Supporting Information

Ruthenium and Iron-Catalysed Decarboxylative N-alkylation of Cyclic α-Amino Acids with Alcohols: Sustainable Routes to Pyrrolidine and Piperidine Derivatives

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General methods

Chromatography and spectroscopy

Column chromatography was performed using Merck silica gel type 9385 230-400 mesh and typically pentane and ethyl acetate or ethyl acetate and methanol as eluent.

TLC: Merck silica gel 60, 0.25 mm. The components were visualized by UV or KMnO4 staining.

Gas Chromatography was used for product identification as well as determination of conversion and selectivity values. Product identification was performed by GC-MS (Shimadzu QP2010 Ultra) with an HP-1MS column, and helium as carrier gas. GC-MS method: The temperature program started at 50 °C for 5 min, heated by 30°C/minute to 250 °C and held for 15 min.

Mass spectrometry: Mass spectra were recorded on an AEI-MS-902 mass spectrometer (EI+) or a LTQ Orbitrap XL (ESI+).

NMR spectroscopy: 1H and 13C NMR spectra were recorded on a Varian Mercury Plus 400, Agilent MR 400 (400 and 101 MHz, respectively) and Bruker Avance NEO 600 (600 and 151 MHz, respectively) using CDCl3, CD2OD, or Toluene-d8 as a solvent. 1H and 13C NMR spectra were recorded at room temperature. Chemical shift values are reported in ppm with the solvent resonance as the internal standard (CDCl3: 7.26 for 1H, 77.00 for 13C; CD2OD: 3.31 for 1H, 49.00 for 13C; Toluene-d8: 7.09, 7.01, 6.97, 2.08 for 1H, 137.48, 128.87, 127.96, 125.13, 20.43 for 13C). Data are reported as follows: chemical shifts, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, br. = broad, m = multiplet), coupling constants (Hz), and integration.

All reactions were carried out under an Argon atmosphere using oven (120 °C) dried glassware and using standard Schlenk techniques. 1-Hydroxytetraphenylcyclopentadienyl-(tetraphenyl-2,4-cyclopentadien-1-one)-µ-hydrotetracarbonyldiruthenium(II) (Shvo’s catalyst, C1) was purchased from Strem Chemicals, Inc. Complex C2 was synthesized according to the literature procedure.[1] All other reagents were purchased from Sigma-Aldrich, Acros and TCI in reagent or higher grade and were used as received without further purification.

Representative procedures

General procedure for the decarboxylative N-alkylation of amino acids
An oven-dried 20 mL Schlenk tube, equipped with a stirring bar, was charged with amino acid (0.5 mmol, 1 equiv.), corresponding alcohol (1 or 2 mmol, 2 or 4 equiv.), Shvo’s catalyst (C1, 0.005 mmol, 1 mol%) or Knöller’s complex (C2, 0.02 mmol, 4 mol%), and toluene (as a solvent, 2 mL). Solid materials were weighed into the Schlenk tube under air. Then the Schlenk tube was subsequently connected to an argon line and vacuum-argon exchanges were performed three times. Liquid starting materials and solvent were charged under an argon stream. The Schlenk tube was capped and the mixture was rapidly stirred at room temperature for 1 min, then was placed into a pre-heated oil bath at 120 °C and stirred for a given time (typically, 24 h). Then, the reaction mixture was cooled down to room temperature, the crude mixture was filtered through silica gel, eluted with ethyl acetate, and concentrated in vacuo. The residue was purified by flash column chromatography to provide the pure amine product.
Supplementary figures

**Supplementary Figure 1:** *In situ* $^1$H NMR study of the decarboxylative N-alkylation of DL-proline (1a, 0.5 mmol) with 4-methoxybenzyl alcohol (2a, 1 mmol) in presence of Shvo’s catalyst (C1, 0.005 mmol) in toluene-d$_8$ at 120 °C after 1 hours.

**Supplementary Figure 2:** Evidence of the side product (III') formation according to the $[^1$H-$^{13}$C]HSQC (A) and $[^1$H-$^{13}$C]HMBC (B) 2D NMR analysis.
**Supplementary Figure 3:** Evidence of the acyclic intermediate formation (IVb) according to the $^{1}H-^{13}C$ HSQC (A) and $^{1}H-^{13}C$ HMBC (B) 2D NMR analysis.

**Supplementary Figure 4:** Evidence of the Ru-H species formation.
Supplementary Figure 5: Formation of α-aminonitrile by unique decarboxylative N-alkylation (for proposed mechanism see Figure 4) followed by base-catalysed α-aminonitrile isomerization as proposed by Siedel (J. Am. Chem. Soc. 2012, 134, 15305–15308).

