Enantioselective Narasaka-Heck Cyclizations: Synthesis of Tetrasubstituted Nitrogen-Bearing Stereocenters

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General experimental details

Starting materials sourced from commercial suppliers were used as received unless otherwise stated. Dry solvents, where necessary, were obtained by distillation using standard procedures or by passage through a column of anhydrous alumina using equipment from Anhydrous Engineering based on the Grubbs’ design. Petrol refers to the fraction of petroleum ether boiling in the range of 40-60 °C. The removal of solvents in vacuo was achieved using both a Büchi rotary evaporator (bath temperatures up to 40 °C) at a pressure of either 15 mmHg (diaphragm pump) or 0.1 mmHg (oil pump), as appropriate, and a high vacuum line at room temperature. Reactions requiring anhydrous conditions were run under an atmosphere of dry nitrogen; glassware, syringes and needles were either flame-dried immediately prior to use or placed in an oven (150 °C) for at least 2 h and allowed to cool either in a desiccator or under high vacuum on a Schlenk line; liquid reagents, solutions or solvents were added via syringe through rubber septa; solid reagents were added via Schlenk type adapters. Commercially available Merck Kieselgel 60F254 aluminium-backed plates were used for TLC analysis. Visualisation was achieved by UV fluorescence and/or basic KMnO4 solution and heat. Flash column chromatography (FCC) was performed using Merck Kieselgel 60 (40–63 μm). The crude material was applied to the column as a solution of either the appropriate eluent or minimum amount of CH2Cl2, or by pre-adsorption onto silica, as appropriate. Melting points were determined using a Gallenkamp melting point apparatus and temperature controller and are uncorrected. Optical rotations were measured using an ADP220 polarimeter (Bellingham & Stanley Ltd.) and are reported in deg.cm2.g−1. Infra-red spectra were recorded in the range 4000-600 cm−1 on a Perkin Elmer Spectrum One spectrometer either as neat films or solids compressed onto a diamond window. Abbreviations used are: w (weak), m (medium), s (strong) and br. (broad). NMR spectra were recorded on a JEOL Eclipse 300, JEOL ECS 400, Varian 400-MR, Varian VNMR S500a or Varian VNMR S500b spectrometer. Chemical shifts are quoted in parts per million (ppm); 1H NMR spectra are referenced to residual protons of the deuterated solvent as an internal standard; 13C NMR are referenced to the deuterated solvent as an internal standard; 19F NMR spectra are referenced to CCl3F as an external standard; 31P NMR spectra are referenced to H3PO4 as an external standard. Coupling constants (J) are quoted to the nearest 0.5 Hz for 1H NMR and nearest 0.1 Hz for 13C NMR. Other abbreviations used are: s (singlet), d (doublet), t (triplet), q (quartet), hep (heptet), m (multiplet), and br (broad). Assignments of 1H NMR and 13C NMR signals were made, where possible, using COSY, DEPT, HMQC, HMBC and nOe experiments. The proton and carbon assignments are
listed based on the ‘non-IUPAC’ numbering system associated with each structure. Mass spectra were determined by the University of Bristol mass spectrometry service by either electron impact (EI+) or chemical ionisation (CI+) using a VG Micromass Autosepec spectrometer, or by electrospray ionisation (ESI+) using a Brüker Daltonics MicrOTOF II spectrometer. Chiral HPLC was performed using either the racemate or the antipode as a standard on an Agilent 1290 Infinity system equipped with a quaternary pump, diode array detector and column thermostat under the conditions specified in each case.

**General Procedures**

**General Procedure A for the preparation of alcohol precursors from the corresponding aldehyde/esters:** To a solution of the appropriate ester/aldehyde (100 mol%) in anhydrous THF (1 mL/mmol) at 0 °C was slowly added 1M LiAlH₄ (110 mol%) in THF (2 mL/mmol). The mixture was stirred at room temperature until complete consumption of ester/aldehyde was observed by TLC (approx. 1-5 hours). The mixture was cooled to 0 °C and water (0.5 mL/mmol), NaOH (1 mL/mmol) and water (1 mL/mmol) were added sequentially. The suspension was filtered through celite®, washing with CH₂Cl₂ (150 mL/mmol), and the resulting solution was concentrated *in vacuo*. Purification of the residue by FCC under the conditions noted, afforded the corresponding alcohol.

**General Procedure B for the preparation of bromide precursors from the corresponding alcohol:**
To a solution of the appropriate alcohol (100 mol%) in Et₂O (2 mL/mmol) at 0 °C was added PBr₃ (50 mol%). The solution was warmed to room temperature and stirred for 16 hours. The reaction was cooled to 0 °C and water (1 mL/mmol) and 5% aq. K₂CO₃ (1 mL/mmol) were added. The organic portion was isolated, washed with brine (1 mL/mmol), dried (Na₂SO₄) and concentrated *in vacuo* to afford the corresponding bromide, which was used in the next stage without further purification unless otherwise stated.

**General Procedure C for the preparation of ketone precursors via the corresponding β-keto ester.**

**Part A:** To NaH (100 mol%, 60% dispersion in mineral oil), the appropriate β-keto ester (100 mol%) was added at 0 °C. Anhydrous DMF (5 mL/mmol) was added to the reaction via cannula. The mixture was stirred at room temperature until gas evolution ceased (approx. 15 minutes). The appropriate chloride/bromide (110 mol%) was then added *via* syringe and the mixture was heated at 70 °C for 16 hours. The mixture was cooled to room temperature and the solvent removed by concentration *in vacuo* to afford the alkylated product which was used without further purification unless otherwise stated. **Part B:** To the residue in THF (2 mL/mmol), MeOH (1 mL/mmol), water (1 mL/mmol) and KOH (500 mol%) were added. The mixture was then heated at 75 °C until complete consumption of intermediate
ester was observed by TLC (approx. 6-16 hours). After cooling to room temperature, the mixture was acidified with aq. 1 M HCl (8 mL/mmol) and extracted with Et₂O (20 mL/mmol). The organic extracts were washed with brine (10 mL/mmol), dried (Na₂SO₄) and concentrated \textit{in vacuo}. Purification of the residue by FCC, under the conditions noted, afforded the corresponding alkylated ketone.

**General Procedure D for oxime ester formation:** Part A: H₂NOH·HCl (120 mol%) and NaOAc (120 mol%) were added to a solution of the appropriate ketone (100 mol%) in MeOH (3 mL/mmol). The mixture was heated at 75 °C for the specified time. After cooling to room temperature, the mixture was diluted with EtOAc (10 mL/mmol), washed with brine (10 mL/mmol), dried (Na₂SO₄) and concentrated \textit{in vacuo}. The oxime obtained in this way was used in the next stage without further purification, unless otherwise stated. Part B: To a solution of the appropriate oxime (100 mol%) in anhydrous CH₂Cl₂ (3 mL/mmol) at 0 °C was added, \textit{via} syringe, Et₃N (200 mol%) and then ClC(O)C₆F₅ (120 mol%). The mixture was then warmed to room temperature and stirred for the specified time. MeOH (0.5 mL/mmol) and then EtOAc (15 mL/mmol) were added. The mixture was then washed with saturated aq. Na₂CO₃ (2 × 15 mL/mmol) and brine (15 mL/mmol), dried (Na₂SO₄) and concentrated \textit{in vacuo}. The residue was purified by FCC, under the conditions noted, to afford the corresponding oxime ester.

**General Procedure E for asymmetric Narasaka-Heck cyclizations:** An oven-dried reaction tube, fitted with magnetic stirrer, was charged with Pd₂(dba)₃ (3.75 mol%), (S₆,S₆)-L-2f (7.5 mol%) and oxime ester substrate (100 mol%). The tube was fitted with a rubber septum and purged with argon. Anhydrous DMF (10 mL/mmol) and then reagent grade Et₃N (200 mol%) were added \textit{via} syringe. The mixture was then placed in a preheated oil bath at the specified temperature until complete consumption of starting material was observed (approx. 1-7 hours, as noted). The mixture was then cooled to room temperature and concentrated \textit{in vacuo} (approx. 1.0 mmHg). The residue was purified by flash column chromatography, under the conditions noted, to afford the target heterocycle.
**Experimental Procedures**

The synthesis of binaphthyl \( P,N \)-ligand \((S,\text{S})\)-L-1 was carried out following reported literature procedures.\(^1\)\(^2\)

The synthesis of H8-binaphthyl \( P,N \)-ligand \((S,\text{S})\)-L-3 was carried out following reported literature procedures.\(^3\)

\[(S)-2'-(\text{Diphenylphosphoryl})-N-((S)-1-hydroxy-3-phenylpropan-2-yl)-5,5',6,6',7,7',8,8'-\text{octahydro-}[1,1'-\text{binaphthalene}]\text{-2-carboxamide} \]

\[{[\alpha]}_{D}^{21} = -53.0 \text{ (c = 1.0, CHCl}_3\text{).} \]

**\( ^1\text{H NMR} \)** (400 MHz, CDCl\(_3\)): 8.31 (d, \( J = 8.5 \text{ Hz}, \text{1H, NH} \)), 7.78-7.68 (m, \( 3\text{H, ArH} \)), 7.54-7.25 (m, \( 10\text{H, ArH} \)), 7.21-7.08 (m, \( 4\text{H, ArH} \)), 4.13-4.06 (m, \( 1\text{H, CH}_2 \)), 3.38 (dd, \( J = 11.5, 3.0 \text{ Hz}, \text{1H, CH}_3 \)), 3.26 (dd, \( J = 11.5, 4.0 \text{ Hz}, \text{1H, CH}_3 \)), 2.96-2.86 (m, \( 2\text{H, CH}_2 \)), 2.84-2.72 (m, \( 2\text{H, CH}_2 \)), 2.54-2.43 (m, \( 2\text{H, CH}_2 \)), 2.29-2.21 (m, \( 1\text{H, CH}_2 \)), 1.88 (dt, \( J = 18.0, 6.5 \text{ Hz}, \text{1H, CH}_2 \)), 1.75-1.50 (m, \( 5\text{H, CH}_2 \)), 1.38-1.20 (m, \( 4\text{H, CH}_2 \)), 0.87-0.78 (m, \( 1\text{H, CH}_2 \)).

**\( ^{13}\text{C NMR} \)** (100 MHz, CDCl\(_3\)): 170.7 (\( \text{C}O \)), 144.2 (d, \( J = 8.2, \text{ArC} \)), 143.2 (d, \( J = 2.6, \text{ArC} \)), 141.5 (\( \text{ArC} \)), 138.9 (d, \( J = 10.4, \text{ArC} \)), 138.6 (d, \( J = 14.9, \text{ArC} \)), 135.4 (\( \text{ArC} \)), 134.7 (d, \( J = 4.2, \text{ArC} \)), 134.6 (\( \text{ArC} \)), 132.0 (d, \( J = 9.2, \text{ArCH} \)), 131.9 (d, \( J = 105.1, \text{ArC} \)), 131.9 (d, \( J = 2.8, \text{ArCH} \)), 131.4 (d, \( J = 2.9, \text{ArCH} \)), 131.3 (d, \( J = 9.8, \text{ArCH} \)), 130.7 (d, \( J = 13.6, \text{ArCH} \)), 130.4 (d, \( J = 104.6, \text{ArC} \)), 129.2 (\( \text{ArCH} \)), 129.2 (\( \text{ArCH} \)), 128.5 (d, \( J = 11.9, \text{ArCH} \)), 128.3 (\( \text{ArCH} \)), 128.1 (d, \( J = 14.0, \text{ArCH} \)), 128.0 (d, \( J = 12.5, \text{ArCH} \)), 126.3 (\( \text{ArCH} \)), 126.2 (\( \text{ArCH} \)), 126.0 (d, \( J = 104.4, \text{ArC} \)), 125.3 (\( \text{ArCH} \)), 124.2 (\( \text{ArCH} \)), 117.9 (\( \text{ArCH} \)), 110.6 (\( \text{ArCH} \)), 63.0 (\( \text{CH}_2 \)), 53.3 (\( \text{CH} \)), 36.9 (\( \text{CH}_2 \)), 30.3 (\( \text{CH}_2 \)), 29.6 (\( \text{CH}_2 \)), 27.0 (2C, \( 2 \times \text{CH}_2 \)), 22.9 (\( \text{CH}_2 \)), 22.3 (\( \text{CH}_2 \)), 22.2 (\( \text{CH}_2 \)), 22.0 (\( \text{CH}_2 \)).

