Supporting Information

Pd/Xiang-Phos-Catalyzed Enantioselective Intermolecular Carboheterofunctionalizations Under Mild Conditions

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1. General Information

Unless otherwise noted, all reactions were carried out under a nitrogen atmosphere; materials obtained from commercial suppliers were used directly without further purification. The \([\alpha]_D\) was recorded using PolAAr 3005 High Accuracy Polarimeter. \(^1\)H NMR spectra and \(^{13}\)C NMR spectra were recorded on a Bruker 400 MHz or 500 MHz spectrometer in chloroform-d$_3$, and were calibrated with CDCl$_3$ (\(\delta = 77.00\) ppm). \(^{19}\)F NMR spectra were recorded on a Bruker 400 MHz spectrometer in chloroform-d$_3$. Chemical shifts (in ppm) were referenced to tetramethylsilane (\(\delta = 0\) ppm) in CDCl$_3$ as an internal standard. The data is being reported as (s = singlet, d = doublet, dd = doublet of doublet, t = triplet, m = multiplet or unresolved, br = broad signal, coupling constant(s) in Hz, integration).

Trichloromethane (CHCl$_3$), dichloromethane, dichloroethane and acetonitrile were freshly distilled from CaH$_2$; tetrahydrofuran (THF), toluene and ether were dried with sodium benzophenone and distilled before use.

Reactions were monitored by thin layer chromatography (TLC) using silicycle pre-coated silica gel plates. Flash column chromatography was performed on silica gel 60 (particle size 200-400 mesh ASTM, purchased from Yantai, China) and eluted with petroleum ether/ethyl acetate. All reagents and solvents were used as received from commercial sources (Energy Chemical, J&K®, Adamas-beta®, Bidepharm) without further purification. The substrates 2b-f were synthesized according to published procedures\(^1\). The spectral data of the substrates were consisted with that reported in the literature\(^2\). The enantiomeric excesses of the products were determined by chiral stationary phase HPLC using a Chiralpak IA, IB, IC, IF, ADH, ODH, OJH, OJ3.
2. Optimization of the intermolecular carboheterofunctionalizations

2.1 Table S1. Detailed optimization of the enantioselective intermolecular carboamination of 2,3-dihydrofuran and 1a

| Entry | Pd          | L* | Base    | Solvent | Temp. (°C) | Yield (Ee) (%) | r.r. [d] |
|-------|-------------|----|---------|---------|------------|----------------|---------|
| 1     | Pd2(dba)3  | L3 | CH3ONa  | DCM     | 100        | 81(48)        | 13:2    |
| 2     | Pd2(dba)3  | L3 | NaO'Bu  | DCM     | 100        | 73(47.3)      | 5:1     |
| 3     | Pd2(dba)3  | L3 | LiO'Bu  | DCM     | 100        | trace-        | -       |
| 4     | Pd2(dba)3  | L3 | KO'Bu   | DCM     | 100        | mix-          | -       |
| 5     | Pd2(dba)3  | L3 | NaOEt   | DCM     | 100        | 52(40.3)      | 2:1     |
| 6     | Pd2(dba)3  | L3 | NaOPh   | DCM     | 100        | 63(77.5)      | 2:1     |
| 7     | Pd2(dba)3  | L3 | Cs2CO3  | DCM     | 100        | mix-          | -       |
| 8     | Pd2(dba)3  | L3 | NaOPh   | MTBE    | 100        | 44(60)        | 1:1     |
| 9     | Pd2(dba)3  | L3 | NaOPh   | THF     | 100        | 41(23)        | 1:2     |
| 10    | Pd2(dba)3  | L3 | NaOPh   | 1,2-DCE | 100        | 81(76)        | 9:1     |
| 11    | Pd2(dba)3  | L3 | NaOPh   | CHCl3   | 100        | mix-          | -       |
| 12    | Pd2(dba)3  | L3 | NaOPh   | Toluene | 100        | 42(53)        | 1:1     |
| 13    | Pd2(dba)3  | L3 | NaOPh   | MeOH    | 100        | 39(59)        | 1:1     |
| 14    | Pd2(dba)3  | L3 | NaOPh   | MeCN    | 100        | mix-          | -       |
| 15    | Pd2(dba)3  | L3 | NaOPh   | DMF     | 100        | 69(0)         | 6:1     |
| 16    | Pd2(dba)3  | L4 | NaOPh   | 1,2-DCE | 100        | 78(87)        | 9:1     |
| 17    | Pd2(dba)3  | L5 | NaOPh   | 1,2-DCE | 100        | 81(93.1)      | >30:1   |
| 18    | Pd2(dba)3  | L6 | NaOPh   | 1,2-DCE | 100        | trace-        | -       |
| 19    | Pd2(dba)3  | L7 | NaOPh   | 1,2-DCE | 100        | 77(77)        | 15:1    |
| 20    | Pd2(dba)3  | L8 | NaOPh   | 1,2-DCE | 100        | 83(93)        | >30:1   |
| 21    | Pd2(dba)3  | L8 | NaOPh   | 1,2-DCE | 100        | 79(93.7)      | >30:1   |
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|   | Reaction Conditions                                                                 | Yield (%) | Ratio       |
|---|-------------------------------------------------------------------------------------|-----------|-------------|
| 22| Pd$_2$(dbat)$_3$•CHCl$_3$ L8 NaOPh 1,2-DCE 100                                      | 81(93.9)  | >30:1       |
| 23| Pd(OAc)$_2$ L8 NaOPh 1,2-DCE 100                                                    | 74(94.1)  | >30:1       |
| 24| $(\eta^3$-C$_3$H$_5)_2$Pd$_2$Cl$_2$ L8 NaOPh 1,2-DCE 100                           | 69(93.7)  | >30:1       |
| 25| Pd A L8 NaOPh 1,2-DCE 100                                                          | 82(94.1)  | >30:1       |
| 26| Pd B L8 NaOPh 1,2-DCE 100                                                          | 74(86.9)  | >30:1       |
| 27| Pd C L8 NaOPh 1,2-DCE 100                                                          | N.D.      |             |
| 28| Pd D L8 NaOPh 1,2-DCE 100                                                          | 77(81.3)  | >30:1       |
| 29| Pd E L8 NaOPh 1,2-DCE 100                                                          | trace     | -           |
| 30| Pd A L8 NaOPh 1,2-DCE 80                                                           | 81(93.1)  | >30:1       |
| 31| Pd A L8 NaOPh 1,2-DCE 50                                                            | 81(95.3)  | >30:1       |
| 32| Pd A L8 NaOPh 1,2-DCE 20                                                            | 84(95.5)  | >30:1       |
| 33| Pd A L8 NaOPh 1,2-DCE 20                                                            | 73(91.6)  | >30:1       |
| 34| Pd A L8 NaOPh 1,2-DCE 20                                                            | 77(93.8)  | >30:1       |
| 35| Pd A L8 NaOPh 1,2-DCE 20                                                            | 81(95.3)  | >30:1       |
| 36| Pd A L8 NaOPh 1,2-DCE 20                                                            | 79(94.9)  | >30:1       |
| 37| Pd A L8 NaOPh 1,2-DCE 20                                                            | 79(95.7)  | >30:1       |

[a] Unless otherwise specified, all reactions were carried out with 1a (0.2 mmol), 2a (0.8 mmol, 4 eq), [Pd] source (0.01 mmol, 5 mol%), N-Me-Xiang-Phos (0.024 mmol, 12 mol%), Base (0.8 mmol, 4 eq), H$_2$O (7.2 μL, 2 eq) in solvent (1 mL, 0.2 M). [b] Yield of isolated product. [c] Determined by chiral HPLC. [d] Reaction r.r.s of 3a:4a, determined by chiral HPLC. [e] 2.5 mol% Pd A, 6 mol% L8 were employed. [f] 2 eq NaOPh and 1 eq H$_2$O were employed. [g] 1 eq H$_2$O were employed. [h] 50 mol% H$_2$O were employed. [i] 2 eq H$_2$O was removed.
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2.2 Table S2. Detailed optimization of the enantioselective intermolecular carbo-etherification of 2,3-dihydrofuran and 5a[a]

![Chemical Structures](image)

| Entry | Pd           | L*   | Base      | Solvent | Temp. (°C) | Yield (Ee) (%) |
|-------|--------------|------|-----------|---------|------------|----------------|
| 1     | Pd2(dba)3    | L3   | NaO'Bu    | Toluene | 80         | 40(87.1)      |
| 2     | Pd2(dba)3    | L3   | NaOPh     | Toluene | 80         | 30(37.9)      |
| 3     | Pd2(dba)3    | L3   | CH3ONa    | Toluene | 80         | trace         |
| 4     | Pd2(dba)3    | L3   | CH3OLi    | Toluene | 80         | trace         |
| 5     | Pd2(dba)3    | L3   | LiO'Bu    | Toluene | 80         | trace         |
| 6     | Pd2(dba)3    | L3   | KO'Bu     | Toluene | 80         | mix           |
| 7     | Pd2(dba)3    | L3   | Cs2CO3    | Toluene | 80         | mix           |
| 8[a]  | Pd2(dba)3    | L3   | NaO'Bu    | THF     | 80         | 30(74.5)      |
| 9[a]  | Pd2(dba)3    | L3   | NaO'Bu    | MTBE    | 80         | 34(67.1)      |
| 10[a] | Pd2(dba)3    | L3   | NaO'Bu    | DCM     | 80         | 45(32.5)      |
| 11[a] | Pd2(dba)3    | L3   | NaO'Bu    | 1,2-DCE | 80         | 39(20.3)      |
| 12[a] | Pd2(dba)3    | L3   | NaO'Bu    | Toluene | 80         | 40(71.5)      |
| 13    | Pd2(dba)3    | L3   | NaO'Bu    | Toluene | 20         | 55(95.3)      |
| 14    | Pd2(dba)3    | L3   | NaO'Bu    | THF     | 20         | 30(97)        |
| 15    | Pd2(dba)3    | L3   | NaO'Bu    | Toluene | 20         | 23(94.3)      |
| 16    | Pd2(dba)3•CHCl3 | L3     | NaO'Bu    | Toluene | 20         | 38(96.5)      |
| 17    | Pd(OAc)2    | L3   | NaO'Bu    | Toluene | 20         | 49(91.5)      |
| 18    | (η3-C3H5)2Pd2Cl2 | L3       | NaO'Bu    | Toluene | 20         | 53(94.3)      |
| 19    | Pd A         | L3   | NaO'Bu    | Toluene | 20         | 51(94.7)      |
| 20    | Pd B         | L3   | NaO'Bu    | Toluene | 20         | 42(83.1)      |
| 21    | Pd C         | L3   | NaO'Bu    | Toluene | 20         | trace         |
| 22    | Pd D         | L3   | NaO'Bu    | Toluene | 20         | 33(77.2)      |
| 23    | Pd E         | L3   | NaO'Bu    | Toluene | 20         | mix           |
| 24    | Pd2(dba)3    | L4   | NaO'Bu    | Toluene | 20         | 49(94.3)      |
### Supporting Information

|   | Reagent     | Ligand | Base    | Solvent | Temp | Yield (%) |
|---|-------------|--------|---------|---------|------|-----------|
| 25 | Pd$_2$(dba)$_3$ | L5     | NaO' Bu | Toluene | 20   | 44(85)    |
| 26 | Pd$_2$(dba)$_3$ | L6     | NaO' Bu | Toluene | 20   | trace     |
| 27 | Pd$_2$(dba)$_3$ | L7     | NaO' Bu | Toluene | 20   | 60(96.3)  |
| 28 | Pd$_2$(dba)$_3$ | L8     | NaO' Bu | Toluene | 20   | 52(81.9)  |
| 29[e] | Pd$_2$(dba)$_3$ | L7     | NaO' Bu | Toluene | 20   | 21(91.1)  |
| 30[f] | Pd$_2$(dba)$_3$ | L7     | NaO' Bu | Toluene | 20   | 35(94.5)  |