Note 1: Additional description belonging to Supplementary Figures 5
We rationalise the formation of aminonitrile regioisomer 5′ via the hydrogen borrowing/decarboxylative degradation sequence when mandelonitrile substrates are used as carbonyl precursors (Table 4, main text), in accordance with our general mechanistic proposal (Figure 4). Isomerisation of α-aminonitrile 5′ to 5 have been previously investigated and described by Siedel.[2,3] Due to the excess of proline in our system, we assume analogous isomerisation pathways to take place via an azomethine ylide intermediate (Supplementary Figure 5). The formation of the two regioisomers would depend on the charge distribution in the azomethine ylide. Li and co-workers have investigated the energy of resonance structures of the corresponding ylides leading to 5 and 5′ in favour of regioisomer 5,[2] which perfectly matches with the obtained experimental data in our work (Table 4).

Alternative pathways, for example the loss of HCN upon reaction of proline with the carbonyl compound formed by dehydrogenation of the mandelonitrile substrate, followed by subsequent direct decarboxylation to the corresponding azomethine ylide would also be possible.

Note 2: Deuterium incorporation experiment was carried out in the following way:
An oven-dried 20 mL Schlenk tube, equipped with a stirring bar, was charged with DL-proline (1a, 0.1 mmol, 1 equiv.), benzyl alcohol-α,α-d2 (2f-d2, 0.2 mmol, 2 equiv.), Shvo’s catalyst (C1, 0.001 mmol, 1 mol%), and toluene-d8 (as a solvent, 0.4 mL). Solid materials were weighed into the Schlenk tube under air. Then the Schlenk tube was subsequently connected to an argon line and vacuum-argon exchanges were performed three times. Liquid starting materials and solvent were charged under an argon stream. The Schlenk tube was then capped and the mixture was rapidly stirred at room temperature for 1 min, then was placed into a pre-heated oil bath at 120 °C and stirred for 2 h.
The deuterium is transferred from the benzylic position of the alcohol substrate (2f-d2) to the product confirms that the reaction indeed proceeds through a hydrogen borrowing pathway. The deuterium was incorporated at the α-position to the nitrogen at the endocyclic position and/or the benzylic position of the product, confirming that the azomethine ylide tautomerises during the reaction. Multiple deuterium atoms can be found in the products shown in Supplementary Figure 6. An additional reason for deuterium incorporation could be the existence of a hydrogenation/dehydrogenation equilibrium between IVa and IVb as well as between VI and Va/Vb (Figure 4 in the main text). Such dehydrogenation step with analogous substrates was already proposed in literature (C. Bruneau, J. Am. Chem. Soc. 2011, 133, 10340–10343) using similar Ru transfer hydrogenation catalyst.

**Supplementary Figure 6:** $^1$H NMR spectrum of the depicted on scheme above deuterium incorporation reaction.
Supplementary Figure 7: The plot of selectivity of the intermediate/product formation vs reaction time in the reaction between p-methoxybenzyl alcohol (2a) and DL-proline (1a) in presence of Shvo’s catalyst (C1).

Note 3: Kinetic experiments were carried out in the following way:

An oven-dried 20 mL Schlenk tube, equipped with a stirring bar, was charged with DL-proline (0.3 mmol, 1 equiv.), p-methoxybenzyl alcohol (0.6 mmol, 2 equiv.), Shvo’s catalyst (C1, 0.003 mmol, 1 mol%), and toluene-d₈ (as a solvent, 1 mL). Solid materials were weighed into the Schlenk tube under air. Then the Schlenk tube was subsequently connected to an argon line and vacuum-argon exchanges were performed three times. Liquid starting materials and solvent were charged under an argon stream. The Schlenk tube was capped and the mixture was rapidly stirred at room temperature for 1 min, then was placed into a pre-heated oil bath at 120 °C and stirred for a specified time (5 min, 15 min, 30 min, 1h, 1h 30 min, 2 h). All reactions were set up in parallel. Then, the reaction mixture was cooled down to room temperature and 1,3,5-trimethoxybenzene (0.1 mmol, 0.3 equiv.) as an internal standard was added. Preparing the sample, 0.6 mL of the reaction mixture was placed to a J-Young NMR tube under argon. All spectra were recorded using Bruker Avance NEO 600 machine.

The obtained data is summarized in the table below.

| Entry | Time, h | III | IVb | VI | Ru-H species |
|-------|--------|-----|-----|----|--------------|
| 1     | 0.08   | 4   | 11  | 0  | 0.08         |
| 2     | 0.25   | 6   | 17  | 35 | 0.08         |
| 3     | 0.5    | 10  | 21  | 42 | 0.1          |
| 4     | 1      | 15  | 16  | 78 | 0.16         |
| 5     | 1.5    | 17  | 5   | 99 | 0.23         |
| 6     | 2      | 24  | 0   | 100| 0.3          |
Spectral data of isolated compounds

1-(4-Methoxybenzyl)pyrrolidine (3aa)