**\( ^{31}\text{P NMR} \)** (162 MHz, CDCl\(_3\)): 31.5 (s).

**MS**: (ESI\(^+\)) Found [M+H]\(^+\): 640.2975, C\(_{42}\)H\(_{43}\)NO\(_3\)PN requires 640.2975.
((S)-2'-(S)-4-Benzyl-4,5-dihydrooxazol-2-yl)-5',6',6',7',7',8,8'-octahydro-[1,1'-binaphthalen]-2-yl)diphenylphosphine oxide

[a]D^11 -7.76 (c = 1.16, CHCl₃).

1H NMR (400 MHz, CDCl₃): 7.66-7.60 (m, 2H, ArH), 7.43-7.06 (m, 16H, ArH), 6.89 (d, J = 8.0 Hz, 1H, ArH), 4.17 (dddd, J = 9.5, 7.5, 7.5, 7.0 Hz, 1H, CH₂), 3.95 (dd, J = 9.5, 8.0 Hz, 1H, CH₂), 3.69 (t, J = 8.0 Hz, 1H, CH₂), 2.83-2.70 (m, 5H, CH₂), 2.51-2.43 (m, 2H, CH₂), 2.19 (dt, J = 17.0, 6.5 Hz, 1H, CH₂), 1.94-1.81 (m, 3H, CH₂), 1.76-1.49 (m, 7H, CH₂).

13C NMR (100 MHz, CDCl₃): 162.9 (CN), 145.1 (d, J = 8.5, ArC), 141.2 (d, J = 2.8, ArC), 140.4 (ArC), 138.9 (ArC), 138.6 (d, J = 4.2, ArC), 136.4 (d, J = 10.5, ArC), 134.8 (d, J = 102.7, ArC), 133.4 (d, J = 102.7, ArC), 132.1 (d, J = 9.3, ArCH), 131.8 (d, J = 9.7, ArCH), 131.1 (d, J = 11.9, ArCH), 130.9 (d, J = 2.8, ArCH), 130.3 (d, J = 2.8, ArCH), 129.1 (ArCH), 128.6 (ArCH), 128.2 (ArCH), 127.8 (d, J = 11.8, ArCH), 127.3 (ArCH), 127.3 (d, J = 105.4, ArC), 127.2 (ArCH), 126.5 (ArCH), 126.1 9 ArCH), 124.0 (ArC), 70.8 (CH₂), 68.1 (CH), 42.0 (CH₂), 30.4 (CH₂), 30.2 (CH₂), 27.9 (CH₂), 27.1 (CH₂), 23.3 (CH₂), 23.1 (CH₂), 22.6 (CH₂), 22.4 (CH₂), 1 × ArC not observed.

31P NMR (162 MHz, CDCl₃): 28.1 (s).

FTIR: 2927, 1642, 1436, 1177, 1115, 1071 cm⁻¹.

MS: (ESI⁺) Found [M+H]⁺: 622.2876, C₂₂H₄₁NO₃P requires 622.2869.

(S)-4-Benzyl-2-(S)-2'-(diphenylphosphanyl)-5',6',6',7',7',8,8'-octahydro-[1,1'-binaphthalen]-2-yl)-4,5-dihydrooxazole (Sₜₜ,S) L-3

[a]D^11 -70.1 (c = 1.0, CHCl₃).

1H NMR (400 MHz, CDCl₃): 7.71 (d, J = 8.0 Hz, 1H, ArH), 7.27-7.02 (m, 18H, ArH), 4.13 (ddd, J = 9.5, 7.5, 6.5 Hz, 1H, CH₂), 3.83 (dd, J = 9.5, 8.0 Hz, 1H, CH₂), 3.61 (dd, J = 8.0, 8.0 Hz, 1H, CH₂), 2.89-2.77 (m, 5H, CH₂), 2.40-2.33 (m, 2H, CH₂), 2.10-2.02 (m, 1H, CH₂), 1.94-1.90 (m, 2H, CH₂), 1.74-1.55 (m, 6H, CH₂), 1.51-1.41 (m, 1H, CH₂), 1.32-1.23 (m, 1H, CH₂).

13C NMR (100 MHz, CDCl₃): 163.6 (CN), 147.1 (ArC), 146.8 (ArC), 140.7 (d, J = 8.7, ArC), 140.5 (ArC), 138.9 (d, J = 13.0, ArC), 138.4 (d, J = 13.4, ArC), 138.1 (d, J = 1.1, ArC), 136.0 (d, J = 1.9, ArC), 135.2 (d, J = 6.9, ArC), 134.0 (d, J = 20.5, ArCH), 133.4 (d, J = 18.8, ArCH), 132.8 (d, J = 6.8, ArC), 131.3 (d, J = 2.3, ArCH), 129.1 (ArCH), 128.3 (2C, 2 × ArCH), 128.2 (ArCH), 128.1 (d, J = 7.0, ArCH), 128.0 (ArCH), 127.7 (d, J = 5.8, ArCH), 127.5 (ArCH), 126.7 (ArCH), 126.1 (ArCH), 124.8 (d, J = 3.0, ArC), 70.8 (CH₂), 68.1 (CH), 42.0, 30.4, 30.2, 27.9, 27.1, 23.3, 23.1, 22.6, 22.4 (9 × CH₂).

31P NMR (162 MHz, CDCl₃): -15.5 (s).
The synthesis of enantioenriched triflate (S)-S1 was carried out following procedures which were, in some cases, different to the original report.

1,5-Bis(3-methoxyphenyl)pentan-3-one
To a solution of NaOH (22.7 g, 568 mmol) in H₂O (200 mL) and EtOH (200 mL) at 0 °C was added a solution of acetone (8.14 mL, 111 mmol) and m-anisaldehyde (27.0 mL, 222 mmol) in EtOH (50 mL) dropwise over 30 minutes. During this time the reaction mixture turned from colorless to yellow. After the addition was complete the reaction mixture was stirred for a further 2 hours after which time it was diluted with CH₂Cl₂ (150 mL) and the phases were separated. The organic layer was washed with H₂O/brine (1:1, 140 mL), dried (Na₂SO₄), filtered and concentrated in vacuo to give crude 1,5-bis(3-methoxyphenyl)-1,4-pentadien-3-one as a viscous, yellow oil (32.6 g). This material was used in the next step without further purification.

^1H NMR (400 MHz, CDCl₃): 7.70 (d, J = 16.0 Hz, 2H, CH), 7.33 (t, J = 8.0 Hz, 2H, ArCH), 7.21 (d, J = 7.5 Hz, 2H, ArCH), 7.13 (t, J = 2.0 Hz, 2H, ArCH), 7.06 (d, J = 16.0 Hz, 2H, CH), 6.96 (ddd, J = 8.0, 2.5, 1.0 Hz, 2H, ArCH), 3.85 (s, 6H, OCH₃).

The crude 1,5-bis(3-methoxyphenyl)-1,4-pentadien-3-one (assuming 111 mmol) was dissolved in EtOAc (300 mL) and Pd/C (760 mg, 10% Pd, 7.20 mmol) was added under nitrogen. The atmosphere was saturated with hydrogen gas (1 atm) and stirred vigorously under a balloon of hydrogen until consumption of starting material was confirmed by TLC. The reaction mixture was then degassed with argon, filtered through a pad of celite® and concentrated in vacuo. Purification of the residue (4:1 hexane:EtOAc) afforded the title compound (15.5 g, 47% over 2 steps) as a colorless oil.

^1H NMR (400 MHz, CDCl₃): 7.20-7.15 (2H, m, ArH), 6.74-6.70 (6H, m, ArH), 3.77 (6H, s, OCH₃), 2.85 (t, J = 8.0 Hz, 4H, CH₂), 2.69 (t, J = 8.0 Hz, 4H, CH₂).

^13C NMR (100 MHz, CDCl₃): 209.4 (CO), 160.1 (ArC), 143.1 (ArC), 129.9, 121.0, 114.6, 111.8 (4 × ArCH), 55.6 (OCH₃), 44.9 (CH₂), 30.3 (CH₂). The spectroscopic properties of this compound were consistent with the data available in the literature.4

1,5-Bis(2-bromo-5-methoxyphenyl)pentan-3-one
To a solution of 1,5-bis(3-methoxyphenyl)pentan-3-one (15.5 g, 52.0 mmol) in acetone (100 mL) at 0 °C was added N-bromosuccinimide (19.4 g, 109 mmol) portionwise under nitrogen, followed by a few drops of aq. 1 M HCl. After 1 minutes, the cloudy reaction mixture turned clear which indicated reaction
completion. The mixture was then concentrated in vacuo and the residue was redissolved in Et₂O (300 mL), washed with H₂O (100 mL), brine (100 mL), dried (Na₂SO₄), filtered and concentrated in vacuo to give the title compound (23.3 g, 99%) as a colorless oil that solidified on standing. This material was used in the next step without further purification.

**¹H NMR** (400 MHz, CDCl₃): 7.39 (d, J = 8.5 Hz, 2H, ArH), 6.77 (d, J = 3.0 Hz, 2H, ArH), 6.63 (dd, J = 8.5, 3.0 Hz, 2H, ArH), 3.76 (s, 6H, OCH₃), 2.96 (dd, J = 8.5, 7.0 Hz, 4H, CH₂), 2.73 (dd, J = 8.5, 7.0 Hz, 4H, CH₂). The spectroscopic properties of this compound were consistent with the data available in the literature.

4,4'-Dibromo-7,7'-dimethoxy-2,2',3,3'-tetrahydro-1,1'-spirobi[indene]

A heterogeneous solution of 1,5-bis(2-bromo-5-methoxyphenyl)pentan-3-one (4.54 g, 10.0 mmol) and phosphotungstic acid hydrate (4.32 g, 1.50 mmol) in toluene (60 mL) was heated at 140 °C under Dean-Stark conditions for 18 hours. The reaction mixture was then filtered through a pad of celite®, washing with CHCl₃ (150 mL). The filtrate was concentrated in vacuo and purification of the residue by FCC (20:1 hexane:EtOAc), followed by trituration of the resulting solid with ice-cold Et₂O, afforded the title compound (2.83 g, 65%) as a colorless solid.

**¹H NMR** (400 MHz, CDCl₃): 7.26 (d, J = 8.5 Hz, 2H, ArH), 6.52 (dd, J = 8.6, 0.5 Hz, 2H, ArH), 3.52 (s, 6H, OCH₃), 3.07 (dddd, J = 16.5, 9.0, 4.0, 0.5 Hz, 2H, CH₂), 2.95 (dddd, J = 16.5, 8.0, 8.0, 1.0 Hz, 2H, CH₂), 2.32 (dddd, J = 13.0, 9.0, 8.0, 0.5 Hz, 2H, CH₂), 2.16 (dddd, J = 12.5, 8.4, 4.0 Hz, 2H, CH₂). **¹³C NMR** (100 MHz, CDCl₃): 155.5, 144.9, 138.0 (3 × ArC), 130.2, 100.7, 110.4 (3 × ArCH), 61.9 (C), 55.2 (OCH₃), 37.8 (CH₂), 33.1 (CH₂). The spectroscopic properties of this compound were consistent with the data available in the literature.

4,4'-Dibromo-2,2',3,3'-tetrahydro-1,1'-spirobi[indene]-7,7'-diol

To a Schlenk tube containing CH₂Cl₂ (60 mL) at -78 °C was added BBr₃ (6.00 mL, 62.3 mmol) in one portion via syringe. Separately, a -78 °C solution of 4,4'-dibromo-7,7'-dimethoxy-2,2',3,3'-tetrahydro-1,1'-spirobi[indene] (11.5 g, 26.4 mmol) in CH₂Cl₂ (110 mL) was prepared. The BBr₃ solution was cannula-transferred to the solution of 4,4'-dibromo-7,7'-dimethoxy-2,2',3,3'-tetrahydro-1,1'-spirobi[indene] over 10 minutes. The reaction mixture was warmed to room temperature and stirred.
until complete conversion to product was observed by TLC analysis (approx. 48 hours). The mixture was diluted with CH₂Cl₂ (125 mL), cooled to 0 °C and carefully quenched with saturated aq. NaHCO₃ (250 mL). The layers were separated and the organic layer washed with brine (100 mL), dried (Na₂SO₄), filtered and concentrated in vacuo to give 4,4'-dibromo-2,2',3,3'-tetrahydro-1,1'-spirobi[indene]-7,7'-diodiol (10.2 g, 95%) as a colorless foam. This material was used in the next step without further purification.

**1H NMR** (400 MHz, CDCl₃): 7.30 (d, J = 8.5 Hz, 2H, ArH), 6.59 (dt, J = 8.5, 0.5, 2H, ArH), 3.11-2.94 (m, 4H, CH₂), 2.31 (ddd, J = 13.0, 7.5, 2.0, 2H, CH₂), 2.24-2.15 (m, 2H, CH₂). The spectroscopic properties of this compound were consistent with the data available in the literature.