[a] Unless otherwise specified, all reactions were carried out with 5a (0.2 mmol), 2a (1 mmol, 5 eq), [Pd] source (0.005 mmol, 2.5 mol%), N-Me-Xiang-Phos (0.01 mmol, 5 mol%), Base (0.4 mmol, 2 eq), H$_2$O (3.6 μL, 1 eq) in solvent (1 mL, 0.2 M). [b] Yield of isolated product. [c] Determined by chiral HPLC. [d] Pd$_2$(dba)$_3$ was added to 5 mol%, also L3 was added to 10 mol%. [e] 1 eq H$_2$O was removed. [f] 4 eq NaO' Bu and 1 eq H$_2$O were employed.
3. Experimental procedures

3.1 General procedure for the synthesis of \((S, R_S)-N-\text{Me-X4/X5}\).

To a solution of di-1-adamantylphosphine borane (5 mmol) in dry THF (25 mL) was added \(^{n}\text{BuLi}\) (1.2 eq, 1.6 M in hexane) dropwise under argon at -78 °C. The resulting solution at this temperature during 1 hour and 1,2-dibromo compound (5 mmol) was added dropwise followed by \(^{n}\text{BuLi}\) (1.2 eq, 1.6 M in hexane). After 10 minutes at -78 °C, \((R_S)\)-sulfinyl imine (6 mmol) was added and the reaction mixture was warmed to room temperature overnight. The reaction mixture was quenched by the addition of \(\text{NH}_4\text{Cl}\) (aq.) and diluted with EtOAc. The organic layer was separated, and the aqueous layer was extracted twice with EtOAc. The combined organic layers were dried over \(\text{Na}_2\text{SO}_4\), filtered, concentrated. The crude product was dealed with \(\text{Et}_2\text{NH}\) (15 mL) and the resulting solution was stirred under argon at 55 °C. After the reaction was complete (monitored by TLC), solvent was removed under reduced pressure. The crude product was then purified by flash column chromatography on silica gel (Petroleum ether : EtOAc = 10:1) to afford the desired Xiang-Phos.

To a solution of Xiang-Phos (2 mmol) in dry THF (5 mL) was added \(^{n}\text{BuLi}\) (1.5 eq, 1.6 M in hexane) dropwise under argon at -30 °C. The resulting solution was stillled at this temperature for 1 hour and then MeI (2 eq) was added dropwise at -50 °C. The resulting solution was stillled at this temperature for 1.5 hours and then stillled at 0 °C for another 1.5 hours. The reaction mixture was quenched by the addition of \(\text{NH}_4\text{Cl}\) (aq.) and diluted with EtOAc. The organic layer was separated, and the aqueous layer was extracted twice with EtOAc. The combined organic layers were dried over Na\(_2\)SO\(_4\), filtered, concentrated. The crude product was then purified by flash column chromatography on silica gel (Petroleum ether: EtOAc = 10:1) to afford the desired N-Me-Xiang-Phos.
3.2 General procedure for the intermolecular carboamination of 2,3-dihydrofuran using 2-bromoaniline derivatives (GP1)

To a sealed tube was added Pd A (5 mol%), N-Me-X5 (12 mol%). The flask was evacuated and refilled with argon. Then 2-Br-anilines 1 (0.2 mmol) and dry 1,2-DCE (1 mL) were added to the tube. NaOPh (4 eq) and H2O (2 eq) were subsequently added under a flow of argon, followed by 2a (4 eq). The mixture was stirred at 20 or 60 °C for 12-36 h. After the reaction was complete (monitored by TLC), solvent was removed under reduced pressure. The crude product was then purified by flash column chromatography on silica gel using hexane/EtOAc as the eluent to afford the desired product 3.

3.3 General procedure for the intermolecular carboetherification of 2,3-dihydrofuran using 2-bromophenol derivatives (GP2)

To a sealed tube was added Pd2(dba)3 (2.5 mmol%), N-Me-X4 (5 mol%). The flask was evacuated and refilled with argon. Then 2-Br-phenols 5 (0.3 mmol) and dry toluene (1.5 mL) were added to the tube. NaO'Bu (2 eq) and H2O (1 eq) were subsequently added under a flow of argon, followed by 2a (5 eq). The mixture was stirred at 20 or 50 °C for 24-48 h. After the reaction was complete (monitored by TLC), solvent was removed under reduced pressure. The crude product was then purified by flash column chromatography on silica gel using hexane/Et2O as the eluent to afford the desired product 6.
3.4 General procedure for the synthesis of 2-substituted-2,3-dihydrofurans (GP3)\textsuperscript{1}

\[
\begin{align*}
\text{O} & \quad \text{Br} \\
(5 \text{ eq}) & \quad \text{R} \\
\text{Pd}_2(\text{dba})_3 (2.5 \text{ mol\%}) & \quad \text{CPhos (5 mol\%)} \\
\text{DIPEA (3 eq)} & \quad 1,4\text{-dioxane (0.4 M)} \\
110 \ ^\circ \text{C}, 36 \text{ h} & \\
\end{align*}
\]

In a glovebox, a 50 mL Young valve Schlenk was charged with Pd\textsubscript{2}(dba\textsubscript{3}) (126 mg, 0.138 mmol, 2.5 mol\%), CPhos (120 mg, 0.275 mmol, 5 mol\%) and distilled and degassed 1,4-dioxane (10 mL). The Schlenk was taken outside the glovebox, connected to a two-manifold line and the mixture was stirred at room temperature for 10 minutes. Next, the corresponding aryl bromide (5.5 mmol, 1 equiv.), DIPEA (2.8 mL, 16.5 mmol, 3.0 equiv.) and 2,3-dihydrofuran (2.0 mL, 27.5 mmol, 5 equiv.) were added consecutively under a flow of N\textsubscript{2} gas. The sealed reaction tube was immerge in an oil bath pre-heated at 110 \ ^\circ \text{C} for 36 h. After cooling to room temperature, the reaction mixture was poured into Et\textsubscript{2}O (20 mL) under vigorous stirring and the resulting precipitate was removed passing the suspension through a short pad of Celite. The volatiles were evaporated and the resulting oil was directly subjected to flash chromatography (Pentane/Et\textsubscript{2}O).
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4. General Data for (S, R)-N-Me-X4/X5, 3 and 6

(R)-N-((S)-(3-(di((1S,3R,5S,7S)-adamantan-1-yl)phosphanyl)-5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalen-2-yl)(phenyl)methyl)-N,2-dimethylpropane-2-sulfinamide

(S, R)-N-Me-X4; colorless solid (hexane/EtOAc/DCM = 3:1:1, 38% overall yield); m.p. = 227-229 °C; [α]₀²⁰ = 85.438 (c = 0.375, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 7.77 (d, J = 4.5 Hz, 1H), 7.60 (d, J = 2.1 Hz, 1H), 7.21 – 7.18 (m, 2H), 7.14 – 7.11 (m, 3H), 6.88 (d, J = 9.7 Hz, 1H), 2.58 (s, 3H), 1.98 (d, J = 11.9 Hz, 3H), 1.90 (s, 3H), 1.85 (d, J = 11.8 Hz, 3H), 1.73 (d, J = 2.8 Hz, 3H), 1.68 (d, J = 15.2 Hz, 10H), 1.50 (s, 6H), 1.44 (s, 6H), 1.39 (d, J = 19.3 Hz, 6H), 1.32 (s, 6H), 1.05 (s, 9H). ¹³C NMR (126 MHz, CDCl₃) δ 145.69, 144.40 (d, J = 23.8 Hz), 141.43, 139.89, 135.50 (d, J = 2.6 Hz), 131.89, 129.09 (d, J = 25.4 Hz), 127.43, 126.80, 125.72 (d, J = 5.8 Hz), 70.94 (d, J = 33.3 Hz), 58.56, 41.83, 41.76 (dd, J = 12.6, 7.1 Hz), 41.68, 37.65, 37.47, 37.00, 36.82, 36.62, 36.44, 35.06 (d, J = 5.5 Hz), 34.34, 33.96, 31.83 (dd, J = 24.9, 15.2 Hz), 30.41, 28.80 (dd, J = 8.7, 6.1 Hz), 24.22. ³¹P NMR (202 MHz, CDCl₃) δ 15.94. HRMS (ESI) m/z calcd. For C₄₆H₆₇NOP[S+M+H] = 712.4675, found = 712.4666; IR spectrum (neat) (cm⁻¹) = 2980, 2909, 2359, 1198, 1167, 1086, 961, 949, 928, 880, 733, 669.

(R)-N-((S)-(3-(di((1S,3R,5S,7S)-adamantan-1-yl)phosphanyl)-5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalen-2-yl)(3,5-di-tert-butyl-4-methoxyphenyl)methyl)-N,2-dimethylpropane-2-sulfinamide

(S, R)-N-Me-X5; colorless solid (hexane/EtOAc/DCM = 3:1:1, 31% overall yield); m.p. = 159-161 °C; [α]₀²⁰ = 96.185 (c = 0.375, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 7.81 (d, J = 4.5 Hz, 1H), 7.60 (d, J = 2.1 Hz, 1H), 6.97 (s, 2H), 6.75 (d, J = 9.9 Hz, 1H), 3.57 (s, 3H), 2.59 (s, 3H), 1.99 (d, J = 11.9 Hz, 3H), 1.90 – 1.85 (m, 6H), 1.76 – 1.71 (m, 4H), 1.69 – 1.64 (m, 6H), 1.52 – 1.46 (m, 7H), 1.43 – 1.40 (m, 12H), 1.32 – 1.29 (m, 26H), 1.00 (s, 9H). ¹³C NMR (126 MHz, CDCl₃) δ 158.23, 145.62, 144.58 (d, J = 23.9 Hz), 141.86, 141.19, 135.45 (d, J = 2.5 Hz), 133.51, 130.90, 129.12 (d, J = 25.4 Hz), 125.12 (d, J = 5.8 Hz), 71.12 (d, J = 34.4 Hz), 64.23, 58.40, 41.68 (dd, J = 12.8, 7.5 Hz), 37.51 (d, J = 23.3 Hz), 36.94 (d, J
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= 22.0 Hz), 36.55 (d, J = 24.1 Hz), 35.57, 35.12, 34.41, 33.94, 32.45, 32.07, 32.02, 31.62, 31.42, 30.73, 28.82 (dd, J = 8.6, 6.9 Hz), 24.15. $^{31}$P NMR (202 MHz, CDCl$_3$) δ 15.24. HRMS (ESI) m/z calcd. For C$_{55}$H$_{85}$NO$_2$PS [M+H]$^+$ = 854.6033, found = 854.6048; IR spectrum (neat) (cm$^{-1}$) = 2895, 1450, 1362, 1250, 1198, 1167, 1088, 961, 930, 880, 777, 733.