The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords 3aa (90 mg, 94% using C1; 73 mg, 77% using C2). Colorless oil was obtained after column chromatography (SiO₂, EtOAc/MeOH 70:30). ¹H NMR (400 MHz, CDCl₃): δ 7.25 (d, J = 8.4 Hz, 2H), 6.85 (d, J = 8.8 Hz, 2H), 3.79 (s, 3H), 3.57 (s, 2H), 2.52-2.49 (m, 4H), 1.80-1.77 (m, 4H). ¹³C NMR (151 MHz, CDCl₃): δ 158.79, 130.48, 130.25, 113.68, 59.79, 55.25, 53.87, 23.38. HRMS (APCI⁺, m/z) calculated for C₁₂H₁₇NO [M+H]⁺: 192.13829; found: 192.13791. The spectral data are identical to the previously reported.[⁴]

1-(4-Methylbenzyl)pyrrolidine (3ab)

The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords 3ab (75 mg, 86% using C1; 32 mg, 37% using C2). Yellow oil was obtained after column chromatography (SiO₂, EtOAc/MeOH 90:10). ¹H NMR (400 MHz, CDCl₃): δ 7.24 (d, J = 7.6 Hz, 2H), 7.13 (d, J = 8.0 Hz, 2H), 3.63 (s, 2H), 2.57-2.54 (m, 4H), 2.34 (s, 3H), 1.82-1.78 (m, 4H). ¹³C NMR (101 MHz, CDCl₃): δ 139.22, 138.24, 131.66, 131.59, 62.78, 56.51, 26.05, 23.76. HRMS (APCI⁺, m/z) calculated for C₁₂H₁₇N [M+H]⁺: 176.14338; found: 176.14316.

1-(4-(tert-butyl)benzyl)pyrrolidine (3ac)

The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords 3ac (101 mg, 93% using C1; 82 mg, 75% using C2). Slightly yellow oil was obtained after column chromatography (SiO₂, EtOAc/MeOH 70:30). ¹H NMR (400 MHz, CD₂OD): δ 7.35 (d, J = 8.4 Hz, 2H), 7.25 (d, J = 8.4 Hz, 2H), 3.59 (s, 2H), 2.55-2.52 (m, 4H), 1.80-1.77 (m, 4H), 1.30 (s, 9H). ¹³C NMR (101 MHz, CD₂OD): δ 152.64, 137.39, 131.47, 127.47, 62.32, 56.12, 36.59, 33.14, 25.36. HRMS (APCI⁺, m/z) calculated for C₁₃H₂₄N [M+H]⁺: 218.19033; found: 218.19014. The spectral data are identical to the previously reported.[⁵]

1-(Naphthalen-2-ylmethyl)pyrrolidine (3ad)

The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords 3ad (96 mg, 91% using C1; 20 mg, 19% using C2). Yellow oil was obtained after column chromatography (SiO₂, EtOAc/MeOH 90:10). ¹H NMR (400 MHz, CDCl₃): δ 7.88-7.83 (m, 4H), 7.59-7.47 (m, 3H), 3.83 (s, 2H), 2.63-2.60 (m, 4H), 1.88-1.84 (m, 4H). ¹³C NMR (101 MHz, CDCl₃): δ 139.68, 136.17, 135.44, 130.57, 130.48, 130.36, 130.08, 129.92, 128.60, 128.22, 63.60, 56.98, 26.25. HRMS (APCI⁺, m/z) calculated for C₁₃H₁₈N [M+H]⁺: 212.14338; found: 212.14311. The spectral data are identical to the previously reported.[⁶]
1-(benzo[d][1,3]dioxol-5-ylmethyl)pyrroldine (3ae)

![Chemical structure](image)

The compound was synthesised according to the **General procedure.** DL-Proline (57.5 mg, 0.5 mmol) affords 3ae (97 mg, 94% using C1; 96 mg, 94% using C2). Slightly yellow oil was obtained after column chromatography (SiO₂, EtOAc/MeOH 70:30). **¹H NMR** (400 MHz, CDCl₃): δ 6.85 (d, J = 1.2 Hz, 1H), 6.77-6.72 (m, 2H), 5.92 (s, 2H), 3.54 (s, 2H), 2.53-2.50 (m, 4H), 1.80-1.76 (m, 4H). **¹³C NMR** (101 MHz, CDCl₃): δ 150.20, 149.17, 135.42, 124.69, 112.13, 110.54, 103.49, 62.82, 56.45, 26.03. **HRMS** (APCI⁺, m/z) calculated for C₁₂H₁₆NO₂ [M+H]⁺: 206.11756; found: 206.11736. The spectral data are identical to the previously reported.⁷

1-benzylpyrroldine (3af)

![Chemical structure](image)