7(S)-4,4'-Dibromo-2,2',3,3'-tetrahydro-1,1'-spirobi[indene]-7,7'-diyl bis((1R,2S,5R)-2-isopropyl-5-methylcyclohexyl) bis(carbonate)

To a solution of NaOH (4.44 g, 111 mmol) in H₂O (75 mL) was added 4,4'-dibromo-2,2',3,3'-tetrahydro-1,1'-spirobi[indene]-7,7'-diol (10.2 g, 25.0 mmol) and a solution of tetrabutylammonium bromide (3.72 g, 11.5 mmol) in CHCl₃ (75 mL). The mixture was cooled to 0 °C and (1R)-(-)-menthyl chloroformate (16.0 mL, 74.7 mmol) was added dropwise over 10 minutes. The reaction mixture was warmed to room temperature and stirred for 10 minutes. After this time, the phases were separated and the aqueous phase was extracted with CH₂Cl₂ (2 × 50 mL). The combined organic phases were washed with brine (50 mL), dried (Na₂SO₄), filtered and concentrated in vacuo. Recrystallisation of the residue from hot hexane (approx. 700 mL) afforded the title compound (6.97 g, 36%) as a colorless solid.

[^2]D -83.8 (c = 0.8, CHCl₃) [Lit. 7[^2]D -91.0 (c = 1.0, CHCl₃)].

**M.P.** 218-220 °C (hexane) [Lit. 7 220-222 °C (hexane)].

**1H NMR** (500 MHz, CDCl₃): 7.35 (d, J = 8.5 Hz, 2H, ArH), 6.87 (d, J = 8.5 Hz, 2H, ArH), 4.36 (ddd, J = 11.0, 11.0, 4.5 Hz, 2H, CH₃), 3.10-2.96 (m, 4H, CH₂), 2.31-2.22 (m, 4H, CH₂), 1.87-1.83 (m, 2H, CH₂), 1.67-1.60 (m, 6H, CH₂), 1.44-1.35 (m, 2H, CH₂), 1.30 (ddt, J = 12.5, 11.0, 3.0 Hz, 2H, CH₂), 1.01-0.78 (m, 18H, CH₂), 0.71 (d, J = 7.0 Hz, 6H, CH₂). The spectroscopic properties of this compound were consistent with the data available in the literature.
Bis((1R,2S,5R)-2-isopropyl-5-methylcyclohexyl) ((S)-2,2',3,3'-tetrahydro-1,1'-spirobi[indene]-7,7'-diyl) bis(carbonate) 

To a solution of (S)-4,4'-dibromo-2,2',3,3'-tetrahydro-1,1'-spirobi[indene]-7,7'-diyl bis((1R,2S,5R)-2-isopropyl-5-methylcyclohexyl) bis(carbonate) (3.16 g, 4.09 mmol) in THF (80 mL) at -78 °C was added n-BuLi (1.58 M in hexane, 6.46 mL, 10.2 mmol). The reaction was stirred at this temperature for 1 hour followed by addition of AcOH (2.05 mL, 35.9 mmol). The reaction mixture was then warmed to room temperature and concentrated in vacuo. The residue was taken up in Et₂O (300 mL), washed with saturated aq. NaHCO₃ (50 mL), H₂O (50 mL), brine (50 mL), dried (Na₂SO₄), filtered and concentrated in vacuo to yield bis((1R,2S,5R)-2-isopropyl-5-methylcyclohexyl) ((S)-2,2',3,3'-tetrahydro-1,1'-spirobi[indene]-7,7'-diyl) bis(carbonate) (2.52 g, quant.) as a colorless solid. This material was used in the next step without further purification.

¹H NMR (400 MHz, CDCl₃): 7.19 (t, J = 7.5 Hz, 2H, ArH), 7.10 (d, J = 7.5 Hz, 2H, ArH), 6.92 (d, J = 8.0 Hz, 2H, ArH), 4.34 (td, J = 11.0, 4.5 Hz, 2H, CH), 3.07-2.91 (m, 4H, CH₂), 1.91-1.86 (m, 2H, CH), 1.64-1.17 (m, 10H, CH), 1.00-0.75 (m, 18H, CH₂), 0.67 (d, J = 7.0 Hz, 6H, CH). The spectroscopic properties of this compound were consistent with the data available in the literature.

(S)-2,2',3,3'-Tetrahydro-1,1'-spirobi[indene]-7,7'-diol

To a solution of KOH (22.0 g, 396 mmol) in 10% degassed H₂O/EtOH (460 mL) was added bis((1R,2S,5R)-2-isopropyl-5-methylcyclohexyl) ((S)-2,2',3,3'-tetrahydro-1,1'-spirobi[indene]-7,7'-diyl) bis(carbonate) (2.52 g, 4.09 mmol). The resulting reaction mixture was heated at reflux for 1 hour after which time consumption of starting material was evidenced by TLC analysis. The mixture was cooled to room temperature and the EtOH removed in vacuo. The aqueous phase was extracted with hexane (2 × 90 mL) and then acidified to pH 2 through dropwise addition of 2 M HCl, during which time a white precipitate was formed. The suspension was extracted with Et₂O (2 × 150 mL) and the combined organic phases were dried (Na₂SO₄) and concentrated in vacuo to yield the title compound (948 mg, 92%) as a colorless solid. This material was used the next step without further purification.

¹H NMR (400 MHz, CDCl₃): 7.17 (d, J = 8.0 Hz, 2H, ArH), 6.90 (dd, J = 7.5, 1.0 Hz, 2H, ArH), 6.69 (d, J = 8.0 Hz, 2H, ArH), 4.61 (br.s, 2H, OH), 3.11-2.98 (m, 4H, CH₂), 2.32 (ddd, J = 13.0, 7.0, 2.0 Hz,
The spectroscopic properties of this compound were consistent with the data available in the literature.\(^9\)

\((S)-2,2',3,3'-\text{Tetrahydro-1,1'}\text{-spirobi[indene]-7,7'}\text{-diyl bis(trifluoromethanesulfonate)} (S)\text{-S1}\)

To a solution of \((S)-2,2',3,3'-\text{tetrahydro-1,1'}\text{-spirobi[indene]-7,7'}\text{-dion} (2.00 \text{ g, 7.94 mmol}) and pyridine (2.80 mL, 34.8 mmol) in \(\text{CH}_2\text{Cl}_2\) (40 mL) at 0 °C was added trifluoromethanesulfonic anhydride (2.94 mL, 17.5 mmol). The reaction stirred at this temperature until consumption of starting material was observed by TLC. The mixture was then concentrated in vacuo and purified by FCC (40:1 hexane:EtOAc) to afford the title compound (3.48 g, 85%) as a colorless oil that solidified to a waxy solid on standing.

\([\alpha]^{21}_D -60.2 \text{ (c = 1.0, CHCl}_3\text{)}, [\text{Lit.}]^{285} [\alpha]_D -64 \text{ (c = 0.5, CH}_2\text{Cl}_2\text{)].\)

\(^1\text{H NMR} (400 \text{ MHz, CDCl}_3): 7.30-7.23 \text{ (m, 4H, Ar}_H\text{), 7.14-7.10 \text{ (m, 2H, Ar}_H\text{), 3.14-3.03 \text{ (m, 4H, C}_H\text{2), 2.39-2.26 \text{ (m, 4H, C}_H\text{2).}}\)

\(^1\text{F NMR} (376 \text{ MHz, CDCl}_3): -74.9 \text{ (s). The spectroscopic properties of this compound were consistent with the data available in the literature.}^{10}\)

The majority of SIPHOX ligands employed in this study were synthesized from enantioenriched triflate \((S)-\text{S1}\) by reported procedures.\(^11\)

\((S)-2-((S)-7'-\text{(Bis(3,5-dimethylphenyl)phosphanyl)}-2,2',3,3'-\text{tetrahydro-1,1'-spirobi[inden]-7-yl)-4-phenyl-4,5-dihydrooxazole} (S,S)-L-2\)

\([\alpha]^{21}_D -180 \text{ (c = 1.12, CHCl}_3\text{)} [\text{Lit.}]^{11} [\alpha]^{17}_D -180.9 \text{ (c = 0.5, CH}_2\text{Cl}_2\text{)].\)

\(^1\text{H NMR} (500 \text{ MHz, CDCl}_3): 7.77 \text{ (d, J = 7.5 Hz, 1H, Ar}_H\text{), 7.40 \text{ (d, J = 7.5, 7.5, 1.0 Hz, 1H, Ar}_H\text{), 7.31-7.17 \text{ (m, 5H, Ar}_H\text{), 7.10 \text{ (t, J = 7.5 Hz, 1H, Ar}_H\text{), 7.00-6.94 \text{ (m, 3H, Ar}_H\text{), 6.86 \text{ (d, J = 9.5 Hz, 2H, Ar}_H\text{), 6.81 \text{ (d, J = 8.0 Hz, 2H, Ar}_H\text{), 6.63 \text{ (d, J = 7.5 Hz, 2H, Ar}_H\text{), 4.84 \text{ (dd, J = 10.0, 7.5 Hz, 1H, CH}_3\text{), 3.62 \text{ (dd, J = 10.0, 7.5 Hz, 1H, CH}_3\text{), 3.52 \text{ (dd, J = 10.0, 8.0 Hz, 1H, CH}_3\text{), 3.11-2.97 \text{ (m, 3H, CH}_3\text{), 2.91-2.85 \text{ (m, 1H, CH}_2\text{), 2.71-2.65 \text{ (m, 1H, CH}_2\text{), 2.27-2.22 \text{ (m, 1H, CH}_2\text{), 2.20 \text{ (s, 6H, CH}_3\text{), 2.16-2.11 \text{ (m, 8H, CH}_3\text{ & CH}_3\text{).}}\)

\(^1\text{C NMR} (125 \text{ MHz, CDCl}_3): 165.2 \text{ (CN), 154.9 \text{ (d, J = 25.7, Ar}_C\text{), 149.6 \text{ (d, J = 2.9, Ar}_C\text{), 145.2 \text{ (d, J = 2.6, Ar}_C\text{), 144.2 \text{ (d, J = 7.7, Ar}_C\text{), 142.7 \text{ (Ar}_C\text{), 138.4 \text{ (d, J = 12.8, Ar}_C\text{), 137.2 \text{ (d, J = 13.9, Ar}_C\text{),}\]
137.2 (d, J = 6.9, ArC), 137.0 (d, J = 7.1, ArC), 133.5 (d, J = 2.5, ArC), 132.7 (d, J = 21.5, ArC), 131.7 (d, J = 20.5, ArCH), 131.3 (d, J = 20.2, ArCH), 129.7 (d, J = 7.5, ArCH), 129.0 (ArCH), 128.4 (ArCH), 127.1 (ArCH), 127.0 (ArCH), 126.5 (ArCH), 126.4 (ArCH), 126.2 (ArCH), 125.0 (d, J = 4.3, ArH), 124.7 (ArCH), 73.6 (quaternary C), 69.2 (CH), 63.6 (d, J = 3.4, C), 40.6 (d, J = 4.4, CCH), 38.3 (CCH), 30.9 (CCH), 30.7 (CCH), 21.3 (CCH), 21.2 (CCH); 1 × ArC and 1 × ArCH not observed.

$^{31}$P NMR (202 MHz, CDCl$_3$): -20.4 (s).

FTIR: 2863, 1641, 1579, 1452, 1353 cm$^{-1}$.

MS: (ESI$^+$) Found [M+H]$^+$: 606.2924, C$_{42}$H$_{21}$NOP requires 606.2920.

The spectroscopic properties of this compound were consistent with the data available in the literature.$^{11}$

(R)-2-Methyl-5-phenyl-2-vinyl-3,4-dihydro-2H-pyrrole 3a

$$\text{Ph} \quad \text{N} \quad \text{Me}$$

General Procedure E: Oxime ester 2a$^{12}$ (50 mg, 0.13 mmol) was employed and the reaction was heated at 120 °C for 1.5 hours. Purification of the residue by FCC (x2, toluene:EtOAc 10:1 – 5:1 then hexane:EtOAc 5:1) afforded the title compound (15 mg, 65%, 93:7 e.r.) as a colorless oil.

$[^{[\alpha]}]_{D}^{19}$ +31.3 (c = 0.26, CHCl$_3$).