(3aR,8aR)-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole

![Structure](image)

3aa; colorless solid (hexane/EtOAc = 8:1, 84% isolated yield); m.p. = 97-98 °C; [α]$_D^{20}$ = 24.960 (c = 0.625, CHCl$_3$); $^1$H NMR (500 MHz, CDCl$_3$) δ 7.86 (d, J = 8.3 Hz, 2H), 7.36 (d, J = 8.1 Hz, 1H), 7.24 (d, J = 8.2 Hz, 2H), 7.18 – 7.12 (m, 2H), 6.98 (t, J = 7.5 Hz, 1H), 6.26 (d, J = 6.6 Hz, 1H), 3.97 (t, J = 8.0 Hz, 1H), 3.90 (t, J = 7.5 Hz, 1H), 3.33 – 3.28 (m, 1H), 2.37 (s, 3H), 2.33 – 2.25 (m, 1H), 2.01 (dd, J = 12.2, 4.7 Hz, 1H). $^{13}$C NMR (126 MHz, CDCl$_3$) δ 143.82, 141.43, 136.46, 131.32, 129.50, 128.30, 127.32, 124.83, 123.48, 112.74, 95.71, 66.35, 45.45, 33.62, 21.44. Enantiomeric excess: 96%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 80/20; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: t$_R$ = 20.2 min, second peak: t$_R$ = 28.4 min; HRMS (ESI) m/z calcd. for C$_{17}$H$_{17}$NNaO$_3$S [M+Na]$^+$ = 338.0821, found = 338.0820; IR spectrum (neat) (cm$^{-1}$) = 2878, 1481, 1460, 1354, 1169, 1091, 949, 881, 752, 663.

(3aR,8aR)-5-fluoro-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole

![Structure](image)

3ba; colorless solid (hexane/EtOAc = 8:1, 97% isolated yield); m.p. = 68-70 °C; [α]$_D^{20}$ = 34.672 (c = 0.55, CHCl$_3$); $^1$H NMR (500 MHz, CDCl$_3$) δ 7.81 (d, J = 8.3 Hz, 2H), 7.33 (dd, J = 8.8, 4.4 Hz, 1H), 7.25 (d, J = 8.1 Hz, 2H), 6.89 – 6.83 (m, 2H), 6.24 (d, J = 6.6 Hz, 1H), 3.98 (dd, J = 12.1, 4.2 Hz, 1H), 3.86 (t, J =
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= 7.6 Hz, 1H), 3.35 – 3.30 (m, 1H), 2.38 (s, 3H), 2.33 – 2.25 (m, 1H), 1.99 (dd, J = 12.3, 4.7 Hz, 1H). \(^{13}\)C NMR (126 MHz, CDCl\(_3\)) \(\delta\) 160.47, 158.55, 144.03, 137.51 (d, J = 2.0 Hz), 136.10, 133.41 (d, J = 8.1 Hz), 129.59, 127.25, 114.87 (d, J = 23.4 Hz), 113.89 (d, J = 8.3 Hz), 112.05 (d, J = 24.1 Hz), 96.22, 66.36, 45.47 (d, J = 1.7 Hz), 33.45, 21.46. \(^{19}\)F NMR (376 MHz, CDCl\(_3\)) \(\delta\) -119.61. Enantiomeric excess: 87%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: \(t_R\) = 19.0 min, second peak: \(t_R\) = 29.5 min; HRMS (ESI) m/z calcd. for C\(_{17}\)H\(_{16}\)FNNaO\(_3\)S [M+Na\(^+\)] = 356.0727, found = 356.0721; IR spectrum (neat) (cm\(^{-1}\)) = 2884, 1356, 1167, 1092, 961, 883, 814, 710, 669, 598.

\((3aR,8aR)-5\)-chloro-8-tosyl-3,3a,8a-tetrahydro-2H-furo[2,3-b]indole

\(3ca\); colorless solid (hexane/EtOAc = 8:1, 94% isolated yield); m.p. = 90-91 °C; \([\alpha]_D^{20}\) = 35.818 (c = 0.55, CHCl\(_3\)); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta\) 7.83 (d, J = 8.3 Hz, 2H), 7.31 (d, J = 8.6 Hz, 1H), 7.27 – 7.25 (m, 2H), 7.13 (dd, J = 8.6, 1.9 Hz, 1H), 7.10 (s, 1H), 6.25 (d, J = 6.6 Hz, 1H), 3.98 (t, J = 8.0 Hz, 1H), 3.89 – 3.86 (m, 1H), 3.33 – 3.28 (m, 1H), 2.38 (s, 3H), 2.33 – 2.25 (m, 1H), 2.00 (dd, J = 12.3, 4.7 Hz, 1H). \(^{13}\)C NMR (126 MHz, CDCl\(_3\)) \(\delta\) 144.12, 140.17, 136.11, 133.32, 129.61, 128.32, 127.28, 125.04, 113.76, 96.05, 66.37, 45.32, 33.47, 21.47. Enantiomeric excess: 87%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 80/20; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: \(t_R\) = 26.5 min, second peak: \(t_R\) = 31.9 min; HRMS (ESI) m/z calcd. for C\(_{17}\)H\(_{16}\)ClNNaO\(_3\)S [M+Na\(^+\)] = 372.0432, found = 372.0423; IR spectrum (neat) (cm\(^{-1}\)) = 2884, 1356, 1167, 1090, 961, 930, 881, 814, 710, 669, 590.
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(3aR,8aR)-5-methyl-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole

3da; amorphous colorless solid (hexane/EtOAc = 8:1, 95% isolated yield); m.p. = 53-54 °C; [α]D20 = 49.781 (c = 0.55, CHCl3); 1H NMR (500 MHz, CDCl3) δ 7.83 (d, J = 8.3 Hz, 2H), 7.27 (d, J = 8.0 Hz, 1H), 7.23 (d, J = 8.1 Hz, 2H), 6.97 (d, J = 8.3 Hz, 1H), 6.93 (s, 1H), 6.21 (d, J = 6.6 Hz, 1H), 3.95 (t, J = 7.9 Hz, 1H), 3.84 (t, J = 7.5 Hz, 1H), 3.34 – 3.29 (m, 1H), 2.36 (s, 3H), 2.30 – 2.22 (m, 4H), 2.00 (dd, J = 12.2, 4.7 Hz, 1H). 13C NMR (126 MHz, CDCl3) δ 143.70, 139.14, 136.42, 133.21, 131.46, 129.47, 128.84, 127.27, 125.40, 112.70, 95.91, 66.37, 45.45, 33.57, 21.43, 20.77. Enantiomeric excess: 95%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: tR = 15.7 min, second peak: tR = 22.9 min; HRMS (ESI) m/z calcld. for C18H19NNaO3S [M+Na]+ = 352.0978, found = 352.0975; IR spectrum (neat) (cm⁻¹) = 2880, 1599, 1354, 1165, 1092, 991, 880, 814, 708, 662, 578.

(3aR,8aR)-5-methoxy-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole
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3ea; colorless solid (hexane/EtOAc = 5:1, 93% isolated yield); m.p. = 151-153 °C; [α]_D^{20} = 81.647 (c = 0.54, CHCl₃); ^1H NMR (500 MHz, CDCl₃) δ 7.78 (d, J = 8.2 Hz, 2H), 7.33 (d, J = 8.8 Hz, 1H), 7.22 (d, J = 8.2 Hz, 2H), 6.72 (dd, J = 8.8, 2.6 Hz, 1H), 6.68 (d, J = 2.4 Hz, 1H), 6.17 (d, J = 6.5 Hz, 1H), 3.96 (t, J = 8.1 Hz, 1H), 3.82 – 3.79 (m, 1H), 3.74 (s, 3H), 3.37 – 3.32 (m, 1H), 2.36 (s, 3H), 2.30 – 2.22 (m, 1H), 2.00 (dd, J = 12.2, 4.8 Hz, 1H). ^13C NMR (126 MHz, CDCl₃) δ 156.59, 143.73, 134.95, 133.08, 129.48, 127.19, 114.06, 113.24, 110.77, 96.15, 66.38, 55.56, 45.64, 33.46, 21.43. Enantiomeric excess: 90%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: t_R = 26.7 min, second peak: t_R = 44.4 min; HRMS (ESI) m/z calcd. for C_{18}H_{19}NNaO_{4}S [M+Na]^+ = 368.0927, found = 368.0919; IR spectrum (neat) (cm⁻¹) = 2884, 1198, 1084, 961, 928, 881, 733, 669.

(3aR,8aR)-8-tosyl-5-(trifluoromethyl)-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole

3fa; amorphous colorless solid (hexane/EtOAc = 8:1, 96% isolated yield); m.p. = 52-53 °C; [α]_D^{20} = 4.896 (c = 0.625, CHCl₃); ^1H NMR (500 MHz, CDCl₃) δ 7.89 (d, J = 8.4 Hz, 2H), 7.45 – 7.41 (m, 2H), 7.38 (s, 1H), 7.28 (d, J = 8.1 Hz, 2H), 6.35 (d, J = 6.6 Hz, 1H), 4.02 – 3.96 (m, 2H), 3.31 – 3.26 (m, 1H), 2.39 (s, 3H), 2.37 – 2.230 (m, 1H), 2.05 (dd, J = 12.4, 4.6 Hz, 1H). ^13C NMR (126 MHz, CDCl₃) δ 144.38, 136.20, 132.02, 129.70, 127.41, 126.05 (q, J = 3.9 Hz), 125.50 (q, J = 32.6 Hz), 124.08 (q, J = 271.6 Hz), 122.08 (q, J = 3.7 Hz), 112.16, 96.13, 66.38, 45.26, 33.60, 21.50. ^19F NMR (376 MHz, CDCl₃) δ -61.64. Enantiomeric excess: 94%, determined by HPLC (Chiralpak AD-H, hexane/i-PrOH = 80/20; flow rate
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0.8 ml/min; 25 °C; 254 nm), first peak: t_R = 11.2 min, second peak: t_R = 14.5 min; HRMS (ESI) m/z calcd. for C_{18}H_{16}F_{3}NNaO_{3}S [M+Na]^+ = 406.0695, found = 406.0692; IR spectrum (neat) (cm^{-1}) = 2880, 1620, 1445, 1337, 1285, 1167, 1121, 1078, 989, 961, 877, 721, 664, 596.

