: 231.1671.

3. 1-(5-methoxypyridin-2-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine

![Structure](image)

White solid

\(^{1}\)H NMR (400 MHz, CDCl\(_3\)): \(\delta = 7.93\) (d, J = 2.8 Hz, 1H), \(7.46\) (d, J = 9.2 Hz, 1H), \(7.12\) (dd, J = 12 Hz, 1H), \(3.76\) (s, 3H), \(3.72\) (t, J = 6 Hz, 2H), \(3.32\) (t, J = 5.6 Hz, 2H), \(3.19\) (m, 2H), \(2.03\) (quintet, J = 6 Hz, 2H), \(1.85\) (quintet, J = 6 Hz, 2H) ppm. \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta = 151.54, 150.39, 150.20, 132.90, 122.82, 120.71, 55.81, 48.55, 48.33, 44.68, 43.37, 23.22, 22.44\) ppm. MS (ESI-HRMS, CHCl\(_3\)): \(m/z\) [M+H]\(^+\) \(C_{13}H_{18}N_{4}O\) calcd for: 247.1559; found: 247.1631.
4. 1-(6-methoxypyridin-2-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine

![Chemical structure](image)

Yellow oil

$^1$H NMR (400 MHz, CDCl$_3$): $\delta = 7.44$ (t, $J = 8$ Hz, 1H), 7.27 (m, 1H), 6.24 (dd, $J = 12$ Hz, 1H), 3.92 (t, $J = 6$ Hz, 2H), 3.85 (s, 3H), 3.45 (t, $J = 5.6$ Hz, 2H), 3.26 (m, 4H), 2.04 (quintet, $J = 6$ Hz, 2H), 1.92 (quintet, $J = 6$ Hz, 2H) ppm. $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 162.27$, 154.04, 149.67, 138.61, 109.14, 100.96, 52.86, 48.26, 48.17, 43.23, 43.05, 23.15, 22.18 ppm. MS (ESI-HRMS, CHCl$_3$): $m/z$ [M+H]$^+$ C$_{13}$H$_{18}$N$_4$O calc for: 247.1559; found: 247.1632.

5. 1-(6-(2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidin-1-yl)pyridin-3-yl)ethanone

![Chemical structure](image)

White solid

$^1$H NMR (400 MHz, CDCl$_3$): $\delta = 8.76$ (dd, $J = 2.4$ Hz, 1H), 7.96 (dd, $J = 8.8$ Hz, 1H), 7.75 (dd, $J = 8.8$ Hz, 1H), 3.97 (t, $J = 5.6$ Hz, 2H), 3.42 (t, $J = 6$ Hz, 2H), 3.24 (m, 4H), 2.47 (s, 3H), 2.01 (quintet, $J = 6$ Hz, 2H), 1.89 (quintet, $J = 6$ Hz, 2H) ppm. $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 195.74$, 158.58, 148.87, 135.23, 115.54, 48.28, 48.19, 43.37, 42.89, 26.09, 23.34, 22.08 ppm. MS (ESI-HRMS, CHCl$_3$): $m/z$ [M+H]$^+$ C$_{14}$H$_{18}$N$_4$O calc for: 259.1559; found: 259.1614.

6. 1-(6-bromopyridin-2-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine

![Chemical structure](image)

White solid

$^1$H NMR (400 MHz, CDCl$_3$): $\delta = 7.68$ (d, $J = 8$ Hz, 1H), 7.28 (t, $J = 8$ Hz, 1H), 6.88 (d, $J = 7.2$ Hz, 1H), 3.86 (t, $J = 6$ Hz, 2H), 3.39 (t, $J = 4.8$ Hz, 2H), 3.22 (m, 4H), 2.0 (quintet, $J = 6$ Hz, 2H), 1.87 (quintet, $J = 6$ Hz, 2H) ppm. $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 158.05$, 148.91,
140.69, 137.76, 119.21, 115.78, 48.46, 48.30, 43.58, 43.07, 23.03, 22.32 ppm. MS (ESI-HRMS, CHCl₃): m/z [M+H]+ C₁₂H₁₅N₄Br caled for: 295.0558; found: 295.0631.