$^1$H NMR (400 MHz, CDCl$_3$): 7.91-7.85 (m, 2H, ArH), 7.47-7.37 (m, 3H, ArH), 6.05 (dd, J = 17.5, 10.5 Hz, 1H, HCC=CH$_2$), 5.13 (dd, J = 17.5, 1.0 Hz, 1H, HCC=CH$_2$), 5.02 (dd, J = 10.5, 1.0 Hz, 1H, HCC=CH$_2$), 3.11-2.91 (m, 2H, Ar(CN)CCH$_2$CH$_2$), 2.15-1.84 (m, 2H, Ar(CN)CCH$_2$CH$_2$), 1.45 (d, J = 1.0 Hz, 3H, (NC)CH$_3$).

$^{13}$C NMR (100 MHz, CDCl$_3$): 171.4 (C=N), 144.3 (HCC=CH$_2$), 134.6 (ArC), 130.4, 128.4, 127.8 (3 × ArCH), 111.3 (HC=CH$_2$), 77.0 (quaternary C), 35.3 (Ar(CN)CCH$_2$CH$_2$), 34.9 (Ar(CN)CCH$_2$CH$_2$), 26.9 ((NC)CH$_3$).

The spectroscopic properties of this compound were consistent with the data available in the literature.$^{12}$ The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexanes-iso-PrOH 99:1 + 0.1% diethylamine, 0.7 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF$_3$)$_2$C$_6$H$_3$)$_3$ (15 mol%) as ligand; t$_r$ (minor) = 9.6 min and t$_r$ (major) = 13.1 min.
To a solution of 2-acetonaphthone (2.00 g, 11.8 mmol) and \(N,N'\)-dimethylhydrazine (1.07 mL, 14.1 mmol) in benzene (10 mL) was added a few drops of trifluoroacetic acid. The reaction mixture was then heated at reflux under Dean-Stark conditions until consumption of starting material was observed by TLC analysis. The mixture was then concentrated \textit{in vacuo} to afford the title compound (2.38 g, 95\%) as a yellow oil that solidified on standing. This material was used without further purification. \( ^1H \text{NMR} \) (400 MHz, CDCl\(_3\)): 7.98 (1H, br.s, ArH), 7.94 (\(J = 6.5, 2.0 \text{ Hz}, 1\H, \text{dd, ArH}\)), 7.78-7.69 (3H, m, ArH), 7.39-7.35 (2H, m, ArH), 2.57 (6H, s, N(CH\(_3\))\(_2\)), 2.36 (3H, s, (CN)CH\(_3\)). To a solution of 1,1-dimethyl-
2-(1-(naphthalen-2-yl)ethyldene)hydrazine (500 mg, 2.36 mmol) in THF (11 mL) at -78 °C was added n-BuLi (1.52 M in hexane, 1.68 mL, 2.55 mmol) dropwise via syringe over 2 minutes. After stirring at this temperature for 30 minutes, (E)-1-bromo-2-methylbut-2-ene\textsuperscript{12} (419 mg, 2.83 mmol) was added via syringe in one portion. The reaction was stirred at this temperature for a further 90 minutes, after which time it was quenched by addition of 1 M HCl (10 mL). It was warmed to room temperature and hydrolysis of the intermediate hydrazone was monitored by TLC. After stirring for 90 minutes, the phases were separated and the aqueous phase with extracted with EtOAc (50 mL). The combined organic phases were washed with brine (50 mL), dried (Na\textsubscript{2}SO\textsubscript{4}), filtered and concentrated in vacuo. Purification of the residue by FCC (hexane:EtOAc 30:1) afforded the title compound (427 mg, 76%) as a pale yellow oil.

\textbf{\textsuperscript{1}H NMR} (400 MHz, CDCl\textsubscript{3}): 8.48 (br.s, 1H, ArH), 8.04 (dd, J = 8.5, 2.0 Hz, 1H, ArH), 7.97 (d, J = 8.0 Hz, 1H, ArH), 7.91-7.87 (m, 2H, ArH), 7.62-7.53 (m, 2H, ArH), 5.34-5.28 (m, 1H, C=CH), 3.22-3.18 (m, 2H, Ar(CN)CH\textsubscript{2}), 2.50-2.46 (m, 2H, Ar(CN)CH\textsubscript{2}CH\textsubscript{2}), 1.70 (t, J = 1.0 Hz, 3H, C(CH\textsubscript{3})=CHCH\textsubscript{3}), 1.60 (dq, J = 6.5, 1.0 Hz, 3H, C(CH\textsubscript{3})=CHCH\textsubscript{3}).

\textbf{\textsuperscript{13}C NMR} (100 MHz, CDCl\textsubscript{3}): 261.1251 (C=O), 135.5 (ArC), 134.5 (quaternary C), 134.3 (ArC), 132.5 (ArC), 129.6, 129.5, 128.4, 128.3, 127.7, 126.7, 123.9 (7 × ArC), 119.1 (C=CH), 37.5 (Ar(CN)CH\textsubscript{2}), 34.1 (Ar(CN)CH\textsubscript{2}CH\textsubscript{2}), 15.9 (C(CH\textsubscript{3})=CHCH\textsubscript{3}), 13.4 (C=CHCH\textsubscript{3}).

\textbf{FTIR}: 2920, 1680, 1627, 1468, 1357, 1294, 1123 cm\textsuperscript{-1}.

\textbf{MS}: (ESI\textsuperscript{*}) Found [M+Na]\textsuperscript{+}: 261.1251, C\textsubscript{17}H\textsubscript{16}O\textsubscript{4}Na requires 261.1250.

\textbf{(4E)-4-Methyl-1-(naphthalen-2-yl)hex-4-en-1-one O-perfluorobenzoyl oxime 2b}

\begin{center}
\includegraphics[width=0.2\textwidth]{structure.png}
\end{center}

\textbf{General Procedure D: Part A}: (E)-4-Methyl-1-(naphthalen-2-yl)hex-4-en-1-one (415 mg, 1.74 mmol) was employed affording the corresponding oxime (430 mg, 97%) as a colorless solid. \textbf{Part B}: The corresponding oxime (430 mg, 1.70 mmol) was employed. Purification of the residue by FCC (hexane:EtOAc 30:1) afforded the title compound (477 mg, 63%, 13:1 mixture of oxime isomers) as a colorless solid.

\textbf{\textsuperscript{1}H NMR} (400 MHz, CDCl\textsubscript{3}): Signals for the major isomer only 8.18-8.17 (m, 1H, ArH), 7.92-7.86 (m, 4H, ArH), 7.58-7.52 (m, 2H, ArH), 5.27-5.22 (m, 1H, C=CH), 3.12-3.08 (m, 2H, Ar(CN)CH\textsubscript{2}), 2.32-2.28 (m, 2H, Ar(CN)CH\textsubscript{2}CH\textsubscript{2}), 1.62 (tq, J = 1.0, 1.0 Hz, 3H, C(CH\textsubscript{3})=CHCH\textsubscript{3}), 1.56-1.54 (m, 3H, C(CH\textsubscript{3})=CHCH\textsubscript{3}).

\textbf{\textsuperscript{13}C NMR} (100 MHz, CDCl\textsubscript{3}): 168.5 (C=N), 156.6 (CO), 134.5 (ArC), 133.7 (quaternary C), 132.9 (ArC), 130.5 (ArC), 128.8, 128.6, 128.0, 127.7, 126.7, 126.7, 124.0 (7 × ArCH), 120.3 (C=CH), 36.5 (Ar(CN)CH\textsubscript{2}CH\textsubscript{2}), 27.8 (Ar(CN)CH\textsubscript{2}), 15.5 (C(CH\textsubscript{3})=CHCH\textsubscript{3}), 13.4 (C=CHCH\textsubscript{3}); Signals...
corresponding to the perfluorinated benzoyl ester moiety were not resolvable due to their anticipated weak intensity.

$$\delta_F$$ (376 MHz, CDCl\textsubscript{3}) -136.9 (2F), -137.4 (0.15F), -147.5 (1F), -148.1 (0.07F), -159.7 (2F), -160.0 (0.15F).

**FTIR**: 2992, 2903, 1756, 1650, 1526, 1496, 1323 cm\textsuperscript{-1}.

**MS** (ESI\textsuperscript{+}) Found [M+H]\textsuperscript{+}: 448.1321, C\textsubscript{24}H\textsubscript{19}F\textsubscript{5}NO\textsubscript{2} requires 448.1330.

(R)-2-Methyl-5-(naphthalen-2-yl)-2-vinyl-3,4-dihydro-2H-pyrrole 3b

General Procedure E: Oxime ester 2b (50 mg, 0.11 mmol) was employed and the reaction was heated at 80 °C for 5.5 hours. Purification of the residue by FCC (x2, toluene:EtOAc 15:1 – 5:1 then hexane:EtOAc 5:1) afforded the title compound (15.5 mg, 60%, 93:7 e.r.) as a colorless solid.

[a]\textsubscript{D}\textsuperscript{21} +32.4 (c = 0.68, CHCl\textsubscript{3}).

**M.P.** 73-74° (CH\textsubscript{2}Cl\textsubscript{2}-pentane).

**\textsuperscript{1}H NMR** (400 MHz, CDCl\textsubscript{3}): 8.20 (br.s, 1H, ArH), 8.12 (dd, J = 8.5, 1.5 Hz, 1H, ArH), 7.91-7.84 (m, 3H, ArH), 7.54-7.48 (m, 2H, ArH), 6.11 (dd, J = 17.5, 10.5 Hz, 1H, HC=CH\textsubscript{2}), 5.16 (dd, J = 17.5, 1.5 Hz, 1H, HC=CH\textsubscript{2}), 5.03 (dd, J = 10.5, 1.5 Hz, 1H, HC=CH\textsubscript{2}), 3.21-3.05 (m, 2H, Ar(CN)C\textsubscript{2}H\textsubscript{2}CH\textsubscript{2}), 2.14 (ddd, J = 12.5, 9.0, 6.0 Hz, 1H, Ar(CN)CH\textsubscript{2}C\textsubscript{2}H\textsubscript{2}), 1.94 (ddd, J = 12.5, 9.0, 7.0 Hz, 1H, Ar(CN)CH\textsubscript{2}C\textsubscript{2}H\textsubscript{2}), 1.48 (s, 3H, (NC)C\textsubscript{2}H\textsubscript{3}).

**\textsuperscript{13}C NMR** (100 MHz, CDCl\textsubscript{3}): 171.3 (C=N), 144.3 (HC=CH\textsubscript{2}), 134.4, 132.9, 132.1 (3 × ArC), 128.7, 128.1, 128.0, 127.7, 127.0, 126.3, 124.8 (7 × ArCH), 111.4 (HC=CH\textsubscript{2}), 76.8 (quaternary C), 35.4 (Ar(CN)CH\textsubscript{2}C\textsubscript{2}H\textsubscript{2}), 34.9 (Ar(CN)CH\textsubscript{2}C\textsubscript{2}H\textsubscript{2}), 27.0 ((NC)CH\textsubscript{3}).

**FTIR**: 2961, 1612, 1447, 1405, 1351, 1296 cm\textsuperscript{-1}.

**MS** (ESI\textsuperscript{+}) Found [M+H]\textsuperscript{+}: 236.1429, C\textsubscript{17}H\textsubscript{18}N requires 236.1434.

The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexanes-i-PrOH-diethylamine 99:1:0.1, 0.7 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF\textsubscript{3})\textsubscript{2}C\textsubscript{6}H\textsubscript{3})\textsubscript{3} (15 mol%) as ligand; t\textsubscript{R} (minor) = 8.2 min and t\textsubscript{R} (major) = 10.9 min. Crystals suitable for X-ray diffraction were grown by vapour diffusion of pentane into a concentrated CH\textsubscript{2}Cl\textsubscript{2} solution of 3b at 5 °C. The absolute structure of this compound was determined by X-ray crystallography.
ORTEP view of dihydropyrrole (R)-3b, ellipsoids at 30%, hydrogen atoms omitted for clarity; Crystal data for dihydropyrrole (R)-3b: C_{17}H_{17}NO, MW, 235.31, orthorhombic, space group P_{2_1}2_12_1, a = 6.0770(11) Å, b = 7.7665(14) Å, c = 27.619(5) Å, V = 1303.5(4) Å³, α = 90°, β = 90°, γ = 90°, Z = 4, D_c = 1.199 g/cm³, CuKα radiation, λ = 1.54178 Å, μ = 0.525 mm⁻¹, T = 100 K, crystal size 0.456 × 0.288 × 0.281 mm, Microstar, 12133 reflections collected, 2295 were unique, R_int = 0.0359; R_1 = 0.0273 and wR_2 = 0.0711, GOF = 1.076 for 164 refined parameters. Flack parameter = -0.04(10).