The compound was synthesised according to the **General procedure.** DL-Proline (57.5 mg, 0.5 mmol) affords 3af (34 mg, 42% using C1; 46 mg, 58% using C2). Colorless solid was obtained after column chromatography (SiO₂, EtOAc/MeOH 50:50). **¹H NMR** (400 MHz, CD₂OD): δ 7.34-7.23 (m, 5H), 3.62 (s, 2H), 2.55-2.52 (m, 4H), 1.81-1.78 (m, 4H). **¹³C NMR** (101 MHz, CD₂OD): δ 139.66, 131.82, 130.72, 129.95, 62.42, 56.06, 25.30. **HRMS** (APCI⁺, m/z) calculated for C₁₁H₁₄N [M+H]⁺: 162.12773; found: 162.12732. The spectral data are identical to the previously reported.⁸

3-(pyrrolidin-1-ylmethyl)pyridine (3ag)

![Chemical structure](image)

The compound was synthesised according to the **General procedure.** DL-Proline (57.5 mg, 0.5 mmol) affords 3ag (31 mg, 40% using C1). Yellow oil was obtained after column chromatography (SiO₂, EtOAc/MeOH 90:10 to 70:30). **¹H NMR** (400 MHz, CD₂OD): δ 8.57 (d, J = 1.6 Hz, 1H), 8.51 (dd, J = 4.8 Hz, J = 1.2 Hz, 1H), 7.90 (d, J = 8.0 Hz, 1H), 7.47-7.44 (m, 1H), 3.91 (s, 2H), 2.81-2.77 (m, 4H), 1.91-1.88 (m, 4H). **¹³C NMR** (101 MHz, CD₂OD): δ 152.34, 150.94, 140.73, 135.31, 126.53, 58.92, 56.08, 25.33. **HRMS** (APCI⁺, m/z) calculated for C₁₀H₁₃N₂ [M+H]⁺: 163.12298; found: 163.12287. The spectral data are identical to the previously reported.⁹

1-(thiophen-2-ylmethyl)pyrroldine (3ah)

![Chemical structure](image)

The compound was synthesised according to the **General procedure.** DL-Proline (57.5 mg, 0.5 mmol) affords 3ah (28 mg, 33% using C1; 38 mg, 45% using C2). Slightly yellow oil was obtained after column chromatography (SiO₂, EtOAc/MeOH 90:10). **¹H NMR** (400 MHz, CDCl₃): δ 7.26-7.23 (m, 1H), 6.99-6.94 (m, 2H), 3.94 (s, 2H), 2.71-2.68 (m, 4H), 1.86-1.82 (m, 4H). **¹³C NMR** (151 MHz, CDCl₃): δ 140.46, 126.80, 126.72, 125.43, 54.09, 53.69, 23.58. **HRMS** (APCI⁺, m/z) calculated for C₉H₁₄NS [M+H]⁺: 168.08415; found: 168.08396.

1-(4-Fluorobenzyl)pyrroldine (3ai)

![Chemical structure](image)

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The compound was synthesised according to the **General procedure**. DL-Proline (57.5 mg, 0.5 mmol) affords 3ai (67 mg, 75% using C1; 23 mg, 26% using C2). Yellow-brown oil was obtained after column chromatography (SiO2, EtOAc/MeOH 90:10). 1H NMR (400 MHz, CDCl3): δ 7.27 (dd, J = 8.4 Hz, J = 5.6 Hz, 2H), 6.97 (t, J = 8.4 Hz, 2H), 3.56 (s, 2H), 2.50-2.46 (m, 4H), 1.78-1.75 (m, 4H). 13C NMR (101 MHz, CDCl3): δ 164.54 (d, J C-F = 246.4 Hz), 137.65 (d, J C-F = 3.0 Hz), 132.97 (d, J C-F = 8.1 Hz), 117.59 (d, J C-F = 21.2 Hz), 62.48, 56.69, 26.07. HRMS (APCI+, m/z) calculated for C11H13FN [M+H]+: 180.11830; found: 180.11807.

1-(4-Chlorobenzyl)pyrrolidine (3aj)

The compound was synthesised according to the **General procedure**. DL-Proline (57.5 mg, 0.5 mmol) affords 3aj (88 mg, 90% using C1; 67 mg, 68% using C2). Colorless oil was obtained after column chromatography (SiO2, EtOAc/MeOH 70:30). 1H NMR (400 MHz, CDCl3): δ 7.28-7.26 (m, 4H), 3.58 (s, 2H), 2.51-2.48 (m, 4H), 1.80-1.77 (m, 4H). 13C NMR (101 MHz, CDCl3): δ 140.32, 135.27, 132.83, 131.00, 62.52, 56.73, 26.09. HRMS (APCI+, m/z) calculated for C11H11ClN [M+H]+: 196.08875; found: 196.08835. The spectral data are identical to the previously reported.10]

1-(4-(Trifluoromethyl)benzyl)pyrrolidine (3ak)