(3aR,8aR)-8-tosyl-5-(trifluoromethoxy)-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole

3ga: colorless solid (hexane/EtOAc = 8:1, 87% isolated yield); m.p. = 46-48 °C; [α]_D^{20} = 12.339 (c = 0.53, CHCl_3); ^1H NMR (500 MHz, CDCl_3) δ 7.86 (d, J = 8.3 Hz, 2H), 7.35 (d, J = 8.7 Hz, 1H), 7.28 (d, J = 9.1 Hz, 2H), 7.03 – 7.00 (m, 2H), 6.30 (d, J = 6.6 Hz, 1H), 4.00 (t, J = 8.0 Hz, 1H), 3.92 (t, J = 7.6 Hz, 1H), 3.35 – 3.30 (m, 1H), 2.39 (s, 3H), 2.36 – 2.28 (m, 1H), 2.01 (dd, J = 12.4, 4.7 Hz, 1H). ^13C NMR (126 MHz, CDCl_3) δ 145.11 (d, J = 1.8 Hz), 144.21, 140.14, 136.23, 133.14, 129.67, 127.36, 121.33, 120.38 (q, J = 256.8 Hz), 118.15, 113.21, 96.20, 66.37, 45.39, 33.55, 21.49. ^19F NMR (376 MHz, CDCl_3) δ -58.24. Enantiomeric excess: 87%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 80/20; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: t_R = 15.0 min, second peak: t_R = 19.6 min; HRMS (ESI) m/z calcd. for C_{18}H_{16}F_{3}NNaO_{3}S [M+Na]^+ = 422.0644, found = 422.0639; IR spectrum (neat) (cm^{-1}) = 2874, 1599, 1485, 1357, 1250, 1161, 1094, 991, 872, 814, 662, 586.
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(3aR,8aR)-6-fluoro-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole

3ha; colorless solid (hexane/EtOAc = 8:1, 75% isolated yield); m.p. = 51-53 °C; [α]D^20 = 10.2 (c = 0.5, CHCl₃); δH NMR (500 MHz, CDCl₃) δ 7.87 (d, J = 8.4 Hz, 2H), 7.27 (d, J = 9.2 Hz, 2H), 7.10 (dd, J = 9.9, 2.3 Hz, 1H), 7.06 – 7.01 (m, 1H), 6.67 (td, J = 8.6, 2.3 Hz, 1H), 6.29 (d, J = 6.6 Hz, 1H), 3.97 (t, J = 8.1 Hz, 1H), 3.87 (t, J = 7.4 Hz, 1H), 3.32 – 3.27 (m, 1H), 2.39 (s, 3H), 2.31 – 2.23 (m, 1H), 1.98 (dd, J = 12.2, 4.7 Hz, 1H). ^13C NMR (126 MHz, CDCl₃) δ 163.89, 161.94, 144.18, 142.73 (d, J = 11.9 Hz), 136.26, 129.65, 127.37, 126.69 (d, J = 2.6 Hz), 125.52 (d, J = 10.0 Hz), 110.02 (d, J = 22.9 Hz), 100.99 (d, J = 28.6 Hz), 96.59, 66.40, 44.93, 33.74, 21.50. ^19F NMR (282 MHz, CDCl₃) δ -112.53. Enantiomeric excess: 95%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: tR = 13.5 min, second peak: tR = 16.5 min; HRMS (ESI) m/z calcd. for C_{17}H_{16}FNNaO_3S [M+Na]^+ = 356.0727, found = 356.0719; IR spectrum (neat) (cm⁻¹) = 2874, 1603, 1437, 1350, 1161, 1143, 1099, 999, 864, 813, 706, 664, 583.

(3aR,8aR)-6-chloro-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole

3ia; colorless solid (hexane/EtOAc = 8:1, 67% isolated yield); m.p. = 93-94 °C; [α]D^20 = 10.782 (c = 0.46, CHCl₃); δH NMR (500 MHz, CDCl₃) δ 7.87 (d, J = 8.3 Hz, 2H), 7.37 (d, J = 1.8 Hz, 1H), 7.28 (d, J = 8.1 Hz, 2H), 7.04 (d, J = 8.0 Hz, 1H), 6.95 (dd, J = 8.0, 1.8 Hz, 1H), 6.27 (d, J = 6.6 Hz, 1H), 3.97 (t, J = 8.0 Hz, 1H), 3.89 – 3.86 (m, 1H), 3.30 – 3.25 (m, 1H), 2.40 (s, 3H), 2.32 – 2.24 (m, 1H), 1.97 (dd, J = 12.3, 4.7 Hz, 1H). ^13C NMR (126 MHz, CDCl₃) δ 144.20, 142.58, 136.25, 134.10, 129.85, 129.68, 127.36,
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125.60, 123.48, 113.05, 96.29, 66.37, 45.08, 33.63, 21.52. Enantiomeric excess: 92%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: $t_R = 13.9$ min, second peak: $t_R = 18.5$ min; HRMS (ESI) m/z calcd. for $\text{C}_{17}\text{H}_{16}\text{ClNaO}_3\text{S}$ $[\text{M}+\text{Na}]^+ = 372.0432$, found = 372.0420; IR spectrum (neat) (cm$^{-1}$) = 2874, 1418, 1356, 1169, 1092, 1078, 993, 961, 881, 665, 583.

(3aR,8aR)-6-methyl-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-$b$]indole

3ja: amorphous colorless solid (hexane/EtOAc = 8:1, 66% isolated yield); m.p. = 98-99 °C; $[\alpha]_D^{20} = 21.220$ (c = 0.5, CHCl$_3$); $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.86 (d, $J = 8.3$ Hz, 2H), 7.25 (d, $J = 9.4$ Hz, 2H), 7.20 (s, 1H), 7.00 (d, $J = 7.6$ Hz, 1H), 6.80 (d, $J = 7.6$ Hz, 1H), 6.24 (d, $J = 6.6$ Hz, 1H), 3.95 (t, $J = 8.0$ Hz, 1H), 3.85 (t, $J = 7.5$ Hz, 1H), 3.34 – 3.28 (m, 1H), 2.38 (s, 3H), 2.31 (s, 3H), 2.28 – 2.23 (m, 1H), 1.98 (dd, $J = 12.2$, 4.6 Hz, 1H). $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 143.76, 141.62, 138.50, 136.67, 129.52, 128.42, 127.33, 124.44, 124.29, 113.49, 96.08, 66.38, 45.18, 33.72, 21.66, 21.49. Enantiomeric excess: 93%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: $t_R = 11.6$ min, second peak: $t_R = 17.1$ min; HRMS (ESI) m/z calcd. for $\text{C}_{18}\text{H}_{19}\text{NaO}_3\text{S}$ $[\text{M}+\text{Na}]^+ = 352.0978$, found = 352.0975; IR spectrum (neat) (cm$^{-1}$) = 2886, 1612, 1493, 1350, 1165, 1094, 961, 928, 814, 733, 665, 584.
methyl (3aR,8aR)-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole-6-carboxylate

3ka: colorless solid (hexane/EtOAc = 5:1, 72% isolated yield); m.p. = 173-175 °C; [α]D20 = 16.8 (c = 0.625, CHCl3); 1H NMR (500 MHz, CDCl3) δ 8.00 (d, J = 1.1 Hz, 1H), 7.89 (d, J = 8.3 Hz, 2H), 7.71 (dd, J = 7.8, 1.3 Hz, 1H), 7.27 (d, J = 10 Hz, 2H), 7.20 (d, J = 7.8 Hz, 1H), 6.32 (d, J = 6.6 Hz, 1H), 4.00 – 3.93 (m, 2H), 3.91 (s, 3H), 3.30 – 3.24 (m, 1H), 2.38 (s, 3H), 2.36 – 2.29 (m, 1H), 2.03 (dd, J = 12.0, 4.4 Hz, 1H). 13C NMR (126 MHz, CDCl3) δ 166.49, 144.12, 141.82, 136.59, 136.24, 130.66, 129.63, 127.41, 125.25, 124.72, 113.33, 95.99, 66.34, 52.23, 45.50, 33.52, 21.50. Enantiomeric excess: 80%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 60/40; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: tR = 21.1 min, second peak: tR = 40.0 min; HRMS (ESI) m/z calcd. for C19H19NNaO5S [M+Na]+ = 396.0876, found = 396.0866; IR spectrum (neat) (cm⁻¹) = 2884, 1368, 1088, 961, 928, 881, 750, 665, 586.

(3aR,8aR)-8-tosyl-6-(trifluoromethyl)-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole
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3la; colorless solid (hexane/EtOAc = 8:1, 84% isolated yield); m.p. = 124-126 °C; [α]D<sub>20</sub> = 2.8 (c = 0.5, CHCl<sub>3</sub>); <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.87 (d, J = 8.3 Hz, 2H), 7.61 (s, 1H), 7.29 – 7.24 (m, 4H), 6.32 (d, J = 6.6 Hz, 1H), 4.01 – 3.94 (m, 2H), 3.30 – 3.25 (m, 1H), 2.39 (s, 3H), 2.36 – 2.30 (m, 1H), 2.02 (dd, J = 12.5, 4.9 Hz, 1H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 144.37, 142.02, 136.07, 135.33, 130.88 (q, J = 32.4 Hz), 129.71, 127.39, 125.22, 123.82 (q, J = 272.5 Hz), 120.46 (q, J = 3.9 Hz), 109.43 (q, J = 3.9 Hz), 96.07, 66.36, 45.40, 33.55, 21.50. <sup>19</sup>F NMR (376 MHz, CDCl<sub>3</sub>) δ -62.34. Enantiomeric excess: 85%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: t<sub>R</sub> = 10.3 min, second peak: t<sub>R</sub> = 13.0 min; HRMS (ESI) m/z calcd. for C<sub>18</sub>H<sub>16</sub>F<sub>3</sub>NNaO<sub>3</sub>S [M+Na]<sup>+</sup> = 406.0695, found = 406.0691; IR spectrum (neat) (cm<sup>-1</sup>) = 2884, 1435, 1361, 1317, 1168, 1121, 1092, 1078, 961, 732, 664.