(R,E)-2-Methyl-5-(naphthalen-2-yl)-2-(pent-1-en-1-yl)-3,4-dihydro-2H-pyrrole 3c

General Procedure E: Oxime ester 2c^{12} (50.0 mg, 0.102 mmol) was employed and the reaction was heated at 120 °C for 2 hours. FCC (toluene:EtOAc 16:1) afforded the title compound (21.0 mg, 74%, 20:1 r.r., 91:9 e.r.) as a pale yellow oil.

[α]_D^{23} +25.9 (c = 0.46, CHCl₃).

¹H NMR (400 MHz, CDCl₃): 8.24-8.06 (m, 2H, ArH), 7.91-7.79 (m, 3H, ArH), 7.58-7.44 (m, 2H, ArH), 5.71 (dt, J = 15.5 and 1.0 Hz, 1H, HC=CHCH₂), 5.56 (dt, J = 15.5 and 6.5 Hz, 1H, HC=CHCH₂), 3.20-3.03 (m, 2H, Ar(CN)CH₂), 2.15-2.07 (m, 1H, Ar(CN)CH₂CH₂), 2.03 (m, 2H, C=CHCH₂), 1.98-1.88 (m, 1H, Ar(CN)CH₂CH₂), 1.47 (s, 3H, (NC)CH₂), 1.41 (tq, J = 7.5 and 7.5 Hz, 2H, C=CHCH₂CH₂), 0.90 (t, J = 7.5 Hz, 3H, C=CH(CH₂)₂CH₃).

¹³C NMR (100 MHz, CDCl₃): 170.8 (C=N), 136.3 (C=CH), 134.3, 133.0, 132.3 (3 × ArC), 128.7, 128.0 (2 signals), 127.7, 127.3 (5 × ArCH), 126.9 (C=CH), 126.3, 124.8 (2 × ArCH), 76.3 (quaternary C), 36.1 (Ar(CN)CH₂), 34.9 (Ar(CN)CH₂CH₂), 34.6 (C=CHCH₂), 27.4 ((NC)CH₂), 22.5 (C=CHCH₂CH₂), 13.7 (C=CH(CH₂)₂CH₃).
Spectroscopic properties were identical to that described previously for the racemic material.¹²

The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexane-i-PrOH (95:5, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF₃)₂C₆H₃)₃ (15 mol%) as ligand; tᵣ (minor) = 8.6 min and tᵣ (major) = 10.0 min.

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<td>0.1393</td>
<td>2082.02515</td>
<td>230.67490</td>
<td>50.3155</td>
</tr>
</tbody>
</table>
(E)-4-Methyl-1,6-diphenylhex-4-en-1-one

General Procedure C: Ethyl benzoylacetate (0.42 mL, 2.44 mmol) and (E)-(4-bromo-3-methylbut-2-en-1-yl)benzene\(^{13}\) (600 mg, 2.68 mmol) were employed. Purification of the residue by FCC (hexane:EtOAc 40:1) afforded the title compound (444 mg, 69%) as a colorless oil.

\(^{1}H\) NMR (400 MHz, CDCl\(_3\)): 7.98-7.95 (m, 2H, ArH), 7.58-7.54 (m, 1H, ArH), 7.48-7.44 (m, 2H, ArH), 7.31-7.26 (m, 2H, ArH), 7.21-7.16 (m, 3H, ArH), 5.44-5.39 (m, 1H, C=CH), 3.38 (d, \(J = 7.5\) Hz, 2H, C=CH\(_2\)Ar), 3.13-3.09 (m, 2H, Ar(CO)CH\(_3\)), 2.51-2.47 (m, 2H, Ar(CO)CH\(_2\)CH\(_3\)), 1.79 (d, \(J = 1.5\) Hz, 3H, CH\(_3\)C=CH).

\(^{13}C\) NMR (100 MHz, CDCl\(_3\)): 200.0 (C=O), 141.4 (ArC), 137.0 (ArC), 135.0 (C=CH), 132.9, 128.5, 128.3 (2C), 128.0, 125.7 (6 × ArC), 123.6 (C=CH), 37.3 (Ar(CO)CH\(_3\)), 34.2 (C=CH\(_2\)Ar), 34.0 (Ar(CO)CH\(_2\)CH\(_3\)), 16.4 (CH\(_3\)C=CH).

FTIR: 2991, 1681, 1597, 1491, 1446, 1202 cm\(^{-1}\).

MS: (ESI\(^+\)) Found [M+H]\(^+\): 265.1588, C\(_{19}\)H\(_{17}\)O requires 265.1587.

(4E)-4-Methyl-1,6-diphenylhex-4-en-1-one O-perfluorobenzoyl oxime 2d

General Procedure D: Part A: (E)-4-Methyl-1,6-diphenylhex-4-en-1-one (419 mg, 1.59 mmol) was employed affording the corresponding oxime (436 mg, 98%) as a colorless solid. Part B: The corresponding oxime (420 mg, 1.51 mmol) was employed. Purification of the residue by FCC (hexane:EtOAc 50:1 – 25:1) afforded the title compound (481 mg, 68%, 10:1 mixture of oxime isomers) as a yellow oil that solidified on standing.

\(^{1}H\) NMR (400 MHz, CDCl\(_3\)): Data for major isomer 7.71-7.68 (m, 2H, ArH), 7.49-7.35 (m, 3H, ArH), 7.29-7.24 (m, 2H, ArH), 7.20-7.11 (m, 3H, ArH), 5.33 (tq, \(J = 7.5, 1.5\) Hz, 1H, C=CH), 3.31 (d, \(J = 7.5\) Hz, 2H, C=CH\(_2\)Ar), 3.05-3.01 (m, 2H, Ar(CN)CH\(_2\)), 2.32-2.27 (m, 2H, Ar(CN)CH\(_2\)CH\(_3\)), 1.71 (br.s, 3H, CH\(_3\)C=CH); Diagnostic signals for minor isomer 2.91-2.87 (m, 0.2H, Ar(CN)CH\(_3\)'), 2.25-2.21 (m, 0.2H, Ar(CN)CH\(_2\)CH\(_3\)'), 2.21-2.05 (m, 0.2H, Ar(CN)CH\(_3\)').

\(^{13}C\) NMR (100 MHz, CDCl\(_3\)): Data for major isomer 168.6 (C=N), 156.5 (C=O), 141.1 (ArC), 134.0 (C=CH), 133.1 (ArC), 131.0, 128.8, 128.4, 128.2, 127.5, 125.9 (6 × ArC), 124.9 (C=CH), 36.3 (Ar(CN)CH\(_2\)CH\(_3\)), 34.2 (C=CH\(_2\)Ar), 27.8 (Ar(CN)CH\(_2\)), 16.0 (CH\(_3\)C=CH). Signals corresponding to the perfluorinated benzoyl ester moiety were not resolvable due to their anticipated weak intensity.

\(^{19}F\) NMR (376 MHz, CDCl\(_3\)): -137.0 (2F), -137.2 (0.2F), -147.4 (1F), -148.0 (0.1F), -159.7 (2F), -160.0 (0.2F).
**FTIR**: 2992, 2915, 1756, 1654, 1526, 1497, 1324, 1197 cm\(^{-1}\).

**MS**: (ESI\(^+\)) Found [M+Na]\(^+\): 496.1301, C\(_{26}\)H\(_{20}\)F\(_5\)NO\(_2\)Na requires 496.1306.

(R,E)-2-Methyl-5-phenyl-2-styryl-3,4-dihydro-2H-pyrrole 3d

**General Procedure E**: Oxime ester 2d (50 mg, 0.11 mmol) was employed and the reaction was heated at 100 °C for 2.5 hours. Purification of the residue by FCC (x2, toluene:EtOAc 20:1 – 10:1 then hexane:EtOAc 5:1) afforded the title compound (22 mg, 80%, 95: 5 e.r.) as a colorless oil.

\([\alpha]_{D}^{21}\) +65.5 (c = 0.84, CHCl\(_3\)).

**\(^1\)H NMR** (400 MHz, CDCl\(_3\)): 7.93-7.90 (m, 2H, ArH), 7.46-7.37 (m, 5H, ArH), 7.32-7.27 (m, 2H, ArH), 7.22-7.18 (m, 1H, ArH), 6.50 (d, J = 16.0 Hz, 1H, CH=CHAr), 6.45 (d, J = 16.0 Hz, 1H, CH=CHAr), 3.13-2.98 (m, 2H, Ar(CN)CH\(_2\)), 2.18 (ddd, J = 12.5, 9.0, 6.0 Hz, 1H, Ar(CN)CH\(_2\)), 2.00 (ddd, J = 12.5, 9.0, 7.0 Hz, 1H, Ar(CN)CH\(_2\)), 1.54 (s, 3H, (NC)CH\(_3\)).

**\(^{13}\)C NMR** (100 MHz, CDCl\(_3\)): 171.4 (C=N), 137.4 (ArC), 136.4 (CH=CHAr), 134.6 (ArC), 130.5, 128.4 (2C), 127.8, 127.1 (5 x ArCH), 126.5 (CH=CHAr), 126.3 (ArCH), 76.4 (quaternary C), 36.0 (Ar(CN)CH\(_2\)CH\(_2\)), 35.0 (Ar(CN)CH\(_2\)CH\(_2\)), 27.5 ((NC)CH\(_3\)).

**FTIR**: 2962, 1610, 1450, 1447, 1339 cm\(^{-1}\).

**MS**: (ESI\(^+\)) Found [M+H]\(^+\): 262.1588, C\(_{19}\)H\(_{20}\)N requires 262.1590. The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexanes-i-PrOH 90:10, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF\(_3\))\(_2\)C\(_6\)H\(_3\))\(_3\); t\(_R\) (minor) = 8.6 min and t\(_R\) (major) = 13.0 min. The absolute structure of this molecule was confirmed by Vibrational Circular Dichroism (VCD).
Comparison of experimental VCD spectrum of dihydropyrrole 3d (in duplicate, blue) and simulated spectra of the R (red) and S (green) enantiomers. The agreement between the simulated spectrum of the R enantiomer and the experimental spectrum is good, therefore dihydropyrrole 3d has R configuration.

**Experimental:** A 13.1 mg sample of dihydropyrrole 3d was dissolved in CDCl₃. A VCD spectrum was acquired in 0.100 mm BaF₂ cells for 7 hours each in a BioTools ChiralIR instrument equipped with dual source and dual photoelastic modulator. The resolution was 4 cm⁻¹. The experimental VCD spectrum shows weak characteristic bands.

**Computational Spectral Simulations:** A Monte Carlo molecular mechanics search for low energy geometries was conducted for full structures of the two enantiomers, R and S. MacroModel within the Maestro graphical interface (Schrödinger Inc.) was used to generate starting coordinates for conformers. All conformers within 5 kcal/mole of the lowest energy conformer were used as starting points for density functional theory (DFT) minimizations within Gaussian09. Optimized structures, harmonic
vibrational frequencies/intensities, VCD rotational strengths, and free energies at STP (including zero-point energies) were determined for each conformer. In these calculations, the functional B3LYP and the basis set 6-31G* were used. Simulations of infrared and VCD spectra for each conformation were generated using an in-house built program to fit Lorentzian line shapes (12 cm$^{-1}$ line width) to the computed spectra thereby allowing direct comparisons between simulated and experimental spectra.

Results: The experimental spectrum was compared with simulated spectra of the two enantiomers based on DFT calculations starting with full structures. The comparison is presented above. The agreement between the simulated spectrum of the $R$ enantiomer and the experimental spectrum is good. It is therefore concluded that dihydropyrrole 3d has $R$ configuration.

2-(4-Methoxyphenyl)acetaldehyde

![Chemical structure of 2-(4-Methoxyphenyl)acetaldehyde]

To a solution of methyl 4-methoxyphenylacetate (4.40 mL, 27.8 mmol) in anhydrous toluene (50 mL) at -78 °C was added dropwise diisobutylaluminium hydride (1 M in toluene, 33.4 mL, 33.4 mmol). The reaction was stirred at this temperature for 1 hour. The reaction was quenched with MeOH (5 mL) and then poured into CH$_2$Cl$_2$ (150 mL), then washed sequentially with 1 M HCl (20 mL), brine (20 mL). The organic phase was concentrated in vacuo. FCC (hexane:EtOAc 15:1) afforded the title compound (3.46 g, 83%) as a colorless oil.