The compound was synthesised according to the **General procedure**. DL-Proline (57.5 mg, 0.5 mmol) affords 3ak (96 mg, 84% using C1; 42 mg, 37% using C2). Orange-brown oil was obtained after column chromatography (SiO2, EtOAc/MeOH 90:10). 1H NMR (400 MHz, CDCl3): δ 7.56 (d, J = 8.0 Hz, 2H), 7.45 (d, J = 8.0 Hz, 2H), 3.66 (s, 2H), 2.52-2.49 (m, 4H), 1.80-1.77 (m, 4H). 13C NMR (151 MHz, CDCl3): δ 142.59, 128.14 (q, J C-F = 32.2 Hz), 127.94, 124.12 (q, J C-F = 3.8 Hz), 123.30 (q, J C-F = 272.0 Hz), 59.13, 53.17, 22.47. HRMS (APCI+, m/z) calculated for C12H15F3N [M+H]+: 230.11511; found: 230.11517.

4-(pyrrolidin-1-ylmethyl)benzonitrile (3al)

The compound was synthesised according to the **General procedure**. DL-Proline (57.5 mg, 0.5 mmol) affords 3al (77 mg, 83% using C1, 17 mg 18% using C2). Yellow oil was obtained after column chromatography (SiO2, EtOAc/MeOH 90:10). 1H NMR (400 MHz, CDCl3): δ 7.52 (d, J = 8.0 Hz, 2H), 7.39 (d, J = 8.4 Hz, 2H), 3.60 (s, 2H), 2.45-2.42 (m, 4H), 1.74-1.70 (m, 4H). 13C NMR (151 MHz, CDCl3): δ 145.25, 132.00, 129.26, 118.95, 110.57, 60.10, 54.16, 23.51. HRMS (APCI+, m/z) calculated for C12H15N2 [M+H]+: 187.12298; found: 187.12288.

Methyl 4-(pyrrolidin-1-ylmethyl)benzoate (3am)

The compound was synthesised according to the **General procedure**. DL-Proline (57.5 mg, 0.5 mmol) affords 3am (71 mg, 65% using C1, 15 mg 14% using C2). Orange-brown oil was obtained after column chromatography (SiO2, EtOAc/MeOH 90:10). 1H NMR (400 MHz, CDCl3): δ 7.95 (d,
The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords **3an** (102 mg, 99% using **C1**). Orange oil was obtained after column chromatography (SiO2, EtOAc/MeOH 90:10). **1H NMR** (400 MHz, CD2OD): δ 8.17 (d, J = 8.8 Hz, 2H), 7.57 (d, J = 8.8 Hz, 2H), 3.74 (s, 2H), 2.57-2.53 (m, 4H), 1.82-1.80 (m, 4H). **13C NMR** (101 MHz, CD3OD): δ 149.83, 148.90, 132.34, 125.68, 61.85, 56.29, 25.52. **HRMS** (APCI+, m/z) calculated for C12H18NO2 [M+H]+: 207.1128; found: 207.11284. The spectral data are identical to the previously reported.[11]  

1-(4-Nitrobenzyl)pyrrolidine (3an)  

\[
\text{O}_{2}\text{N} \quad \text{N}\n\]

The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords **3an** (102 mg, 99% using **C1**). Orange oil was obtained after column chromatography (SiO2, EtOAc/MeOH 90:10). **1H NMR** (400 MHz, CD2OD): δ 8.17 (d, J = 8.8 Hz, 2H), 7.57 (d, J = 8.8 Hz, 2H), 3.74 (s, 2H), 2.57-2.53 (m, 4H), 1.82-1.80 (m, 4H). **13C NMR** (101 MHz, CD3OD): δ 149.83, 148.90, 132.34, 125.68, 61.85, 56.29, 25.52. **HRMS** (APCI+, m/z) calculated for C12H18NO2 [M+H]+: 207.1128; found: 207.11284.  

1-(4-Methoxybenzyl)piperidine (3ba)  

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\text{O} \quad \text{N}\n\]

The compound was synthesised according to the General procedure. Piperidine-2-carboxylic acid (64.5 mg, 0.5 mmol) affords **3ba** (55 mg, 54% using **C2**). Colourless oil was obtained after column chromatography (SiO2, EtOAc/MeOH 70:30). **1H NMR** (400 MHz, CD2OD): δ 7.22 (d, J = 8.4 Hz, 2H), 6.85 (d, J = 8.8 Hz, 2H), 3.80 (s, 3H), 3.42 (s, 2H), 2.39-2.30 (m, 4H), 1.59-1.54 (m, 4H), 1.45-1.39 (m, 2H). **13C NMR** (101 MHz, CDCl3): δ 161.23, 133.08, 116.10, 65.83, 57.88, 56.96, 28.57, 27.04. **HRMS** (APCI+, m/z) calculated for C13H20NO [M+H]+: 206.15394; found: 206.15375.  