3ma; colorless solid (hexane/EtOAc = 8:1, 81% isolated yield); m.p. = 94-95 °C; [α]D<sub>20</sub> = 17.232 (c = 0.625, CHCl<sub>3</sub>); <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.86 (d, J = 8.4 Hz, 2H), 7.27 – 7.26 (m, 2H), 7.18 – 7.12 (m, 2H), 6.69 – 6.65 (m, 1H), 6.30 (d, J = 6.7 Hz, 1H), 4.02 – 3.99 (m, 2H), 3.36 – 3.31 (m, 1H), 2.38 (s, 3H), 2.28 – 2.20 (m, 1H), 2.14 (dd, J = 12.5, 4.9 Hz, 1H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 160.00, 158.03, 144.11, 143.60 (d, J = 8.4 Hz), 136.21, 130.18 (d, J = 8.4 Hz), 129.58, 127.33, 117.42 (d, J = 20.6 Hz), 110.18 (d, J = 20.0 Hz), 108.49 (d, J = 3.3 Hz), 96.22, 66.47, 42.77, 31.84, 21.47. <sup>19</sup>F NMR (376 MHz, CDCl<sub>3</sub>) δ -118.56. Enantiomeric excess: 93%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: t<sub>R</sub> = 14.3 min, second peak: t<sub>R</sub> = 18.9 min; HRMS
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(ESI) m/z calcd. for C_{17}H_{16}FNNaO_{3S} [M+Na]^+ = 356.0727, found = 356.0724; IR spectrum (neat) (cm\(^{-1}\)) = 2897, 1626, 1362, 1240, 1171, 1088, 961, 881, 777, 733, 664.

\((3aR,8aR)-4\text{-methyl}-8\text{-tosyl}-3,3a,8,8a\text{-tetrahydro-2H-furo}[2,3-b]\text{indole}\)

3na; amorphous colorless solid (hexane/EtOAc = 8:1, 51% isolated yield); m.p. = 57-59 °C; \([\alpha]_D^{20} = 7.44 (c = 0.5, \text{CHCl}_3)\); \(^1\text{H NMR (500 MHz, CDCl}_3\)): \(\delta 7.85 (d, J = 8.3 \text{ Hz}, 2\text{H}), 7.24 (dd, J = 8.3, 2.7 \text{ Hz}, 3\text{H}), 7.08 \text{ (t, } J = 7.9 \text{ Hz, } 1\text{H}), 6.79 (d, J = 7.6 \text{ Hz, } 1\text{H}), 6.29 (d, J = 6.9 \text{ Hz, } 1\text{H}), 4.00 – 3.96 (m, 1\text{H}), 3.89 – 3.85 (m, 1\text{H}), 3.41 – 3.36 (m, 1\text{H}), 2.37 (s, 3\text{H}), 2.31 – 2.22 (m, 4\text{H}), 1.97 \text{ (dd, } J = 12.2, 5.1 \text{ Hz, } 1\text{H}).\) \(^{13}\text{C NMR (126 MHz, CDCl}_3\)): \(\delta 143.81, 141.30, 136.47, 134.52, 129.54, 128.34, 127.38, 124.76, 110.20, 95.91, 65.93, 44.65, 32.19, 21.51, 18.50.\) Enantiomeric excess: 93%, determined by HPLC (Chiralpak OJ-3, hexane/i-ProOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: \(t_R = 13.9 \text{ min, second peak: } t_R = 20.0 \text{ min; HRMS (ESI) m/z calcd. for C}_{18}H_{19}NNaO_{3S} [M+Na]^+ = 352.0978, found = 352.0972; IR spectrum (neat) (cm\(^{-1}\)) = 2886, 1458, 1356, 1250, 1167, 1084, 1051, 961, 927, 881, 775, 662, 578.\)
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(3aR,8aR)-7-fluoro-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole

3oa: colorless solid (hexane/EtOAc = 8:1, 66% isolated yield); m.p. = 66-67 °C; [α]D20 = 3.18 (c = 0.5, CHCl3); 1H NMR (500 MHz, CDCl3) δ 7.94 (d, J = 7.4 Hz, 2H), 7.29 (d, J = 8.4 Hz, 2H), 6.96 – 6.94 (m, 2H), 6.88 – 6.84 (m, 1H), 6.60 (d, J = 6.4 Hz, 1H), 4.09 – 4.03 (m, 2H), 3.47 – 3.42 (m, 1H), 2.41 (s, 3H), 2.39 – 2.33 (m, 1H), 2.07 (dd, J = 12.3, 4.8 Hz, 1H). 13C NMR (126 MHz, CDCl3) δ 150.22, 148.23, 143.52, 137.76 (d, J = 1.6 Hz), 136.14 (d, J = 2.8 Hz), 129.31, 128.61 (d, J = 10.5 Hz), 127.52 (d, J = 2.2 Hz), 124.92 (d, J = 6.6 Hz), 120.35 (d, J = 3.3 Hz), 116.29 (d, J = 20.3 Hz), 96.35, 66.43, 45.83, 33.60, 21.52. 19F NMR (376 MHz, CDCl3) δ -120.54. Enantiomeric excess: 87%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: tR = 18.1 min, second peak: tR = 38.4 min; HRMS (ESI) m/z calcd. for C17H16FNNaO3S [M+Na]+ = 356.0727, found = 356.0718; IR spectrum (neat) (cm⁻¹) = 2876, 1597, 1348, 1258, 1165, 1094, 1074, 988, 961, 816, 779, 660, 596.

(3aR,8aR)-5,6-difluoro-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole

3pa: colorless solid (hexane/EtOAc = 8:1, 84% isolated yield); m.p. = 123-125 °C; [α]D20 = 20.537 (c = 0.54, CHCl3); 1H NMR (500 MHz, CDCl3) δ 7.83 (d, J = 8.3 Hz, 2H), 7.28 (d, J = 8.1 Hz, 2H), 7.25 – 7.23 (m, 1H), 6.95 – 6.91 (m, 1H), 6.25 (d, J = 6.6 Hz, 1H), 3.99 (t, J = 8.0 Hz, 1H), 3.85 (t, J = 7.5 Hz, 1H), 3.33 – 3.28 (m, 1H), 2.40 (s, 3H), 2.32 – 2.24 (m, 1H), 1.96 (dd, J = 12.4, 4.6 Hz, 1H). 13C NMR
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(126 MHz, CDCl$_3$) $\delta$ 151.07 (d, $J = 13.8$ Hz), 149.10 (d, $J = 13.8$ Hz), 148.02 (d, $J = 13.7$ Hz), 146.08 (d, $J = 13.7$ Hz), 144.35, 137.51 (dd, $J = 9.6$, 2.3 Hz), 135.94, 129.73, 127.31, 126.90 (dd, $J = 5.9$, 3.4 Hz), 113.41 (d, $J = 19.5$ Hz), 102.84 (d, $J = 23.8$ Hz), 96.42, 66.39, 45.20, 33.55, 21.52.

$^{19}$F NMR (376 MHz, CDCl$_3$) $\delta$ -136.09 (d, $J = 20.4$ Hz), -143.62 (d, $J = 20.3$ Hz).

Enantiomeric excess: 89%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: $t_R = 16.1$ min, second peak: $t_R = 20.4$ min; HRMS (ESI) m/z calcd. for C$_{17}$H$_{15}$F$_2$NNaO$_3$ [M+Na]$^+$ = 374.0633, found = 374.0627; IR spectrum (neat) (cm$^{-1}$) = 2882, 1447, 1368, 1202, 1167, 1088, 961, 928, 881, 662, 610.

(7a$R$,10a$R$)-7-tosyl-7a,9,10,10a-tetrahydro-7H-furo[3',2':4,5]pyrrolo[3,2-f]quinoxaline

3qa: colorless solid (hexane/EtOAc = 2:1, 87% isolated yield); m.p. = 210-211 °C; [$\alpha$]$^D_{20} = 96.898$ (c = 0.4, CHCl$_3$); $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 8.75 (dd, $J = 17.0$, 1.8 Hz, 2H), 8.01 (q, $J = 9.2$ Hz, 2H), 7.89 (d, $J = 8.4$ Hz, 2H), 7.27 (d, $J = 6.8$ Hz, 2H), 6.47 (d, $J = 6.8$ Hz, 1H), 4.44 – 4.41 (m, 1H), 4.06 – 4.03 (m, 1H), 3.35 – 3.30 (m, 1H), 2.48 – 2.40 (m, 2H), 2.37 (s, 3H). $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 145.04, 144.32, 143.22, 142.63, 140.62, 139.89, 136.29, 130.85, 129.78, 127.28, 125.12, 117.39, 97.04, 66.67, 44.51, 32.44, 21.51. Enantiomeric excess: 95%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 60/40; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: $t_R = 24.2$ min, second peak: $t_R = 30.3$ min; HRMS (ESI) m/z calcd. for C$_{19}$H$_{17}$N$_3$NaO$_3$S [M+Na]$^+$ = 390.0883, found = 390.0881; IR spectrum (neat) (cm$^{-1}$) = 2884, 1362, 1348, 1258, 1161, 1080, 961, 947, 928, 881, 619, 588.
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(3aR,8aR)-8-(phenylsulfonyl)-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole

3ra; amorphous colorless solid (hexane/EtOAc = 8:1, 92% isolated yield); m.p. = 49-51 °C; [α]D²⁰ = 12.061 (c = 0.65, CHCl₃); ¹H NMR (500 MHz, CDCl₃) δ 7.99 (dd, J = 8.3, 1.0 Hz, 2H), 7.55 – 7.52 (m, 1H), 7.45 (dd, J = 10.6, 4.8 Hz, 2H), 7.38 (d, J = 8.1 Hz, 1H), 7.19 – 7.13 (m, 2H), 6.99 (td, J = 7.5, 0.7 Hz, 1H), 6.28 (d, J = 6.6 Hz, 1H), 3.96 (t, J = 8.0 Hz, 1H), 3.91 (t, J = 7.5 Hz, 1H), 3.32 – 3.26 (m, 1H), 2.33 – 2.25 (m, 1H), 2.02 (dd, J = 12.2, 4.7 Hz, 1H). ¹³C NMR (126 MHz, CDCl₃) δ 141.36, 139.50, 132.96, 131.30, 128.89, 128.36, 127.27, 124.89, 123.58, 112.71, 95.74, 66.38, 45.49, 33.63. Enantiomeric excess: 95%, determined by HPLC (Chiralpak OJ-3, hexane/i-PrOH = 80/20; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: tR = 18.8 min, second peak: tR = 24.8 min; HRMS (ESI) m/z calcd. for C₁₆H₁₄NNaO₃S [M+Na]⁺ = 324.0665, found = 324.0661; IR spectrum (neat) (cm⁻¹) = 2884, 1362, 1169, 1080, 961, 881, 752, 592.