7. 1-(3-methoxypyridin-2-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine

White solid

1H NMR (400 MHz, CDCl₃): δ = 7.93 (d, J = 3 Hz, 1H), 7.33 (d, J = 9 Hz, 1H), 7.17 (dd, J = 12 Hz, 1H), 3.79 (s, 3H), 3.50 (t, J = 6 Hz, 2H), 3.24 (m, 6H), 2.06 (quintet, J = 6 Hz, 2H), 1.83 (quintet, J = 6 Hz, 2H) ppm. ¹³C NMR (100 MHz, CDCl₃): δ = 152.89, 150.62, 150.15, 139.84, 119.95, 118.48, 56.0, 48.28, 48.19, 46.76, 45.9, 24.52, 22.91 ppm. MS (ESI-HRMS, CHCl₃): m/z [M+H]+ C₁₃H₁₈N₄O caleld for: 247.1559; found: 247.1635.

8. 6-(2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidin-1-yl)nicotinic acid

White solid

1H NMR (400 MHz, CDCl₃): δ = 8.82 (dd, J = 2 Hz, 1H), 8.14 (dd, J = 8 Hz, 1H), 7.01 (dd, J = 6.4 Hz, 1H), 3.77 (t, J = 6 Hz, 2H), 3.39 (t, J = 6 Hz, 2H), 3.31 (m, 4H), 2.01 (quintet, J = 6 Hz, 2H), 1.89 (quintet, J = 6 Hz, 2H) ppm. ¹³C NMR (100 MHz, CDCl₃): δ = 170.43, 154.8, 150.2, 149.20, 139.13, 124.05, 116.23, 48.08, 47.76, 45.41, 40.12, 21.80, 20.47 ppm. MS (ESI-HRMS, CHCl₃): m/z [M+H]+ C₁₃H₁₆N₄O₂ caleld for: 261.1352; found: 261.1420.
Figure S1: $^1$H NMR spectrum of compound 11 at room temperature at 400 MHz.

Figure S2: $^{13}$C NMR spectrum of compound 11 at room temperature at 400 MHz.
Figure S3: \textsuperscript{1}H NMR spectrum of compound 7 at room temperature at 400 MHz.

Figure S4: \textsuperscript{13}C NMR spectrum of compound 7 at room temperature at 400 MHz.
Figure S5: $^1$H NMR spectrum of compound 12 at room temperature at 400 MHz.

Figure S6: $^{13}$C NMR spectrum of compound 12 at room temperature at 400 MHz.
Figure S7: $^1$H NMR spectrum of compound 8 at room temperature at 400 MHz.

Figure S8: $^{13}$C NMR spectrum of compound 8 at room temperature at 400 MHz.
Figure S9: $^1$H NMR spectrum of compound 9 at room temperature at 400 MHz.

Figure S10: $^{13}$C NMR spectrum of compound 9 at room temperature at 400 MHz.
**Figure S11.** $^{13}$C NMR spectrum of compound 4 at room temperature at 400 MHz.

**Figure S12.** $^{13}$C NMR spectrum of compound 4 at room temperature at 400 MHz.
Synthetic and characterization details of the previously reported compounds as mentioned in references 16-19 in the main text:

**Compound 1: 1-(pyridin-2-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine**

(±) BINAP (0.06 mmol, 38 mg) was taken in an oven-dried round bottomed flask, which was purged with argon and sealed with a septum. Dry toluene (3 mL) was injected inside. The resulting suspension was heated at 90 °C for 2 min to dissolve the BINAP. This mixture was cooled to room temperature and Pd(OAc)$_2$ (0.04 mmol, 9 mg) was added and stirred for 3 min. To the resulting bright yellow solution was added 2-bromopyridine (4 mmol, 0.38 mL) and 1,3,4,6,7,8-hexahydro-2H-pyrimido[1,2-a]pyrimidine (4.3 mmol, 600 mg). Stirring for 5 min at ambient temperature resulted in a pale orange slurry to which was added KOt-Bu (5.6 mmol, 640 mg). The flask was again purged with argon and the reaction mixture was then stirred at 90°C for 3h after which time it was cooled to r.t. and diethyl ether (60 mL) was added and the solution was filtered. Evaporation of the filtrate gave the ligand as yellow oil. Yield = 780 mg (90%). $^1$H NMR (CDCl$_3$, 300 MHz); 8.24 (dd, J$^d$ = 6.0 Hz, J$^d$ = 2.0 Hz, 1 H), 7.65 (d, J$^d$ = 8.0 Hz, 1 H), 7.47 (td, J$^d$ = 6.0 Hz, J$^d$ = 2.0 Hz, 1 H), 6.77 (td, J$^d$ = 6.0 Hz, J$^d$ = 2.0 Hz, 1 H), 3.87 (t, J$^d$ = 6.0 Hz, 2 H), 3.41 (t, J$^d$ = 6.0 Hz, 2 H), 3.21 (m, 4 H), 2.02 (quint., J$^d$ = 6.0 Hz, 2 H), 1.88 (quint., J$^d$ = 6.0 Hz, 2 H) ppm. $^{13}$C NMR (CDCl$_3$, 75 MHz); 156.6, 149.9, 147.1, 135.9, 118.7, 116.9, 48.8, 48.6, 43.8, 43.7, 23.7, 22.7 ppm. HRMS (ESI), m/z: 217.14452 [M+H$^+$]$^+$ (C$_{12}$H$_{17}$N$_4$ requires 217.14477).

**Compound 2: 1-(pyrimidin-2-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine**

1,3,4,6,7,8-Hexahydro-2H-pyrimido[1,2-a]pyrimidine (150 mg, 1.1 mmol) and 2-bromopyrimidine (160 mg, 1 mmol) were taken in a pressure tube and slowly heated to 130 °C, wherein a brown sticky-solid was obtained. Heating was maintained at 130 °C for an hour, after which the tube was cooled to room temperature and the solid was purified by column-chromatography on Al$_2$O$_3$ with 10% MeOH in CHCl$_3$ as eluent. The product was obtained by evaporation of the solvent and overnight drying under vacuum. Yield = 60 mg (55 %). $^1$H NMR (CDCl$_3$, 400 MHz); 8.72 (d, H, J$^d$ = 5.0 Hz, 2 H), 7.17 (t, J$^d$ = 5.0 Hz, 1 H), 4.34 (t, J$^d$ = 6.0 Hz, 2 H), 3.75 (m, 4 H), 3.69 (t, J$^d$ = 6.0 Hz, 2 H), 2.27 (quint., J$^d$ = 6.0 Hz, 2 H), 2.18 (quint., J$^d$ = 6.0 Hz, 2 H) ppm. $^{13}$C NMR (CDCl$_3$, 75 MHz); 158.3, 157.7, 151.2, 117.1, 48.7, 43.7, 39.1, 20.8, 19.5 ppm. HRMS (ESI), m/z: 218.13925 [M+H$^+$]$^+$ (C$_{11}$H$_{16}$N$_5$ requires 218.14002).