1-(4-Nitrobenzyl)piperidine (3bn)  

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\text{O}_{2}\text{N} \quad \text{N}\n\]

The compound was synthesised according to the General procedure. Piperidine-2-carboxylic acid (64.5 mg, 0.5 mmol) affords **3bn** (71 mg, 64% using **C1**). Colourless oil was obtained after column chromatography (SiO2, EtOAc/MeOH 90:10). **1H NMR** (400 MHz, CD2OD): δ 8.19 (d, J = 8.8 Hz, 2H), 7.58 (d, J = 8.8 Hz, 2H), 3.60 (s, 2H), 2.46-2.36 (br m, 4H), 1.63-1.57 (m, 4H), 1.49-1.44 (m, 2H). **13C NMR** (151 MHz, CD3OD): δ 148.64, 147.12, 131.35, 124.30, 63.73, 55.26, 26.70, 25.12. **HRMS** (APCI+, m/z) calculated for C12H17N2O2 [M+H]+: 221.12845; found: 221.12820.  

1-Cyclohexylpyrrolidine (3aq)  

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\text{N} \quad \text{N}\n\]

The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords **3aq** (43 mg, 57% using **C1**). Yellow oil was obtained after column chromatography (SiO2, EtOAc/MeOH 70:30 to 50:50). **1H NMR** (400 MHz, CD3OD): δ 2.75-2.72 (m, 4H), 2.24-2.18 (m, 1H), 2.04-2.01 (m, 2H), 1.85-1.77 (m, 6H), 1.67-1.64 (m, 1H), 1.35-1.15 (m, 5H). **13C NMR** (101 MHz, CD3OD): δ 66.69, 53.65, 33.66, 28.13, 27.45, 25.22. **HRMS** (APCI+, m/z) calculated for
C_{10}H_{20}N [M+H]^+: 154.15903; found: 154.15897. The spectral data are identical to the previously reported.\[8\]

1-(1,2,3,4-tetrahydronaphthalen-1-yl)pyrrolidine (3at)

The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords 3at (50 mg, 49% using C1). White solid was obtained after column chromatography (SiO\textsubscript{2}, EtOAc/MeOH 70:30). \textsuperscript{1}H NMR (400 MHz, CD\textsubscript{3}OD): δ 7.27-7.24 (m, 1H), 7.15-7.11 (m, 1H), 7.08-7.05 (m, 2H), 3.44-3.42 (m, 1H), 2.94-2.87 (m, 1H), 2.79-2.66 (m, 3H), 2.54-2.50 (m, 2H), 2.14-2.03 (m, 2H), 1.79-1.67 (m, 6H). \textsuperscript{13}C NMR (101 MHz, CD\textsubscript{3}OD): δ 140.07, 139.94, 132.20, 131.53, 129.46, 127.10, 64.27, 53.53, 30.81, 28.28, 25.43, 20.64. HRMS (APCI\textsuperscript{+}, m/z) calculated for C\textsubscript{10}H\textsubscript{20}N [M+H]^+: 202.15903; found: 202.15890.

1-(1-phenylethyl)pyrrolidine (3au)

The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords 3au (109 mg, 62% using C1; 98 mg, 56% using C2). White solid was obtained after column chromatography (SiO\textsubscript{2}, EtOAc/MeOH 90:10). \textsuperscript{1}H NMR (400 MHz, CD\textsubscript{3}OD): δ 7.36-7.22 (m, 5H), 3.35-3.33 (m, 1H), 2.70-2.64 (m, 2H), 2.46-2.42 (m, 2H), 1.84-1.77 (m, 4H), 1.44 (d, J = 6.8 Hz, 3H). \textsuperscript{13}C NMR (101 MHz, CD\textsubscript{3}OD): δ 130.79, 129.73, 129.65, 68.76, 55.29, 25.37, 23.84. HRMS (APCI\textsuperscript{+}, m/z) calculated for C\textsubscript{12}H\textsubscript{18}N [M+H]^+: 176.14338; found: 176.14337. The spectral data are identical to the previously reported.\[8\]

1-(3-phenylpropyl)pyrrolidine (3aw)

The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords 3aw (77 mg, 81% using C1). Yellow oil was obtained after column chromatography (SiO\textsubscript{2}, EtOAc/MeOH 70:30). \textsuperscript{1}H NMR (400 MHz, CD\textsubscript{3}OD): δ 7.27-7.24 (m, 2H), 7.19-7.13 (m, 3H), 2.63 (t, J = 7.6 Hz, 2H), 2.56-2.48 (m, 6H), 1.90-1.78 (m, 6H). \textsuperscript{13}C NMR (101 MHz, CD\textsubscript{3}OD): δ 144.34, 130.65, 130.64, 128.17, 58.27, 56.23, 36.05, 32.63, 25.40. HRMS (APCI\textsuperscript{+}, m/z) calculated for C\textsubscript{13}H\textsubscript{20}N [M+H]^+: 190.15903; found: 190.15911. The spectral data are identical to the previously reported.\[12\]