$^1$H NMR (400 MHz, CDCl$_3$): 9.73 (t, $J = 2.5$ Hz, 1H, (CO)H), 7.14 (d, $J = 8.0$ Hz, 2H, ArH), 6.92 (d, $J = 8.0$ Hz, 2H, ArH), 3.82 (s, 3H, OCH$_3$), 3.64 (d, $J = 2.5$ Hz, 2H, CH$_2$).

$^{13}$C NMR (100 MHz, CDCl$_3$): 199.6 (C=O), 159.0 (ArC), 130.7 (ArCH), 123.7 (ArC), 114.4 (ArCH), 55.3 (OCH$_3$), 49.7 (CH$_2$).

The spectroscopic properties of this compound were consistent with the data in the literature.

Ethyl (E)-4-(4-methoxyphenyl)-2-methylbut-2-enoate

![Chemical structure of Ethyl (E)-4-(4-methoxyphenyl)-2-methylbut-2-enoate]

To a solution of 2-(4-methoxyphenyl)acetaldehyde (1.80 g, 12.00 mmol) in CH$_2$Cl$_2$ (40 mL) at 0 °C was added a solution of ethyl 2-(triphenylphosphoranylidene)butanoate (5.20 g, 14.40 mmol) in CH$_2$Cl$_2$ (30 mL). The reaction was stirred at room temperature for 16 hours and then concentrated in vacuo. The organic phase was concentrated in vacuo. FCC (hexane:EtOAc 70:1 to 40:1) afforded the title compound (2.12 g, 75%) as a colorless oil.
\( ^1H \) NMR (400 MHz, CDCl\(_3\)): 7.13 (d, \( J = 8.0 \) Hz, 2H, ArH), 6.93-6.83 (m, 3H, ArH and HC=C), 4.19 (q, \( J = 7.0 \) Hz, 2H, C(O)OCH\(_2\)CH\(_3\)), 3.80 (s, 3H, OCH\(_3\)), 3.47 (d, \( J = 7.5 \) Hz, 2H, ArCH\(_2\)CH), 1.97-1.94 (m, 3H, HC=CCH\(_3\)), 1.29 (t, \( J = 7.0 \) Hz, 3H, C(O)OCH\(_2\)CH\(_3\)).

\( ^{13}C \) NMR (100 MHz, CDCl\(_3\)): 168.1 (C=O), 158.2 (ArC), 140.4 (HC=C), 131.0 (ArC), 129.4 (ArC), 128.2 (HC=C), 114.1 (ArCH), 60.5 (C(O)OCH\(_2\)CH\(_3\)), 55.3 (OCH\(_3\)), 33.0 (ArCH\(_2\)CH), 14.3 (C(O)OCH\(_2\)CH\(_3\)), 12.5 (HC=CCH\(_3\)).

FTIR: 1708, 1511, 1247 cm\(^{-1}\).

MS: (ESI\(^+\)) Found [M+H\(^+\)]+: 235.1325, C\(_{14}\)H\(_{19}\)O\(_3\) requires 235.1329.

To confirm the olefin geometry, nOe analysis was carried out. An nOe enhancement between C1-H\(_2\) and C2-H was observed and nOe was observed between C1-H\(_2\) and C4-H\(_2\), which is consistent with an (E)-olefin geometry.

\((E)-4-(4-Methoxyphenyl)-2-methylbut-2-en-1-ol\)

\( \text{General Procedure A:} \) In a modification to the general procedure LiAlH\(_4\) (1M in Et\(_2\)O) was employed with ethyl (E)-4-(4-methoxyphenyl)-2-methylbut-2-enoate (2.00 g, 8.55 mmol). FCC (hexane:EtOAc 5:1 to 4:1) afforded the title compound (1.50 g, 91%) as a colorless oil.

\( ^1H \) NMR (400 MHz, CDCl\(_3\)): 7.11 (d, \( J = 8.0 \) Hz, 2H, ArH), 6.84 (d, \( J = 8.0 \) Hz, 2H, ArH), 5.61 (tq, \( J = 7.5 \) and 1.5 Hz, 1H, HC=C), 4.06 (d, \( J = 3.5 \) Hz, 2H, CH\(_2\)OH), 3.80 (s, 3H, OCH\(_3\)), 3.35 (d, \( J = 7.5 \) Hz, 2H, ArCH\(_2\)CH), 1.79 (s, 3H, HC=CCH\(_3\)), 1.37 (t, \( J = 3.5 \) Hz, 1H, OH).

\( ^{13}C \) NMR (100 MHz, CDCl\(_3\)): 157.9 (ArC), 135.4 (HC=C), 133.0 (ArC), 129.2 (ArCH), 125.1 (HC=C), 113.9 (ArCH), 68.8 (CH\(_2\)OH), 55.3 (OCH\(_3\)), 33.0 (ArCH\(_2\)CH), 13.8 (HC=CCH\(_3\)).

FTIR: 3324, 2910, 1509, 1124 cm\(^{-1}\).

MS: (ESI\(^+\)) Found [M+H-H\(_2\)O\(^+\)]+: 175.1120, C\(_{12}\)H\(_{15}\)O requires 175.1129.

\((E)-1-(4-Bromo-3-methylbut-2-en-1-yl)-4-methoxybenzene\)

\( \text{General Procedure B:} \) (E)-4-(4-Methoxyphenyl)-2-methylbut-2-en-1-ol (1.45 g, 7.56 mmol) was employed to afford the title compound (1.26 g, 66%) as a colorless oil.
**1H NMR** (400 MHz, CDCl₃): 7.08 (d, J = 8.0 Hz, 2H, ArH), 6.85 (d, J = 8.0 Hz, 2H, ArH), 5.78 (t, J = 7.5 Hz, 1H, HC=CH), 4.02 (s, 2H, CH₂Br), 3.80 (s, 3H, OCH₃), 3.34 (d, J = 7.5 Hz, 2H, ArCH₂), 1.88 (s, 3H, HC=C(CH₃)₃).

**13C NMR** (100 MHz, CDCl₃): 158.0 (ArC), 132.6 (HC=C), 132.1 (ArC), 130.1 (HC=CH), 129.2, 114.0 (2 × ArC), 55.3 (OCH₃), 41.4 (CH₂Br), 33.6 (ArCH₂), 14.8 (HC=C(CH₃)₃).

**FTIR**: 1510, 1246 cm⁻¹.

**MS**: (CI⁺) Found [M+H]⁺: 255.0378, C₁₂H₁₆O₇Br requires 255.0385.

(E)-6-(4-Methoxyphenyl)-4-methyl-1-phenylhex-4-en-1-one

![Chemical structure](image)

General Procedure C: Ethyl benzoylacetate (0.71 mL, 4.10 mmol) and (E)-1-(4-bromo-3-methylbut-2-en-1-yl)-4-methoxybenzene (1.20 g, 4.72 mmol) were employed. FCC (hexane:EtOAc 40:1) afforded the title compound (1.09 g, 90%) as a colorless oil.

**1H NMR** (400 MHz, CDCl₃): 7.97 (d, J = 7.5 Hz, 2H, ArH), 7.57 (t, J = 7.5 Hz, 1H, ArH), 7.47 (t, J = 7.5 Hz, 2H, ArH), 7.08 (d, J = 8.0 Hz, 2H, ArH), 6.83 (d, J = 8.0 Hz, 2H, ArH), 5.39 (tq, J = 7.5 and 1.0 Hz, 1H, C=C), 3.80 (s, 3H, OCH₃), 3.31 (d, J = 7.5 Hz, 2H, ArC(O)CH₂), 3.10 (t, J = 7.5 Hz, 2H, ArC(O)CH₂), 2.48 (t, J = 7.5 Hz, 2H, ArC(O)CH₂), 1.79 (s, 3H, CH₃C=CH).

**13C NMR** (100 MHz, CDCl₃): 200.0 (C=O), 157.8, 137.0 (2 × ArC), 134.7 (C=CH), 133.5 (ArC), 132.9, 129.1, 128.6, 128.1 (4 × ArC), 124.1 (C=CH), 113.8 (ArCH), 55.3 (OCH₃), 37.3 (ArC(O)CH₂), 34.0 (ArC(O)CH₂CH₂), 33.3 (C=CH₃C=Ar), 16.4 (CH₃C=CH).

**FTIR**: 1684, 1510, 1244 cm⁻¹.


(4E)-6-(4-Methoxyphenyl)-4-methyl-1-phenylhex-4-en-1-one O-perfluorobenzoyl oxime 2e

![Chemical structure](image)

General Procedure D: Part A: (E)-6-(4-Methoxyphenyl)-4-methyl-1-phenylhex-4-en-1-one (0.60 g, 2.04 mmol) was used. The reaction was heated at 75 °C for 2 hours to afford the corresponding oxime (0.56 g, 89%) as a colorless solid. Part B: The corresponding oxime (0.56 g, 1.81 mmol) was employed and the reaction was stirred for 1 hour. FCC (× 2; hexane: EtOAc 30:1; toluene:hexane 2:1) afforded oxime ester X (0.70 g, 77%) as a colorless oil.

**1H NMR** (400 MHz, CDCl₃): 7.71 (d, J = 7.5 Hz, 2H, ArH), 7.52-7.39 (m, 3H, ArH), 7.05 (d, J = 8.0 Hz, 2H, ArH), 6.82 (d, J = 8.0 Hz, 2H, ArH), 5.32 (t, J = 7.5 Hz, 1H, C=CH), 3.80 (s, 3H, OCH₃), 3.26
(d, J = 7.5 Hz, 2H, C=CHCH₂Ar), 3.04 (t, J = 7.5 Hz, 2H, Ar(CN)CH₂), 2.29 (t, J = 7.5 Hz, 2H, Ar(CN)CH₂CH₂), 1.71 (s, 3H, CH₃C=CH).

¹H NMR (100 MHz, CDCl₃): 168.6 (C=N), 157.8 (C=O), 133.6 (C=CH), 133.1 (2 signals) (2 × ArC), 131.0, 129.1, 128.8, 127.5 (4 × ArCH), 125.3 (C=CH), 133.8 (ArCH), 55.2 (OCH₃), 36.3 (Ar(CN)CH₂), 33.3 (C=CHCH₂Ar), 27.8 (Ar(CN)CH₂), 15.9 (CH₃C=CH). Signals corresponding to the perfluorinated benzoyl ester moiety were not resolvable due to their anticipated weak intensity.

¹³C NMR (100 MHz, CDCl₃): 168.6 (C=N), 157.8 (C=O), 133.6 (C=CH), 133.1 (2 signals) (2 × ArC), 131.0, 129.1, 128.8, 127.5 (4 × ArCH), 125.3 (C=CH), 133.8 (ArCH), 55.2 (OCH₃), 36.3 (Ar(CN)CH₂), 33.3 (C=CHCH₂Ar), 27.8 (Ar(CN)CH₂), 15.9 (CH₃C=CH).

¹⁹F NMR (376 MHz, CDCl₃): Signals for the major isomer: -137.0 (2F), -147.5 (1F), -159.7 (2F).

FTIR: 1764, 1507, 1326, 1193 cm⁻¹.

MS: (ESI⁺) Found [M+H]⁺: 292.1688, C₂₀H₂₂NO requires 292.1696.

The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexane-i-PrOH (90:10, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF₃)₂C₆H₃) (15 mol%) as ligand; tₘ (minor) = 9.9 min and tₘ (major) = 15.2 min.

(R,E)-2-(4-Methoxystyryl)-2-methyl-5-phenyl-3,4-dihydro-2H-pyrrole 3e

General Procedure E: Oxime ester 2e (55.0 mg, 0.109 mmol) was employed and the reaction was heated at 120 °C for 1.5 hours. FCC (toluene:EtOAc 60:1 to 30:1) afforded the title compound (27.5 mg, 86%, 95:5 e.r.) as a pale yellow oil.

[α]D²³ +46.1 (c = 0.93, CHCl₃).

¹H NMR (400 MHz, CDCl₃): 7.95-7.87 (m, 2H, ArH), 7.48-7.39 (m, 3H, ArH), 7.32 (d, J = 8.0 Hz, 2H, ArH), 6.84 (d, J = 8.0 Hz, 2H, ArH), 6.44 (d, J = 16.0 Hz, 1H, CH=CHAr), 6.33 (d, J = 16.0 Hz, 1H, CH=CHAr), 3.80 (s, 3H, OCH₃), 3.15-2.90 (m, 2H, Ar(CN)CH₂), 2.23-2.11 (m, 1H, Ar(CN)CH₂CH₂), 2.08-1.92 (m, 1H, Ar(CN)CH₂CH₂), 1.53 (s, 3H, (NC)CH₃).