**Compound 3: 1-(pyrazin-2-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine**

A 30 mL pressure tube with a stirring bar was charged with 1,3,4,6,7,8-hexahydro-2H-pyrimido[1,2-a]pyrimidine (292 mg, 2.1 mmol) and 2-chloropyrazine (115 mg, 1 mmol) was added dropwise. The tube was sealed and heated at 95 °C in an oil bath for 3 h, after which time it was cooled down to room temperature. Toluene (6 ml) was added to the resulting yellow viscous-oil followed by diethyl ether (40 mL). After filtration and evaporation of the solvents, the product was obtained as colourless oil, which could be solidified by keeping the oil at -20 °C for a week to give pale yellow solid. The solid was dissolved into minimal volume of dichloromethane and filtered through a plug of celite to give a clear colourless
solution. Upon evaporation of the solvent under reduced pressure colourless oil was obtained. The oil was solidified at -20 °C and then dried under vacuum to furnish the product as colourless solid. Yield = 189 mg (87%). $^1$H NMR (400 MHz, CDCl$_3$); 9.06 (d, J$^d$ = 1.2 Hz, 1 H), 8.12 (dd, J$^{dd}$ = 1.2, 4.0 Hz, 1 H), 7.94 (d, J$^d$ = 2.4 Hz, 1 H), 3.83 (t, J$^t$ = 6.0 Hz, 2 H), 3.42 (t, J$^t$ = 6.0 Hz, 2 H), 3.25 (t, J$^t$ = 6.0 Hz, 2 H), 3.21 (t, J$^t$ = 6.0 Hz, 2 H), 2.05 (quint., J$^{q}$ = 6.0 Hz, 2 H), 1.90 (quint., J$^{q}$ = 6.0 Hz, 2 H) ppm. $^{13}$C NMR (100 MHz, CDCl$_3$); 152,9, 148.7, 141.9, 140.6, 135.2, 48.6, 48.4, 43.6, 42.8, 23.4, 22.5 ppm. HRMS (ESI), m/z: 218.13975 [M+H$^+$]$^+$ (C$_{11}$H$_{16}$N$_5$ requires 218.14002).

**Compound 5: 1-(5-bromopyridin-2-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine**

A 30 mL pressure tube with a stirring bar was charged with 2,5-dibromopyridine (474 mg, 2 mmol) and 1,3,4,6,7,8-hexahydro-2H-pyrimido[1,2-a]pyrimidine (557 mg, 4 mmol). The tube was sealed and heated to 90 °C in an oil bath for 3 h, after which time it was cooled to room temperature. Toluene (5 ml) was added to the resulting yellow mixture, followed by the addition of diethyl ether (40 ml). After filtration and evaporation of the solvents, a light yellow crystalline solid was obtained which was dried under vacuum overnight. The product was purified by sublimation as white crystalline solid. Yield = 568 mg (96%). $^1$H NMR (400 MHz, CDCl$_3$); 8.27 (dd, J$^{dd}$ = 0.5, 2.5 Hz, 1 H), 7.67 (dd, J$^{dd}$ = 0.5, 9.0 Hz, 1 H), 7.55 (dd, J$^{dd}$ = 2.5, 9.0 Hz, 1 H), 3.89 - 3.83 (m, 2 H), 3.42 (t, J$^t$ = 6.0 Hz, 2 H), 3.32 - 3.27 (m, 4 H), 2.04 (quint., J$^{q}$ = 6.0 Hz, 2 H), 1.90 (quint., J$^{q}$ = 6.0 Hz, 2 H) ppm. $^{13}$C NMR (100 MHz, CDCl$_3$); 154.9, 149.3, 147.3, 137.9, 119.7, 111.4, 48.5, 48.3, 43.6, 43.3, 23.3, 22.4 ppm. HRMS (ESI), m/z: 295.05554 [M+H$^+$]$^+$ (C$_{12}$H$_{16}$BrN$_4$ requires 295.05529). Anal. Calc. for C$_{12}$H$_{15}$N$_4$Br: C, 48.83; N, 18.98; H, 5.12; found: C, 48.83; N, 18.79; H, 5.14.