1-Nonylpyrrolidine (3ay)

The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords 3ay (53 mg, 54% using C1; 72 mg, 73% using C2). Colorless oil was obtained after column chromatography (SiO\textsubscript{2}, EtOAc/MeOH 70:30). \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}): δ 2.52-2.49 (m, 4H), 2.44-2.40 (m, 2H), 1.79-1.76 (m, 4H), 1.54-1.47 (m, 2H), 1.29-1.25 (m, 12H), 0.87 (t, J = 6.4
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Hz, 3H). $^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ 56.71, 54.20, 31.89, 29.61, 29.55, 29.29, 29.00, 27.74, 23.40, 22.67, 14.10. HRMS (APCI$^+$, m/z) calculated for C$_{13}$H$_{28}$N [M+H]$^+$: 198.22163; found: 198.22139.

1-Nonylpiperidine (3by)

The compound was synthesised according to the General procedure. Piperidine-2-carboxylic acid (64.5 mg, 0.5 mmol) affords 3by (58 mg, 55% using C1; 65 mg, 62% using C2). Colorless oil was obtained after column chromatography (SiO$_2$, EtOAc/MeOH 70:30). $^{1}$H NMR (400 MHz, CDCl$_3$): $\delta$ 2.42-2.30 (m, 4H), 2.27-2.23 (m, 2H), 1.60-1.54 (m, 4H), 1.50-1.41 (m, 4H), 1.29-1.18 (m, 12H), 0.86 (t, $J = 6.4$ Hz, 3H). $^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ 62.28, 57.23, 34.52, 32.25, 32.19, 31.92, 30.41, 29.51, 28.55, 27.11, 25.30, 16.73. HRMS (APCI$^+$, m/z) calculated for C$_{14}$H$_{30}$N [M+H]$^+$: 212.23728; found: 212.23742. The spectral data are identical to the previously reported.$^{[13]}$

1-((S,S,R,R,S,10S,13R,14S,17R)-10,13-dimethyl-17-((S)-6-methylheptan-2-yl)hexadecahydro-1H-cyclopenta[a]phenanthren-3-yl)piperidine (3az)

The compound was synthesised according to the General procedure. DL-Proline (57.5 mg, 0.5 mmol) affords 3az (110 mg, 50% using C1). White solid was obtained after column chromatography (SiO$_2$, EtOAc/MeOH 70:30 to 50:50). $^{1}$H NMR (400 MHz, CDCl$_3$): $\delta$ 2.59-2.53 (m, 4H), 1.98-1.91 (m, 2H), 1.83-0.78 (m, 45H), 0.64-0.58 (m, 4H). $^{13}$C NMR (151 MHz, CDCl$_3$): $\delta$ 64.45, 56.57, 56.31, 54.49, 51.73, 45.32, 42.62, 40.09, 39.53, 37.48, 36.19, 35.80, 35.75, 35.53, 32.17, 28.98, 28.26, 28.02, 24.21, 23.84, 23.21, 22.82, 22.57, 21.11, 18.68, 12.34, 12.08. HRMS (APCI$^+$, m/z) calculated for C$_{31}$H$_{56}$N [M+H]$^+$: 442.44073; found: 442.44132.

1-benzylpiperidine-2-carbonitrile (5a)

The compound was synthesised according to the General procedure. Mandelonitrile (133 mg, 1 mmol) affords 5a (132 mg, 71% using C1; 132 mg, 71% using C2; 7:1 mixture of regioisomers). Colorless liquid was obtained after column chromatography (SiO$_2$, EtOAc/pentane 5:95). Characterisation data of the major regioisomer: $^{1}$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.38-7.26 (m, 5H), 3.93 (d, $J = 12.8$ Hz, 1H), 3.71-3.66 (m, 2H), 2.97-2.91 (m, 1H), 2.59 (q, $J = 8.0$ Hz, 1H), 2.22-2.08 (m, 2H), 2.01-1.85 (m, 2H). $^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ 140.27, 131.50, 131.16, 130.15, 120.64, 59.19, 55.87, 53.87, 32.20, 24.56. HRMS (APCI$^+$, m/z) calculated for C$_{12}$H$_{15}$N$_2$ [M+H]$^+$: 187.12298; found: 187.12280. The spectral data are identical to the previously reported.$^{[14]}$
1-(4-methylbenzyl)pyrrolidine-2-carbonitrile (5b)