(3aS,8aR)-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran

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6aa; pale yellow oil (hexane/Et₂O = 20:1, 60% isolated yield); [α]D²⁰ = -94.038 (c = 0.5, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 7.18 (d, J = 7.4 Hz, 1H), 7.14 (t, J = 7.7 Hz, 1H), 6.90 (td, J = 7.4, 0.7 Hz, 1H), 6.81 (d, J = 8.0 Hz, 1H), 6.31 (d, J = 5.7 Hz, 1H), 4.06 (t, J = 8.2 Hz, 1H), 4.00 (dd, J = 8.3, 5.9 Hz, 1H), 3.64 – 3.59 (m, 1H), 2.34 – 2.26 (m, 1H), 2.07 (dd, J = 12.2, 4.9 Hz, 1H). ¹³C NMR (126 MHz, CDCl₃) δ 159.41, 128.66, 127.61, 124.67, 121.11, 110.85, 109.17, 67.18, 46.50, 33.54. Enantiomeric excess: 96%, determined by HPLC (Chiralpak IC, hexane/i-PrOH = 98/2; flow rate 1.0 ml/min; 25 °C; 210 nm), first peak: t_R = 10.3 min, second peak: t_R = 13.0 min; HRMS (ESI) m/z calcd. for C₁₀H₁₀NaO₂ [M+Na]⁺ = 185.0573, found = 185.0589; IR spectrum (neat) (cm⁻¹) = 2974, 1198, 1166, 1083, 961, 882, 779, 733, 669.

(3aS,8aR)-5-fluoro-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran

6ba; pale yellow oil (hexane/Et₂O = 20:1, 77% isolated yield); [α]D²⁰ = -149.872 (c = 0.4, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 6.90 – 6.88 (m, 1H), 6.83 (td, J = 8.9, 2.7 Hz, 1H), 6.71 (dd, J = 8.7, 4.2 Hz, 1H), 6.32 (d, J = 5.7 Hz, 1H), 4.08 (t, J = 8.2 Hz, 1H), 4.00 (dd, J = 8.2, 6.0 Hz, 1H), 3.65 – 6.60 (m, 1H), 2.34 – 2.26 (m, 1H), 2.05 (dd, J = 12.3, 4.9 Hz, 1H). ¹³C NMR (126 MHz, CDCl₃) δ 157.81 (d, J = 237.6 Hz), 155.34 (d, J = 1.4 Hz), 128.89 (d, J = 8.5 Hz), 114.94 (d, J = 24.1 Hz), 111.63 (d, J = 24.7 Hz), 111.47, 109.41 (d, J = 8.5 Hz), 67.21, 46.86 (d, J = 1.7 Hz), 33.40. ¹⁹F NMR (376 MHz, CDCl₃) δ -123.52. Enantiomeric excess: 98%, determined by HPLC (Chiralpak OD-H, hexane/i-PrOH = 98/2; flow rate 1.0 ml/min; 25 °C; 210 nm), first peak: t_R = 8.5 min, second peak: t_R = 9.6 min; HRMS (ESI) m/z calcd. for
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C_{10}H_{9}FNaO_{2} [M+Na]^+ = 203.0479, found = 203.0493; IR spectrum (neat) (cm\(^{-1}\)) = 2986, 1447, 1234, 1190, 1165, 1126, 1097, 1072, 960, 926, 856, 799, 740, 715, 573.

(3aS,8aR)-5-methyl-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran

6ca: pale yellow oil (hexane/Et\(_2\)O = 20:1, 53% isolated yield); [\(\alpha\)]\(_\text{D}^20\) = -168.117 (c = 0.5, CH\(_2\)Cl\(_2\)); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta\) 6.98 (s, 1H), 6.93 (dd, \(J = 8.1, 0.6\) Hz, 1H), 6.69 (d, \(J = 8.1\) Hz, 1H), 6.27 (d, \(J = 5.7\) Hz, 1H), 4.05 (t, \(J = 8.1\) Hz, 1H), 3.95 (dd, \(J = 8.3, 5.9\) Hz, 1H), 3.63 – 3.58 (m, 1H), 2.31 – 2.23 (m, 1H), 2.28 (s, 3H), 2.06 – 2.03 (m, 1H). \(^{13}\)C NMR (126 MHz, CDCl\(_3\)) \(\delta\) 157.31, 130.37, 129.01, 127.51, 125.14, 110.91, 108.65, 67.13, 46.54, 33.48, 20.73. Enantiomeric excess: 95%, determined by HPLC (Chiralpak OD-H, hexane/i-PrOH = 98/2; flow rate 1.0 ml/min; 25 °C; 210 nm), first peak: \(t_R\) = 8.0 min, second peak: \(t_R\) = 8.4 min; HRMS (ESI) m/z calcd. for C\(_{11}\)H\(_{12}\)NaO\(_2\) [M+Na]^+ = 199.0730, found = 199.0732; IR spectrum (neat) (cm\(^{-1}\)) = 2976, 1458, 1448, 1307, 1246, 1202, 1072, 1022, 957, 831, 808, 745, 654.
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(3aS,8aR)-5-methyl-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran

6da; pale yellow oil (hexane/Et₂O = 10:1, 72% isolated yield); [α]$_D^{20}$ = -182.367 (c = 0.54, CH₂Cl₂); $^1$H NMR (500 MHz, CDCl$_3$) δ 6.78 (d, $J = 2.4$ Hz, 1H), 6.73 – 6.69 (m, 2H), 6.29 (d, $J = 5.7$ Hz, 1H), 4.07 (t, $J = 8.1$ Hz, 1H), 3.99 (dd, $J = 8.4$, 5.8 Hz, 1H), 3.77 (s, 3H), 3.66 – 3.61 (m, 1H), 2.10 – 2.06 (m, 1H). $^{13}$C NMR (126 MHz, CDCl$_3$) δ 154.52, 153.44, 128.44, 113.53, 111.07, 110.70, 109.08, 67.12, 55.89, 46.96, 33.39. Enantiomeric excess: 98%, determined by HPLC (Chiralpak IC, hexane/i-PrOH = 98/2; flow rate 1.0 ml/min; 25 °C; 210 nm), first peak: $t_R = 20.3$ min, second peak: $t_R = 24.8$ min; HRMS (ESI) m/z calcd. for C$_{11}$H$_{12}$NaO$_3$ [M+Na]$^+$ = 215.0679, found = 215.0676; IR spectrum (neat) (cm$^{-1}$) = 2980, 1240, 1198, 1076, 1068, 959, 928, 810, 739, 656.

(3aS,8aR)-5-methyl-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran

6ea; pale yellow oil (hexane/Et₂O = 20:1, 51% isolated yield); [α]$_D^{20}$ = -138.84 (c = 0.25, CH₂Cl₂); $^1$H NMR (500 MHz, CDCl$_3$) δ 7.09 (dd, $J = 7.8$, 6.1 Hz, 1H), 6.62 – 6.58 (m, 1H), 6.52 (dd, $J = 9.4$, 2.3 Hz, 1H), 6.34 (d, $J = 5.7$ Hz, 1H), 4.08 (t, $J = 8.2$ Hz, 1H), 3.97 – 3.94 (m, 1H), 3.65 – 3.60 (m, 1H), 2.32 – 2.24 (m, 1H), 2.03 (dd, $J = 12.2$, 4.8 Hz, 1H). $^{13}$C NMR (126 MHz, CDCl$_3$) δ 163.33 (d, $J = 244.2$ Hz), 160.45 (d, $J = 13.1$ Hz), 124.94 (d, $J = 10.5$ Hz), 123.28 (d, $J = 2.6$ Hz), 112.17, 107.76 (d, $J = 22.8$ Hz), 97.61 (d, $J = 26.5$ Hz), 67.28, 45.88, 33.59. $^{19}$F NMR (376 MHz, CDCl$_3$) δ -113.10. Enantiomeric excess: 90%, determined by HPLC (Chiralpak OD-H, hexane/i-PrOH = 98/2; flow rate 1.0 ml/min; 25 °C; 210 nm), first peak: $t_R = 6.6$ min, second peak: $t_R = 7.7$ min; HRMS (ESI) m/z calcd. for C$_{10}$H$_9$FNaO$_2$ [M+Na]$^+$
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= 203.0479, found = 203.0488; IR spectrum (neat) (cm\(^{-1}\)) = 2984, 1610, 1439, 1325, 1256, 1132, 1074, 957, 918, 837, 800, 752, 610.

\[(3aS,8aR)-6\text{-methyl-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran}\]

6fa: pale yellow oil (hexane/Et\(_2\)O = 20:1, 58% isolated yield); \([\alpha]\)\(_{D}^{20}\) = -125.319 (c = 0.25, CH\(_2\)Cl\(_2\)); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta\) 7.05 (d, \(J = 7.5\) Hz, 1H), 6.72 (dd, \(J = 7.5, 0.5\) Hz, 1H), 6.63 (s, 1H), 6.29 (d, \(J = 5.7\) Hz, 1H), 4.05 (t, \(J = 8.1\) Hz, 1H), 3.95 (dd, \(J = 7.8, 6.2\) Hz, 1H), 3.63 – 3.58 (m, 1H), 2.30 (s, 3H), 2.29 – 2.22 (m, 1H), 2.03 (dd, \(J = 12.1, 4.8\) Hz, 1H). \(^{13}\)C NMR (126 MHz, CDCl\(_3\)) \(\delta\) 159.63, 138.91, 124.61, 124.20, 121.83, 111.13, 109.82, 67.15, 46.24, 33.58, 21.47. Enantiomeric excess: 92%, determined by HPLC (Chiralpak IC, hexane/i-PrOH = 98/2; flow rate 1.0 ml/min; 25 °C; 210 nm), first peak: \(t_R = 10.2\) min, second peak: \(t_R = 13.8\) min; HRMS (ESI) m/z calcd. for C\(_{11}H_{12}NaO_2\) [M+Na]\(^+\) = 199.0730, found = 199.0725; IR spectrum (neat) (cm\(^{-1}\)) = 2978, 1591, 1445, 1321, 1252, 1072, 943, 922, 800, 750, 627, 590.
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(3aS,8aR)-7-fluoro-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran

6ga; pale yellow oil (hexane/Et<sub>2</sub>O = 20:1, 64% isolated yield); [α]<sup>20</sup> = -91.870 (c = 0.4, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 6.97 – 6.91 (m, 2H), 6.85 – 6.81 (m, 1H), 6.39 (d, J = 5.6 Hz, 1H), 4.10 (t, J = 8.2 Hz, 1H), 4.05 (dd, J = 8.5, 5.7 Hz, 1H), 3.68 – 3.63 (m, 1H), 2.35 – 2.27 (m, 1H), 2.08 (dd, J = 12.3, 4.9 Hz, 1H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 146.51 (d, J = 246.4 Hz), 146.04 (d, J = 10.5 Hz), 131.23 (d, J = 3.0 Hz), 121.61 (d, J = 5.6 Hz), 119.95 (d, J = 3.5 Hz), 115.75 (d, J = 16.9 Hz), 112.19, 67.41, 46.95 (d, J = 2.0 Hz), 33.39. <sup>19</sup>F NMR (376 MHz, CDCl<sub>3</sub>) δ -137.96. Enantiomeric excess: 98%, determined by HPLC (Chiralpak OD-H, hexane/i-PrOH = 98/2; flow rate 1.0 ml/min; 25 °C; 210 nm), first peak: t<sub>R</sub> = 7.7 min, second peak: t<sub>R</sub> = 9.3 min; HRMS (ESI) m/z calcd. for C<sub>10</sub>H<sub>9</sub>FNaO<sub>2</sub> [M+Na]<sup>+</sup> = 203.0479, found = 203.0482; IR spectrum (neat) (cm<sup>-1</sup>) = 2989, 1599, 1470, 1323, 1260, 1176, 1074, 943, 924, 814, 773, 731, 696, 642.