¹³C NMR (100 MHz, CDCl₃): 171.3 (C=N), 158.9, 134.7 (2 × ArC), 134.3 (CH=CHAr), 130.4 (ArCH), 130.2 (ArC), 128.4, 127.8, 127.5 (3 × ArCH), 126.0 (CH=CHAr), 113.9 (ArC), 76.4 (quaternary C), 55.3 (OCH₃), 36.0 (Ar(CN)CH₂CH₂), 35.0 (Ar(CN)CH₂), 27.6 ((NC)CH₃).

FTIR: 2926, 1608, 1511, 1248 cm⁻¹.

MS: (ESI⁺) Found [M+H]⁺: 292.1688, C₂₀H₂₂NO requires 292.1696.
To a solution of 2-(naphthalene-2-yl)acetic acid (3.00 g, 16.10 mmol) in anhydrous MeOH (20 mL) was added concentrated H$_2$SO$_4$ (1 mL). The reaction was heated to 75 °C for 14 hours. The reaction mixture was concentrated in vacuo. FCC (hexane:EtOAc 5:1) afforded the title compound (2.87 g, 89%) as a colorless oil.

The spectroscopic properties of this compound were consistent with the data in the literature.
2-(Naphthalen-2-yl)acetaldehyde

To a solution of methyl 2-(naphthalen-2-yl)acetate (2.70 g, 13.50 mmol) in anhydrous toluene (35 mL), at -78 °C was added dropwise diisobutylaluminium hydride (1.0 M solution in toluene, 14.90 mL, 14.90 mmol). The reaction was stirred for 1 hour. The reaction was quenched with MeOH (5 mL) and then poured into CH₂Cl₂ (100 mL), then washed sequentially with 1M HCl (15 mL), brine (15 mL). The organic phase was concentrated in vacuo. FCC (hexane:EtOAc 15:1) afforded the title compound (0.92 g, 40%) as a pale yellow oil.

1H NMR (400 MHz, CDCl₃): 9.84 (t, J = 2.5 Hz, 1H, (CO)H), 7.90-7.80 (m, 3H, ArH), 7.71 (s, 1H, ArH), 7.55-7.46 (m, 2H, ArH), 7.34 (dd, J = 8.0 and 1.5 Hz, 1H, ArH), 3.87 (d, J = 2.5 Hz, 2H, CH₂).

13C NMR (100 MHz, CDCl₃): 199.3 (C=O), 133.5, 132.4, 129.1 (3 × ArC), 128.7, 128.5, 127.7, 127.6, 127.4, 126.4, 126.1 (7 × ArCH), 50.7 (CH₂).

The spectroscopic properties of this compound were consistent with the data in the literature.

Ethyl (E)-2-methyl-4-(naphthalene-2-yl)but-2-enoate

To a solution of 2-(naphthalen-2-yl)acetaldehyde (0.82 g, 4.80 mmol) in CH₂Cl₂ (20 mL) at 0 °C was added a solution of ethyl 2-(triphenylphosphoranylidene)butanoate (2.09 g, 5.76 mmol) in CH₂Cl₂ (20 mL). The reaction was stirred at room temperature for 16 hours. The reaction was cooled to room temperature and concentrated in vacuo. The oil was taken up in hexane (80 mL) and the precipitate filtered off. The filtrate was concentrated in vacuo. FCC (hexane:EtOAc 70:1) afforded the title compound (1.09 g, 89%) as a colorless oil.

1H NMR (400 MHz, CDCl₃): 7.85-7.76 (m, 3H, ArH), 7.62 (s, 1H, ArH), 7.51-7.41 (m, 2H, ArH), 7.33 (d, J = 8.0 Hz, 1H, ArH), 7.01 (tq, J = 7.5 and 1.5 Hz, 1H, HC=C), 4.21 (q, J = 7.0 Hz, 2H, (CO)OC₂H₅CH₃), 3.70 (d, J = 7.5 Hz, 2H, ArCH₂CH), 2.02 (s, 3H, HC=CC₂H₅), 1.30 (t, J = 7.0 Hz, 3H, (CO)OCH₂CH₃), 1.20 (s, 3H, HC=CH₂C₂H₅), 1.30 (t, J = 7.0 Hz, 3H, (CO)OCH₂CH₃).

13C NMR (100 MHz, CDCl₃): 168.1 (C=O), 137.8 (HC=C), 136.5, 133.6, 132.2 (3 × ArC), 128.7 (HC=C), 128.3, 127.6, 127.5, 127.1, 126.6, 126.1, 125.5 (7 × ArCH), 60.6 ((CO)OCH₂CH₃), 35.0 (ArCH₂CH), 14.3 ((CO)OCH₂CH₃), 12.6 (HC=CH₂).

FTIR: 1706, 1257 cm⁻¹.

MS: (ESI⁺) Found [M+H]⁺: 255.1379, C₁₇H₁₉O₂ requires 255.1380.
To confirm the olefin geometry, nOe analysis was carried out. An nOe enhancement between C1-$H_2$ and C2-$H$ was observed and nOe was observed between C1-$H_2$ and C4-$H_2$, which is consistent with an (E)-olefin geometry.

(E)-2-Methyl-4-(naphthalen-2-yl)but-2-en-1-ol

General Procedure A: In a modification to the General Procedure, LiAlH$_4$ (1M in Et$_2$O) was employed with ethyl (E)-2-methyl-4-(naphthalene-2-yl)but-2-enoate (1.19 g, 4.69 mmol). FCC (hexane:EtOAc 5:1) afforded the title compound (0.95 g, 96%) as a pale yellow oil.

$^1$H NMR (400 MHz, CDCl$_3$): 7.84-7.75 (m, 3H, ArH), 7.62 (s, 1H, ArH), 7.49-7.40 (m, 2H, ArH), 7.33 (dd, $J = 8.5$ and 1.5 Hz, 1H, ArH), 5.75-5.68 (m, 1H, H$_C$=C), 4.10 (s, 2H, CH$_2$OH), 3.58 (d, $J = 7.5$ Hz, 2H, ArCH$_2$CH), 1.85 (s, 3H, HC=CH$_3$).

$^{13}$C NMR (100 MHz, CDCl$_3$): 138.4 (ArC), 136.0 (HC=C), 133.6, 132.0 (2 × ArC), 128.0, 127.6, 127.4, 127.2, 126.2, 126.0, 125.2 (7 × ArCH), 124.4 (HC=C), 68.8 (CH$_2$OH), 34.1 (ArCH$_2$CH), 13.9 (HC=CH$_3$).

The spectroscopic properties of this compound were consistent with the data in the literature.$^{17}$

(E)-2-(4-Bromo-3-methylbut-2-en-1-yl)naphthalene

General Procedure B: (E)-2-Methyl-4-(naphthalene-2-yl)but-2-en-1-ol (0.90 g, 4.24 mmol) was employed to afford the title compound (1.05 g, 96%) as a colorless oil.

$^1$H NMR (400 MHz, CDCl$_3$): 7.84-7.75 (m, 3H, ArH), 7.60 (s, 1H, ArH), 7.49-7.40 (m, 2H, ArH), 7.30 (dd, $J = 8.5$ and 1.5 Hz, 1H, ArH), 5.88 (t, $J = 7.5$ Hz, 1H, H$_C$=C), 4.04 (s, 2H, CH$_2$Br), 3.56 (d, $J = 7.5$ Hz, 2H, ArCH$_2$CH), 1.93 (s, 3H, HC=CH$_3$).

$^{13}$C NMR (100 MHz, CDCl$_3$): 132.8, 128.9 (2 × ArC), 128.5 (HC=C), 127.3 (ArC), 124.7 (HC=C), 123.4, 122.9, 122.7, 122.3, 121.6, 121.3, 120.6 (7 × ArCH), 36.5 (CH$_2$Br), 29.9 (ArCH$_2$CH), 10.2 (HC=CH$_3$).

FTIR: 1507, 1206 cm$^{-1}$.

MS: (EI$^+$) Found [M]$^+$: 274.0366, C$_{15}$H$_{15}$Br$_{79}$ requires 274.0357.
(E)-4-Methyl-6-(naphthalen-2-yl)-1-phenylhex-4-en-1-one

General Procedure C: Ethyl benzoylacetate (0.57 mL, 3.31 mmol) and (E)-2-(4-bromo-3-methylbut-2-en-1-yl)naphthalene (1.00 g, 3.65 mmol) were employed. FCC (hexane:EtOAc 100:1) afforded the title compound (0.88 g, 85%) as a colorless oil.

$^1$H NMR (400 MHz, CDCl$_3$): 8.00-7.94 (m, 2H, ArH), 7.83-7.74 (m, 3H, ArH), 7.60 (s, 1H, ArH), 7.56 (t, $J = 7.5$ Hz, 1H, ArH), 7.49-7.39 (m, 4H, ArH), 7.31 (dd, $J = 8.5$ and 1.5 Hz, 1H, ArH), 5.49 (tq, $J = 7.5$ and 1.5 Hz, 1H, C=CCH), 3.54 (d, $J = 7.5$ Hz, 2H, ArCCH$_2$), 3.13 (t, $J = 7.5$ Hz, 2H, Ar(CO)CCH$_2$), 2.53 (t, $J = 7.5$ Hz, 2H, Ar(CO)CH$_2$CH$_2$), 1.84 (s, 3H, C$^3$H$_3$C=CH).

$^{13}$C NMR (100 MHz, CDCl$_3$): 200.0 (C=O), 138.9, 137.0 (2 × ArC), 135.3 (C=CH), 133.6 (ArC), 128.6, 128.0, 127.9, 127.6, 127.4, 127.3, 126.1, 125.9, 125.1 (9 × ArC), 123.5 (C=CH), 37.3 (Ar(CO)CH$_2$), 34.4 (C=CH$_2$Ar), 16.5 (CH$_3$C=CH). Signals corresponding to the perfluorinated benzoyl ester moiety were not resolvable due to their anticipated weak intensity.

FTIR: 1684, 1448, 1203 cm$^{-1}$.

MS: (ESI$^+$) Found [M+H]$^+$: 315.1746, C$_{23}$H$_{23}$O requires 315.1743.

(4E)-4-Methyl-6-(naphthalen-2-yl)-1-phenylhex-4-en-1-one O-perfluorobenzoyl oxime 2f

General Procedure D: Part A: (E)-4-Methyl-6-(naphthalen-2-yl)-1-phenylhex-4-en-1-one (0.86 g, 2.73 mmol) was used. The reaction was heated at 75 °C for 2 hours to afford the corresponding oxime (0.84 g, 94%) as a colorless solid. Part B: The corresponding oxime (0.84 g, 2.55 mmol) was employed and the reaction was stirred for 1 hour. FCC (hexane:EtOAc 40:1) afforded the title compound (1.10 g, 82%) as colorless oil.

$^1$H NMR (400 MHz, CDCl$_3$): 7.83-7.69 (m, 5H, ArH), 7.57 (s, 1H, ArH), 7.50-7.38 (m, 5H, ArH), 7.30-7.25 (m, 1H, ArH), 5.46-5.39 (m, 1H, C=CH), 3.48 (d, $J = 7.5$ Hz, 2H, ArCH$_2$CH), 3.07 (t, $J = 7.5$ Hz, 2H, Ar(CN)CH$_2$), 2.34 (t, $J = 7.5$ Hz, 2H, Ar(CN)CH$_2$CH$_2$), 1.77 (s, 3H, CH$_3$C=CH).

$^{13}$C NMR (100 MHz, CDCl$_3$): 168.6 (C=O), 138.6 (ArC), 134.2 (C=CH), 133.6, 133.1, 132.0 (3 × ArC), 131.0, 128.8, 128.0, 127.6, 127.5, 127.3, 127.2, 126.1, 125.9, 125.2 (10 × ArC), 124.8 (C=CH), 36.3 (Ar(CN)CH$_2$CH$_2$), 34.4 (C=CH$_2$Ar), 27.8 (Ar(CN)CH$_2$), 16.1 (CH$_3$C=CH).

FTIR: 1763, 1498, 1325, 1193 cm$^{-1}$.

MS: (ESI$^+$) Found [M+Na]$^+$: 546.1465, C$_{30}$H$_{23}$NO$_2$F$_5$Na requires 546.1463.
(R,E)-2-Methyl-2-(2-(naphthalen-2-ylvinyl)-5-phenyl-3,4-dihydro-2H-pyrrole 3f

General Procedure E: Oxime ester 2f (55.0 mg, 0.105 mmol) was employed and the reaction was heated at 100 °C for 3.75 hours. FCC (toluene:hexane 3:1 to toluene) afforded the title compound (23.0 mg, 71%, 93:7 e.r.) as a pale yellow oil.