**Compound 6: 1-(6-chloropyrimidin-4-yl)-2,3,4,6,7,8-hexahydro-1H-pyrimido[1,2-a]pyrimidine**

A 25 mL microwave tube was charged with 4,6-dichloropyrimidine (152 mg, 1 mmol) and 1,3,4,6,7,8-hexahydro-2H-pyrimido[1,2-a]pyrimidine (282 mg, 2 mmol). To this mixture was added toluene (15 mL). The tube was placed in a 400 MW microwave reactor and heated at 160 °C for 2 h. After the completion of the reaction, the solvent was decanted out and evaporated to dryness under reduced pressure. The product was purified by overnight sublimation at 1.8 mbar and 100 °C followed by recrystallisation by slow diffusion of hexane in chloroform. The product was obtained as pale yellow micro-crystalline solid. Yield = 652 mg (92%). $^1$H NMR (CDCl$_3$, 400 MHz); 8.51 (d, J$^d$ = 0.9 Hz, 1 H), 7.93 (d, J$^d$ = 0.9 Hz, 1 H), 4.02 (t, J$^t$ = 6.0 Hz, 2 H), 3.51 (t, J$^t$ = 6.0 Hz, 2 H), 3.27 (t, J$^t$ = 6.0 Hz, 2 H), 3.18 (t, J$^t$ = 6.0 Hz, 2 H), 2.01 (quint., J$^{q}$ = 6.0 Hz, 2 H), 1.92 (quint., J$^{q}$ = 6.0 Hz, 2 H) ppm. $^{13}$C NMR (CDCl$_3$, 100 MHz) 161.5, 159.3, 157.7, 147.9, 110.3, 48.64, 48.61, 43.8, 42.6, 23.6, 22.3 ppm. HRMS (ESI), m/z: 252.10105 [M+H$^+$]$^+$ (C$_{11}$H$_{15}$N$_5$Cl$_2$ requires 252.10158); m/z: 254.09860 [M+H$^+$]$^+$ (C$_{11}$H$_{13}$N$_3$Cl$_3$ requires 254.10158).
Compound 14: 2,6-bis(N,N-2,3,4,6,7,8-hexahydro-pyrimido[1,2-a]pyrimido)pyridine

(±) BINAP (0.06 mmol, 38 mg) was placed in an oven-dried round bottomed flask purged with nitrogen which was sealed with a septum. Dry toluene (3 mL) was added via syringe. The resulting suspension was heated at 90 °C for 2 min to dissolve the BINAP. This was cooled to room temperature and Pd(OAc)$_2$ (0.04 mmol, 9 mg) was added and stirred for 3 min. To the resulting bright yellow solution, 2,6-dibromopyrimidine (2 mmol, 474 mg) and 1,3,4,6,7,8-hexahydro-2H-pyrimido[1,2-a]pyrimidine (4.3 mmol, 600 mg) were added. Stirring for 5 min at ambient temperature resulted in a pale orange slurry to which was added KOr-Bu (5.6 mmol, 640 mg). The reaction mixture was then stirred at 90 °C for 3.5 h, was cooled to room temperature and diethyl ether (60 mL) was added and the mixture was filtered. Evaporation of the filtrate afforded the ligand as crystalline pale yellow solid. Single crystals suitable for X-ray crystallography were grown by slow evaporation of a diethyl ether solution of the compound. Yield = 563 mg (80 %). $^1$H NMR (CDCl$_3$, 400 MHz); 7.34 (t, $J$ = 8 Hz, 2 H), 7.11 (d, $J$ = 8 Hz, 2 H), 3.83 (t, $J$ = 6 Hz, 4 H), 3.40 (t, $J$ = 6 Hz, 4 H), 3.14 (t, $J$ = 6 Hz, 4 H), 1.95 (quint., $J$ = 6 Hz, 4 H), 1.86 (quint., $J$ = 6 Hz, 4 H) ppm. $^{13}$C NMR (CDCl$_3$, 100 MHz); 154.5, 150.2, 136.6, 110.4, 48.8, 48.6, 43.9, 43.6, 23.7, 22.8 ppm. HRMS (ESI), m/z: 117.62399 [M+2H]$^{2+}$ (C$_{10}$H$_{18}$N$_2$ requires 177.62367), 354.24006 [M+H$^+$] (C$_{10}$H$_{18}$N$_2$ requires 354.24007), 376.22216 [M+Na$^+$] (C$_{10}$H$_{17}$N$_2$Na requires 376.22201). Anal. Calc. for C$_{10}$H$_{18}$N$_2$ + 1 H$_2$O: C, 61.43; H, 7.87; N, 26.39. Found: C, 61.57; H, 7.95; N, 26.53.