The compound was synthesised according to the **General procedure**. 4-Methylmandelonitrile (147 mg, 1 mmol) affords **5b** (148 mg, 74% using **C1**; 144 mg, 72% using **C2**; 3:1 mixture of regioisomers). Colorless liquid was obtained after column chromatography (SiO₂, EtOAc/pentane 5:95). Characterisation data of the major regioisomer: **¹H NMR** (400 MHz, CDCl₃): δ 7.26 (d, J = 8.0 Hz, 2H), 7.15 (d, J = 7.6 Hz, 2H), 3.89 (d, J = 13.2 Hz, 1H), 3.70-3.68 (m, 1H), 3.64 (d, J = 12.8 Hz, 1H), 2.97-2.91 (m, 1H), 2.58 (q, J = 8.4 Hz, 1H), 2.35 (s, 3H), 2.21-2.07 (m, 2H), 2.00-1.86 (m, 2H). **¹³C NMR** (101 MHz, CDCl₃): δ 139.77, 137.21, 131.83, 131.47, 120.66, 58.88, 55.79, 53.82, 32.18, 24.54, 23.79. **HRMS** (APCI⁺, m/z) calculated for C₁₃H₁₇N₂ [M+H]⁺: 201.13863; found: 201.13835. The spectral data are identical to the previously reported.[¹⁵]

1-(4-chlorobenzyl)pyrrolidine-2-carbonitrile (5c)

The compound was synthesised according to the **General procedure**. 4-chloromandelonitrile (167.6 mg, 1 mmol) affords **5c** (164 mg, 75% using **C1**; 168 mg, 76% using **C2**; 11:1 mixture of regioisomers). Colorless liquid was obtained after column chromatography (SiO₂, EtOAc/pentane 5:95). Characterisation data of the major regioisomer: **¹H NMR** (400 MHz, CDCl₃): δ 7.29 (m, 4H), 3.86 (d, J = 13.2 Hz, 1H), 3.68-3.66 (m, 1H), 3.63 (d, J = 13.2 Hz, 1H), 2.93-2.87 (m, 1H), 2.56 (q, J = 8.0 Hz, 1H), 2.21-2.07 (m, 2H), 2.00-1.85 (m, 2H). **¹³C NMR** (101 MHz, CDCl₃): δ 138.83, 135.87, 132.78, 131.29, 120.48, 58.46, 55.84, 53.84, 32.18, 24.59. **HRMS** (APCI⁺, m/z) calculated for C₁₂H₁₄ClN₂ [M+H]⁺: 221.08400; found: 221.08370. The spectral data are identical to the previously reported.[¹⁵]
$^1$H and $^{13}$C NMR spectra

Supplementary Figure 8: $^1$H and $^{13}$C NMR of compound 3aa.
Supplementary Figure 9: $^1$H and $^{13}$C NMR of compound 3ab.
Supplementary Figure 10: $^1$H and $^{13}$C NMR of compound 3ac.
Supplementary Figure 11: $^1$H and $^{13}$C NMR of compound 3ad.
Supplementary Figure 12: $^1$H and $^{13}$C NMR of compound 3ae.
Supplementary Figure 13: $^1$H and $^{13}$C NMR of compound 3af.
Supplementary Figure 14: $^1$H and $^{13}$C NMR of compound 3ag.
Supplementary Figure 15: $^1$H and $^{13}$C NMR of compound 3ah.
Supplementary Figure 16: $^1$H and $^{13}$C NMR of compound 3ai.
Supplementary Figure 17: $^1$H and $^{13}$C NMR of compound 3aj.
Supplementary Figure 18: $^1$H and $^{13}$C NMR of compound 3ak.
Supplementary Figure 19: $^1$H and $^{13}$C NMR of compound 3al.
**Supplementary Figure 20:** $^1$H and $^{13}$C NMR of compound 3am.
Supplementary Figure 21: $^1$H and $^{13}$C NMR of compound 3an.
Supplementary Figure 22: $^1$H and $^{13}$C NMR of compound 3ba.
Supplementary Figure 23: $^1$H and $^{13}$C NMR of compound 3bn.
Supplementary Figure 24: $^1$H and $^{13}$C NMR of compound 3aq.
Supplementary Figure 25: $^1$H and $^{13}$C NMR of compound 3at.
Supplementary Figure 26: $^1$H and $^{13}$C NMR of compound 3au.
Supplementary Figure 27: $^1$H and $^{13}$C NMR of compound 3aw.
Supplementary Figure 28: $^1$H and $^{13}$C NMR of compound 3ay.
Supplementary Figure 29: \( ^1\)H and \( ^{13}\)C NMR of compound 3by.
Supplementary Figure 30: $^1$H and $^{13}$C NMR of compound 3az.
Supplementary Figure 31: $^1$H and $^{13}$C NMR of compound 5a.
Supplementary Figure 32: $^1$H and $^{13}$C NMR of compound 5b.
Supplementary Figure 33: $^1$H and $^{13}$C NMR of compound 5c.
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