(3aS,8aR)-7-methoxy-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran

6ha; pale yellow oil (hexane/Et<sub>2</sub>O = 10:1, 61% isolated yield); [α]<sup>20</sup> = -113.542 (c = 0.625, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 6.88 – 6.85 (m, 1H), 6.81 – 6.80 (m, 1H), 6.76 (d, J = 8.0 Hz, 1H), 6.35 (d, J = 5.7 Hz, 1H), 4.05 – 4.00 (m, 1H), 3.87 (s, 3H), 3.67 – 3.61 (m, 1H), 2.32 – 2.26 (m, 1H), 2.06 (dd, J = 12.2, 4.9 Hz, 1H). <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 147.71, 143.64, 128.63, 121.66, 116.61, 113.50, 67.19, 35.86, 34.64, 33.28. Enantiomeric excess: 99%, determined by HPLC (Chiralpak OD-H,
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hexane/i-PrOH = 98/2; flow rate 1.0 ml/min; 25 °C; 220 nm), first peak: \( t_R = 20.8 \) min, second peak: \( t_R = 30.0 \) min; HRMS (ESI) m/z calcd. for \( \text{C}_{11}\text{H}_{12}\text{NaO}_3 \) [M+Na]\(^+\) = 215.0679, found = 215.0680; IR spectrum (neat) (cm\(^{-1}\)) = 2982, 1618, 1593, 1460, 1302, 1198, 1060, 939, 771, 731, 648.

(2R,3aR,8aR)-2-(p-tolyl)-8-tosyl-3,3a,8a-tetrahydro-2H-furo[2,3-b]indole

3ab: colorless solid (hexane/EtOAc = 7:1, 52% isolated yield); m.p. = 161-163 °C; \([\alpha]_D^{20} = 13.927 \) (c = 0.55, CH\(_2\)Cl\(_2\)); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \( \delta \) 7.89 (d, \( J = 8.3 \) Hz, 2H), 7.40 (d, \( J = 8.1 \) Hz, 1H), 7.21 – 7.15 (m, 4H), 7.12 (s, 4H), 7.01 (td, \( J = 7.5, 0.7 \) Hz, 1H), 6.49 (d, \( J = 6.6 \) Hz, 1H), 4.42 (dd, \( J = 11.2, 4.4 \) Hz, 1H), 4.04 (t, \( J = 7.4 \) Hz, 1H), 2.33 (s, 3H), 2.33 (s, 3H), 2.30 (d, \( J = 4.5 \) Hz, 1H), 2.24 – 2.18 (m, 1H). \(^{13}\)C NMR (126 MHz, CDCl\(_3\)) \( \delta \) 143.73, 141.62, 137.59, 136.65, 136.17, 131.44, 129.43, 128.93, 128.41, 127.52, 126.11, 124.85, 123.42, 112.64, 95.46, 79.18, 46.24, 42.13, 21.42, 21.09. Enantiomeric excess: 85%, determined by HPLC (Chiralpak AD-H, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: \( t_R = 11.4 \) min, second peak: \( t_R = 14.7 \) min; HRMS (ESI) m/z calcd. for \( \text{C}_{24}\text{H}_{23}\text{NNaO}_3\text{S} \) [M+Na]\(^+\) = 428.1291, found = 428.1302; IR spectrum (neat) (cm\(^{-1}\)) = 2884, 1614, 1447, 1354, 1252, 1167, 1074, 961, 928, 814, 768, 733, 664.
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**methyl 4-((2R,3aR,8aR)-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indol-2-yl)benzoate**

3ac; colorless solid (hexane/EtOAc = 4:1, 48% isolated yield); m.p. = 166-168 °C; [α]_D<sup>20</sup> = 5.673 (c = 0.55, CH<sub>2</sub>Cl<sub>2</sub>); ¹H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.99 (d, J = 8.3 Hz, 2H), 7.87 (d, J = 8.3 Hz, 2H), 7.43 (d, J = 8.1 Hz, 1H), 7.33 (d, J = 8.2 Hz, 2H), 7.22 (t, J = 7.8 Hz, 1H), 7.17 (t, J = 6.8 Hz, 3H), 7.03 (dd, J = 7.5, 7.0 Hz, 1H), 6.51 (d, J = 6.6 Hz, 1H), 4.50 (dd, J = 11.3, 4.4 Hz, 1H), 4.07 (t, J = 7.4 Hz, 1H), 3.91 (s, 3H), 2.40 (dd, J = 12.3, 4.5 Hz, 1H), 2.32 (s, 3H), 2.21 – 2.15 (m, 1H). ¹³C NMR (126 MHz, CDCl<sub>3</sub>) δ 166.74, 144.63, 143.89, 141.56, 136.49, 131.08, 129.58, 129.45, 128.59, 127.41, 125.81, 124.86, 123.61, 112.83, 95.57, 78.69, 52.03, 46.25, 42.22, 21.40. Enantiomeric excess: 90%, determined by HPLC (Chiralpak OJ-H, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: t<sub>R</sub> = 38.0 min, second peak: t<sub>R</sub> = 52.3 min; HRMS (ESI) m/z calcd. for C<sub>25</sub>H<sub>23</sub>NNaO<sub>5</sub>S [M+Na]<sup>+</sup> = 472.1189, found = 472.1199; IR spectrum (neat) (cm<sup>-1</sup>) = 2884, 1612, 1277, 1250, 1198, 1082, 1067, 959, 930, 815, 733, 665.
Supporting Information

(2R,3aR,8aR)-2-(benzofuran-5-yl)-8-tosyl-3,3a,8,8a-tetrahydro-2H-furo[2,3-b]indole

3ad: pale yellow solid (hexane/EtOAc = 7:1, 87% isolated yield); m.p. = 59-60 °C; [α]D$^20$ = 12.613 (c = 0.463, CH$_2$Cl$_2$); $^1$H NMR (500 MHz, CDCl$_3$) δ 7.89 (d, J = 8.3 Hz, 2H), 7.60 (d, J = 2.2 Hz, 1H), 7.49 (d, J = 1.5 Hz, 1H), 7.43 – 7.41 (m, 2H), 7.21 – 7.13 (m, 5H), 7.06 – 7.01 (m, 1H), 6.72 (dd, J = 2.1, 0.8 Hz, 1H), 6.53 (d, J = 6.6 Hz, 1H), 4.55 (dd, J = 11.2, 4.4 Hz, 1H), 4.07 (t, J = 7.4 Hz, 1H), 2.37 (dd, J = 12.4, 4.5 Hz, 1H), 2.32 (s, 3H), 2.29 – 2.22 (m, 1H). $^{13}$C NMR (126 MHz, CDCl$_3$) δ 154.57, 145.41, 143.76, 141.64, 136.63, 133.77, 131.44, 129.44, 128.45, 127.49, 124.88, 123.48, 122.58, 121.52, 118.88, 112.70, 111.07, 106.51, 95.47, 79.48, 46.29, 42.61, 21.40. Enantiomeric excess: 86%, determined by HPLC (Chiralpak OJ-H, hexane/i-PrOH = 70/30; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: t$_R$ = 16.5 min, second peak: t$_R$ = 23.9 min; HRMS (ESI) m/z calcld. for C$_{25}$H$_{21}$NNaO$_4$S [M+Na]$^+$ = 454.1083, found = 454.1087; IR spectrum (neat) (cm$^{-1}$) = 2884, 1481, 1352, 1167, 1092, 1074, 1005, 961, 949, 814, 743, 662.
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(2R,3aS,8aR)-2-(p-tolyl)-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran

6ab: pale yellow oil (hexane/Et₂O = 20:1, 78% isolated yield); [α]₂⁰D = -54.179 (c = 0.5, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 7.23 – 7.20 (m, 3H), 7.18 (d, J = 7.7 Hz, 1H), 7.13 (d, J = 8.0 Hz, 2H), 6.94 (td, J = 7.4, 0.7 Hz, 1H), 6.86 (d, J = 8.0 Hz, 1H), 6.47 (d, J = 5.8 Hz, 1H), 4.86 (dd, J = 11.3, 4.6 Hz, 1H), 4.14 (dd, J = 8.0, 6.1 Hz, 1H), 2.40 (dd, J = 12.4, 4.6 Hz, 1H), 2.33 (s, 3H), 2.25 – 2.19 (m, 1H). ¹³C NMR (126 MHz, CDCl₃) δ 159.56, 137.60, 136.50, 129.05, 128.79, 127.82, 126.00, 124.70, 121.19, 110.51, 109.35, 80.04, 47.36, 42.09, 21.11. Enantiomeric excess: 95%, determined by HPLC (Chiralpak IF, hexane/i-PrOH = 95/5; flow rate 0.8 ml/min; 25 °C; 220 nm), first peak: t_R = 10.2 min, second peak: t_R = 11.0 min; HRMS (ESI) m/z calcd. for C₁₇H₁₆NaO₂ [M+Na]⁺ = 275.1043, found = 275.1050; IR spectrum (neat) (cm⁻¹) = 2982, 1597, 1477, 1460, 1323, 1246, 1235, 1180, 1098, 1072, 995, 981, 912, 889, 812, 748, 588.

methyl 4-((2R,3aS,8aR)-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran-2-yl)benzoate

6ac: colorless solid (hexane/Et₂O = 10:1, 45% isolated yield); m.p. = 131-132 °C; [α]₂⁰D = -15.2 (c = 0.35, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 8.00 (d, J = 8.4 Hz, 2H), 7.40 (d, J = 8.2 Hz, 2H), 7.26 – 7.19 (m, 2H), 6.96 (td, J = 7.5, 0.8 Hz, 1H), 6.87 (d, J = 8.0 Hz, 1H), 6.50 (d, J = 5.7 Hz, 1H), 4.93 (dd, J = 11.3, 4.6 Hz, 1H), 4.18 (dd, J = 7.9, 6.1 Hz, 1H), 3.90 (s, 3H), 2.48 (dd, J = 12.4, 4.7 Hz, 1H), 2.22 – 2.16 (m, 1H). ¹³C NMR (126 MHz, CDCl₃) δ 166.84, 159.47, 144.97, 129.72, 129.57, 128.97, 128.72, 126.00, 124.70, 121.40, 120.52, 115.26, 110.51, 109.46, 79.56, 52.09, 47.38, 42.22. Enantiomeric excess:
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81%, determined by HPLC (Chiralpak AD-H, hexane/i-PrOH = 95/5; flow rate 0.8 ml/min; 25 °C; 220 nm), first peak: $t_R = 21.6$ min, second peak: $t_R = 23.5$ min; HRMS (ESI) m/z calcd. for $C_{18}H_{16}NaO_4 [M+Na]^+ = 319.0941$, found = 319.0940; IR spectrum (neat) (cm$^{-1}$) = 2974, 2884, 1381, 1275, 1198, 1086, 947, 880, 733, 623.