Compound 15: 2,6-bis(N,N-2,3,4,6,7,8-hexahydro-pyrimido[1,2-a]pyrimido)pyrazine

(±) BINAP (0.09 mmol, 60 mg) was placed in an oven-dried, nitrogen-purged round-bottomed flask that was sealed with a septum. Dry toluene (3 mL) was added via syringe. The resulting suspension was heated at 90 °C for 2 min to dissolve the BINAP. This was cooled to room temperature and Pd(OAc)$_2$ (0.06 mmol, 14 mg) was added and stirred for 3 min. To the resulting bright yellow solution, 2,6-dichloropyrazine (3.2 mmol, 479 mg) and 1,3,4,6,7,8-hexahydro-2H-pyrimido[1,2-a]pyrimidine (6.9 mmol, 962 mg) were added. Stirring for 5 min at ambient temperature resulted in a pale orange slurry to which was added KOr-Bu (9.0 mmol, 1.01 g). The reaction mixture was then stirred at 90 °C for 16 h, was cooled to room temperature and diethyl ether (60 mL) was added and the mixture was filtered. Evaporation of the filtrate followed by purification by column chromatography on deactivated alumina using 3:2 (DCM:MeOH, v/v) afforded the ligand as crystalline pale yellow solid. Yield = 736 mg (65 %). $^1$H NMR (DMSO-$d_6$, 400 MHz); 8.38 (s, 2 H), 3.70 (t, $J$ = 6 Hz, 4 H), 3.25 (t, $J$ = 6 Hz, 4 H), 3.19 (t, $J$ = 6 Hz, 4 H), 3.15 (t, $J$ = 6 Hz, 4 H), 1.94 (quint., $J$ = 6 Hz, 4 H), 1.77 (quint., $J$ = 6 Hz, 4 H) ppm. $^{13}$C NMR (DMSO-$d_6$, 100 MHz); 149.6, 147.9, 130.7, 47.9, 47.6, 43.1, 42.5, 22.8, 22.1 ppm. HRMS (ESI), m/z: 355.23526 [M+H$^+$] (C$_{17}$H$_{20}$N$_8$ requires 355.23532; Δppm -0.17), 178.1234 (M+2H$^+$) (C$_{17}$H$_{18}$N$_8$ requires 178.12310; Δppm 0.23). Anal. Calc. for C$_{17}$H$_{18}$N$_8$: C, 69.09; H, 7.39; N, 31.61. Found: C, 69.09; H, 7.42; N, 31.58.

Compound 16: 4,6-bis(N,N-2,3,4,6,7,8-hexahydro-pyrimido[1,2-a]pyrimido)pyrimidine

4,6-Dichloropyrimidine (2 mmol, 0.307 g) and 1,3,4,6,7,8-hexahydro-2H-pyrimido[1,2-a]pyrimidine (H-hpp) (4 eq, 8 mmol, 1.126 g) were combined in toluene (20 mL) in a microwave vial. The tube was sealed and placed in a Biotage 400 MW microwave reactor. The suspension was heated to 160 °C for 2 hours, after which time the solution was slowly decanted out and evaporated to dryness. The
crude product could be purified by overnight sublimation at 1.8 mbar and 100 °C, as colourless crystals. Yield = 638 mg (90%). $^1$H-NMR: (400 MHz, CDCl$_3$) δ ppm 8.43 (s, 1 H$_1$), 8.21 (s, 1 H$_3$), 3.96 (t, $J = 6$ Hz, 4 H$_4$), 3.46 (t, $J = 6$ Hz, 4 H$_6$), 3.22 (t, $J = 6$ Hz, 4 H$_7$), 3.14 (t, $J = 6$ Hz, 4 H$_8$), 1.97 (quint, $J''$ = 6 Hz, 4 H$_5$), 1.89 (quint, $J''''$ = 6 Hz, 4 H$_8$). $^{13}$C-NMR: (100 MHz, CDCl$_3$) δ ppm 160.9 (C$_2$), 156.7 (C$_1$), 148.9 (C$_3$), 98.9 (C$_{16}$), 48.7 (C$_7$), 48.7 (C$_8$), 43.9 (C$_9$), 42.4 (C$_{14}$), 23.8 (C$_8$), 22.6 (C$_3$). HRMS (ESI), m/z: 355.23635 [M+H$^+$]$^+$ (C$_{10}$H$_{27}$N$_8$ requires 355.23532). Anal. Calc. for C$_{10}$H$_{27}$N$_8$: C: 60.99; N: 31.61; H: 7.39. Found: C: 60.75; N: 31.70; H: 7.35.