(2R,3aS,8aR)-2-(benzofuran-5-yl)-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran

6ad; pale yellow oil (hexane/Et$_2$O = 20:1, 68% isolated yield); $[\alpha]_D^{20} = - 48.694$ ($c = 0.475$, CH$_2$Cl$_2$); $^1$H NMR (500 MHz, CDCl$_3$) δ 7.59 (d, $J = 2.2$ Hz, 1H), 7.56 (d, $J = 1.4$ Hz, 1H), 7.45 (d, $J = 8.5$ Hz, 1H), 7.26 – 7.22 (m, 2H), 7.21 – 7.18 (m, 1H), 6.95 (dd, $J = 10.8$, 4.0 Hz, 1H), 6.88 (d, $J = 8.0$ Hz, 1H), 6.72 – 6.71 (m, 1H), 6.50 (d, $J = 5.8$ Hz, 1H), 4.98 (dd, $J = 11.3$, 4.6 Hz, 1H), 4.16 (dd, $J = 7.9$, 6.2 Hz, 1H), 2.45 (dd, $J = 12.4$, 4.6 Hz, 1H), 2.30 – 2.24 (m, 1H). $^{13}$C NMR (126 MHz, CDCl$_3$) δ 159.57, 154.59, 145.42, 134.09, 128.81, 127.80, 127.40, 124.71, 122.46, 121.22, 118.80, 111.23, 110.49, 109.36, 106.55, 80.35, 47.40, 42.53. Enantiomeric excess: 94%, determined by HPLC (Chiralpak AD-H, hexane/i-PrOH = 95/5; flow rate 0.8 ml/min; 25 °C; 220 nm), first peak: $t_R = 16.9$ min, second peak: $t_R = 18.9$ min; HRMS (ESI) m/z calcd. for $C_{18}H_{16}NaO_3 [M+Na]^+ = 301.0835$, found = 301.0838; IR spectrum (neat) (cm$^{-1}$) = 2980, 2879, 1597, 1460, 1323, 1248, 1180, 1126, 1070, 993, 889, 814, 736.
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2-((2R,3aS,8aR)-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran-2-yl)quinoline

\[ \text{6ae; yellow solid (hexane/Et}_2\text{O = 8:1, 53\% isolated yield); m.p. = 126-128 °C; [\alpha]_D^{20} = -9.2 (c = 0.4, CH}_2\text{Cl}_2; } \]

\[ \text{\textsuperscript{1}H NMR (500 MHz, CDCl}_3 \text{)} \delta 8.18 (d, J = 8.5 Hz, 1H), 8.02 (d, J = 8.5 Hz, 1H), 7.81 (d, J = 8.1 Hz, 1H), 7.71 – 7.67 (m, 1H), 7.63 (d, J = 8.5 Hz, 1H), 7.52 (t, J = 7.5 Hz, 1H), 7.24 (d, J = 7.4 Hz, 1H), 7.19 (td, J = 7.4, 0.6 Hz, 1H), 6.95 (t, J = 7.4 Hz, 1H), 6.88 (d, J = 8.1 Hz, 1H), 6.56 (d, J = 5.6 Hz, 1H), 5.16 (dd, J = 11.3, 4.8 Hz, 1H), 4.20 (dd, J = 7.7, 6.2 Hz, 1H), 2.69 (dd, J = 12.3, 4.7 Hz, 1H), 2.44 – 2.37 (m, 1H). \text{\textsuperscript{13}C NMR (126 MHz, CDCl}_3 \text{)} \delta 159.82, 159.38, 147.33, 137.07, 129.71, 129.54, 128.89, 127.62, 127.49 (d, J = 41.1 Hz), 126.44, 124.92, 121.42, 118.20, 115.43, 110.80, 109.41, 81.43, 47.32, 40.84. Enantiomeric excess: 89\%, determined by HPLC (Chiralpak IF, hexane/i-PrOH = 95/5; flow rate 0.8 ml/min; 25 °C; 254 nm), first peak: t\textsubscript{R} = 19.4 min, second peak: t\textsubscript{R} = 25.2 min; HRMS (ESI) m/z calcd. for C\textsubscript{19}H\textsubscript{16}NO\textsubscript{2} [M+H\textsuperscript{+}] = 290.1176, found = 290.1185; IR spectrum (neat) (cm\textsuperscript{-1}) = 2976, 2878, 1381, 1321, 1198, 1086, 947, 880, 752, 631.\]
Supporting Information

(3aS,8aR)-8a-methyl-2,3,3a,8a-tetrahydrofuro[2,3-b]benzofuran

6af; pale yellow oil (hexane/Et₂O = 20:1, 47% isolated yield); [α]D²⁰ = -70.12 (c = 0.33, CH₂Cl₂); Enantiomeric excess: 83%, determined by HPLC (Chiralpak OJ-H, hexane/i-PrOH = 98/2; flow rate 0.5 ml/min; 25 °C; 205 nm), first peak: tR = 14.4 min, second peak: tR = 17.3 min. (Please refer to Mazet’s work for ¹H/¹³C NMR and IR)
5. Absolute Configuration of 3 and 6

X-ray structure of 3aa and 3ac:

The configuration of 6aa-6ha was determined by comparing the optical rotation with the reported ones in Mazet’s work (see ref. 1).

For instance:

|     | Our work | Mazet’s work |
|-----|----------|--------------|
| 6ca | [α]D\textsubscript{20} = -168.114 (c = 0.5, CH\textsubscript{2}Cl\textsubscript{2}) | [α]D\textsubscript{23} = -172.0 (c = 0.85, CH\textsubscript{2}Cl\textsubscript{2}) |
| 6da | [α]D\textsubscript{20} = -182.367 (c = 0.54, CH\textsubscript{2}Cl\textsubscript{2}) | [α]D\textsubscript{23} = -166.8 (c = 0.54, CH\textsubscript{2}Cl\textsubscript{2}) |
| 6ha | [α]D\textsubscript{20} = -113.542 (c = 0.625, CH\textsubscript{2}Cl\textsubscript{2}) | [α]D\textsubscript{23} = -108 (c = 0.81, CH\textsubscript{2}Cl\textsubscript{2}) |
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The configuration of 6ab-6ae was determined by comparing the optical rotation and \(^1\)H-\(^1\)H-NOSEY-NMR spectrum with the reported one in Mazet’s work (see ref. 1).

For instance:

| Our work | Mazet’s work |
|----------|--------------|
| ![Image of 6ab](image1.png) | ![Image of 3n](image2.png) |
| \([\alpha]_D^{20} = -54.179\)  
(c = 0.5, CH\(_2\)Cl\(_2\)) | \([\alpha]_D^{23} = -136.7\)  
(c = 0.49, CH\(_2\)Cl\(_2\)) |

The configuration of new modified \(N\)-Me-Xiang-Phos was determined according to the reported \(N\)-Me-Xu-Phos in our previous work, due to the same one-pot synthesis approach (see ref. 3).
6. References

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2 Y.-Z. Chen, M.-L. Peng, D. Zhang, L.-P. Zhang, L.-Z. Wu, C.-H. Tung, Tetrahedron, 2006, 62, 10688–10693.
3 Z.-M. Zhang, B. Xu, Y. Qian, L. Wu, Y. Wu, L. Zhou, Y. Liu, J. Zhang, Angew. Chem. 2018, 130, 10530-10534; Angew. Chem. Int. Ed. 2018, 57, 10373-10377.
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7. $^1$H, $^{13}$C, $^{19}$F, $^{31}$P Spectra for (S,R$_S$)-N-Me-X4/X5, 3 and 6

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
(S,R)-N-Me-X4

$^{31}$P NMR (202 MHz, CDCl$_3$, 298 K)

(S,R)-N-Me-X5

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)
Supporting Information

\[\text{(S,R)}_2-\text{N-Me-X5}\]

$^{13}C$ NMR (126 MHz, CDCl$_3$, 298 K)

$^{31}P$ NMR (202 MHz, CDCl$_3$, 298 K)
Supporting Information

[^]{\text{1}}^{1}H NMR (500 MHz, CDCl$_3$, 298 K)

[^]{\text{13}}^{13}C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$\text{3ba}$

$^1\text{H NMR (500 MHz, CDCl}_3, 298 \text{ K)}$

$\text{3ba}$

$^{13}\text{C NMR (126 MHz, CDCl}_3, 298 \text{ K)}$
$^{19}$F NMR (376 MHz, CDCl$_3$, 298 K)


$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^{19}$F NMR (376 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
$^{19}$F NMR (376 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^1$H NMR (126 MHz, CDCl$_3$, 298 K)
$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^{19}$F NMR (376 MHz, CDCl$_3$, 298 K)
Supporting Information

\[ ^1H \text{ NMR (500 MHz, CDCl}_3, 298 \text{ K)} \]

\[ ^13C \text{ NMR (126 MHz, CDCl}_3, 298 \text{ K)} \]
Supporting Information

$^19$F NMR (376 MHz, CDCl$_3$, 298 K)

![Chemical structure of 3ma](image)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (125 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^{19}$F NMR (376 MHz, CDCl₃, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$\text{^{19}F NMR (376 MHz, CDCl}_3, 298 K)$
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

3ra

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^13$C NMR (126 MHz, CDCl$_3$, 298 K)
$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^{19}$F NMR (376 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

\[ \text{MeO} \]
\[ \text{H} \]
\[ \text{O} \]
\[ \text{H} \]
\[ \text{O} \]

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

\[ \text{MeO} \]
\[ \text{H} \]
\[ \text{O} \]
\[ \text{H} \]
\[ \text{O} \]

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^{19}$F NMR (376 MHz, CDCl$_3$, 298 K)
**Supporting Information**

1H NMR (500 MHz, CDCl₃, 298 K)

13C NMR (126 MHz, CDCl₃, 298 K)
Supporting Information

$^{19}$F NMR (376 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information

$^1$H NMR (500 MHz, CDCl$_3$, 298 K)

$^{13}$C NMR (126 MHz, CDCl$_3$, 298 K)
Supporting Information
Supporting Information

^{1}H NMR (200 MHz, CDCl₃, 298 K)

^{13}C NMR (125 MHz, CDCl₃, 298 K)