$[\alpha]_D^{22} +29.4 (c = 1.02, \text{CHCl}_3)$.

1H NMR (400 MHz, CDCl$_3$): 7.98-7.92 (m, 2H, ArH), 7.82-7.72 (m, 4H, ArH), 7.63 (dd, $J = 8.5$ and 1.5 Hz, 1H, ArH), 7.50-7.39 (m, 5H, ArH), 6.68 (d, $J = 16.0$ Hz, 1H, (NC)CH=CHAr), 6.60 (d, $J = 16.0$ Hz, 1H, (NC)CH=CHAr), 3.18-3.01 (m, 2H, Ar(CN)CH$_2$), 2.29-2.18 (m, 1H, Ar(CN)CH$_2$C$_2$H), 2.09–1.99 (m, 1H, Ar(CN)CH$_2$CH$_2$), 1.60 (s, 3H, (NC)CH$_3$).

13C NMR (100 MHz, CDCl$_3$): 171.5 ($\text{C}=\text{N}$), 136.9 ((NC)CH=CHAr), 134.9, 134.7, 133.7, 132.8 (4 × ArC), 130.5, 128.4, 128.0, 127.9, 127.8, 127.6 (6 × ArCH), 126.7 ((NC)CH=CHAr), 126.1 (2 signals), 125.6, 123.7 (4 × ArCH), 76.5 (quaternary C), 36.1 (Ar(CN)CH$_2$CH$_2$), 35.0 (Ar(CN)CH$_2$), 27.6 ((NC)CH$_3$).

FTIR: 1613, 1448, 1339, 1279 cm$^{-1}$.

MS: (ESI$^+$) Found [M+H]$^+$: 312.1742, C$_{23}$H$_{22}$N requires 312.1747.

The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexane-i-PrOH (90:10, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF$_3$)$_2$C$_6$H$_3$)$_3$ (15 mol%) as ligand; $t_R$ (minor) = 9.9 min and $t_R$ (major) = 14.7 min.
General Procedure C: Part A: Methyl 3-(naphthalene-2-yl)-3-oxopropanoate (0.98 g, 4.30 mmol) and (E)-1-bromo-2,5-dimethylhex-2-ene\textsuperscript{12} (0.90 g, 4.74 mmol) were employed. FCC (hexane:EtOAc 30:1) afforded the title compound (1.40 g, 92%) as a pale yellow oil.

**H NMR** (400 MHz, CDCl\textsubscript{3}): 8.54 (s, 1H, ArH), 8.08-7.96 (m, 2H, ArH), 7.90 (t, \(J = 8.0\) Hz, 2H, ArH), 7.66-7.54 (m, 2H, ArH), 5.24 (t, \(J = 7.0\) Hz, 1H, C=CH), 4.72 (t, \(J = 7.0\) Hz, 1H, (CO)CH(CO)), 3.68 (s, 3H, (CO)OCH\textsubscript{3}), 2.88-2.69 (m, 2H, (Ar(CO)CHCH\textsubscript{2})), 1.83 (dd, \(J = 7.0\) and 7.0 Hz, 2H, C=CHCH\textsubscript{2}), 1.66 (s, 3H, CH\textsubscript{3}=CH), 1.57-1.46 (m, 1H, CH(CH\textsubscript{3})\textsubscript{2}), 0.81 (t, \(J = 6.5\) Hz, 6H, CH(CH\textsubscript{3})\textsubscript{2}).

**C NMR** (100 MHz, CDCl\textsubscript{3}): 194.8 (Ar(C=O), 170.2 ((CO)OCH\textsubscript{3}), 135.7, 133.7, 132.5 (3 \(\times\) ArC), 131.5 (C=CH), 130.5, 129.7, 128.8, 128.6, 127.8 (5 \(\times\) ArCH), 126.9, 126.8 (ArCH and (C=CH), 124.1 (ArCH), 53.0 (Ar(CO)CH), 52.5 ((CO)OCH\textsubscript{3}), 39.0 (Ar(CO)CHCH\textsubscript{2}), 37.1 (C=CHCH\textsubscript{2}), 28.7 (CH(CH\textsubscript{3})\textsubscript{2}), 22.3, 22.2 (CH(CH\textsubscript{3})\textsubscript{2}), 16.3 (CH\textsubscript{3}C=CH).

**FTIR**: 1739, 1681, 1434, 1278, 1153 cm\textsuperscript{-1}.

**MS**: (ESI\textsuperscript{+}) Found [M+H]\textsuperscript{+}: 339.1943, C\textsubscript{22}H\textsubscript{27}O\textsubscript{3} requires 339.1955.
General Procedure C: Part B: Methyl (E)-2-(2-naphthoyl)-4,7dimethyl-oct-4-enoate (1.40 g, 4.14 mmol) was employed. FCC (hexane:EtOAc 20:1) afforded the title compound (0.78 g, 67%) as a colorless oil.

\[\text{H NMR (400 MHz, CDCl}_3\]: 8.49 (s, 1H, ArH), 8.05 (dd, \( J = 8.0 \text{ and } 1.5 \text{ Hz, 1H, ArH})], 7.98 (d, \( J = 8.0 \text{ Hz, } 1H, \text{ ArH})], 7.93-7.87 (m, 2H, ArH), 7.64-7.52 (m, 1H, C=CH), 3.25-3.18 (m, 2H, Ar(CO)CH\_2), 2.50 (t, \( J = 7.0 \text{ Hz, 2H, Ar(CO)CH}_2\)), 1.90 (dd, \( J = 7.0 \text{ and } 7.0 \text{ Hz, 2H, } C=CH\)), 1.70 (s, 3H, C=CH\_2), 1.65-1.55 (m, 1H, CH(CH\_3)\_2), 0.89 (d, \( J = 6.5 \text{ Hz, 6H, CH(CH}_2\_2\)).

\[\text{C NMR (100 MHz, CDCl}_3\]: 200.2 (C=O), 135.5 (ArC), 134.4, 134.2 (ArC and C=CH), 132.9 (ArCH), 129.6, 129.5, 128.4, 128.3, 127.8, 126.7, (6 × ArCH), 124.4 (C=CH), 124.0 (ArCH), 37.1 (C=CH\_2), 34.4 (Ar(CO)CH\_2\_2), 28.8 (CH(CH\_3)\_2), 22.4 (CH(CH\_3)\_2), 16.3 (CH\_2=CH=CH).

FTIR: 1679, 1466, 1364, 1181, 1123 cm\(^{-1}\).

MS: (ESI\(^{+}\) Found [M+H]\(^{+}\): 281.1893, C\(_{20}\)H\(_{25}\)O requires 281.1900.

\((E)-4,7-\text{Dimethyl-1-(naphthalene-2-yl)oct-4-en-1-one O-perfluorobenzoyl oxime}\ 2g\)

General Procedure D: Part A: (E)-4,7-Dimethyl-1-(naphthalene-2-yl)oct-4-en-1-one (0.77 g, 2.75 mmol) was used. The reaction was heated at 75 °C for 3 hours to afford the corresponding oxime (0.78 g, 96%) as a colorless oil. Part B: The corresponding oxime (0.78 g, 2.64 mmol) was employed and the reaction was stirred for 16 hours. FCC (hexane:EtOAc 60:1) afforded oxime ester (1.02 g, 79%, 1:0.1 mixture of oxime isomers) as a yellow solid.

\[\text{H NMR (400 MHz, CDCl}_3\]: Signals for the major isomer: 8.19 (m, 1H, ArH), 7.95-7.86 (m, 4H, ArH), 7.61-7.52 (m, 2H, ArH), 5.19 (t, \( J = 7.0 \text{ Hz, 1H, C=CH})], 3.17-3.09 (m, 2H, Ar(CN)CH\_2), 2.33 (t, \( J = 7.5 \text{ Hz, 2H, Ar(CN)CH}_2\)), 1.85 (dd, \( J = 7.0 \text{ and } 7.0 \text{ Hz, 2H, C=CH}_2\)), 1.63 (s, 3H, CH\_2=CH=CH), 1.61-1.51 (m, 1H, CH(CH\_3)\_2), 0.87 (d, \( J = 6.5 \text{ Hz, 6H, CH(CH}_2\_2\)). Characteristic signals only for the minor isomer: 3.24-3.19 (m, 0.2H, Ar(CN)CH\_2\).

\[\text{C NMR (100 MHz, CDCl}_3\]: Signals for the major isomer only: 168.5 (C=N), 134.4 (ArC), 133.4 (C=CH), 132.9, 130.5 (2 × ArC), 128.8, 128.6, 128.0, 127.7, 127.6, 126.7 (6 × ArCH), 125.4 (C=CH), 124.0 (ArCH), 37.1 (C=CH\_2), 36.7 (Ar(CN)CH\_2\_2), 28.7 (CH(CH\_3)\_2), 27.9 (Ar(CN)CH\_2), 22.3
(CH(CH₃)₂), 15.9 (CH₃C=CH). Signals corresponding to the perfluorinated benzyol ester moiety were not resolvable due to their anticipated weak intensity.

**¹⁹F NMR** (376 MHz, CDCl₃): Signals for the major isomer: -136.9 (2F), -147.5 (1F), -159.7 (2F).
Signals for the minor isomer: -137.0 (0.2F), -147.7 (0.1F), -160.0 (0.2F).

**FTIR**: 1759, 1525, 1494, 1324, 1191 cm⁻¹.

**MS**: (ESI⁺) Found [M+Na]⁺: 512.1612, C₂₇H₂₄NO₂F₃Na requires 512.1619.

(R,E)-2-Methyl-2-(3-methylbut-1-en-1-yl)-5-(naphthalen-2-yl)-3,4-dihydro-2H-pyrrole 3g

General Procedure E: Oxime ester 2g (50.0 mg, 0.102 mmol) was employed and the reaction was heated at 100 °C for 2.5 hours. FCC (hexane:EtOAc 50:1) afforded the title compound (22.0 mg, 78%, 92:8 e.r.) as a pale yellow oil.

[α]₂₃D +99.0 (c = 0.67, CHCl₃).

**¹H NMR** (400 MHz, CDCl₃): 8.21 (s, 1H, ArH), 8.12 (dd, J = 8.5 and 1.5 Hz, 1H, ArH), 7.94-7.82 (m, 3H, ArH), 7.56-7.48 (m, 2H, ArH), 5.54 (dd, J = 15.5 and 6.5 Hz, 1H, HC=CHCH), 3.21-3.02 (m, 2H, Ar(CN)C(CH₃)₂), 2.35-2.24 (m, 1H, CH(CH₃)₂), 1.98-1.88 (m, 1H, Ar(CN)CH₂CH₂), 1.46 (s, 3H, (NC)C(CH₃)₂), 1.00 (d, J = 6.5 Hz, 6H, CH(CH₃)₂).

**¹³C NMR** (100 MHz, CDCl₃): 170.7 (C=N), 134.3 (2 signals) (ArC and (HC=CHCH), 133.2 (HC=CHCH), 133.0, 132.3 (2 × ArC), 128.7, 128.0 (2 signals), 127.7, 126.9, 126.3, 124.8 (7 × ArCH), 76.2 (quaternary C), 36.1 (Ar(CN)CH₂CH₃), 34.9 (Ar(CN)CH₂), 30.9 (CH(CH₃)₂), 27.4 ((NC)CH₂), 22.6, 22.5 (CH(CH₃)₂).

**FTIR**: 1612, 1465, 1363, 1279, 1127 cm⁻¹.

**MS**: (ESI⁺) Found [M+H]⁺: 278.1899, C₂₀H₂₃N requires 278.1903.

The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexane-i-PrOH (95:5, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF₃)₂C₆H₃)₃ (15 mol%) as ligand; tᵣ (minor) = 8.4 min and tᵣ (major) = 9.4 min.
General Procedure A: (E)-2-Ethylbut-2-enal (5.80 mL, 51.02 mmol) was employed. The reaction was stirred at 0 °C for 30 minutes. Careful concentration in vacuo was performed at 0 °C to remove Et₂O. Kugelrohr distillation was performed to remove MeOH to afford the corresponding alcohol (4.04 g, 79%, 1:0.05 mixture of E:Z isomers) as a pale yellow oil.

\(^1\)H NMR (400 MHz, CDCl₃): Data for the major isomer only: 5.46 (q, J = 7.0 Hz, 1H, C=CH), 4.03 (s, 2H, CH₂OH), 2.12 (q, J = 7.5 Hz, 2H, CH₃CH₂), 1.63 (d, J = 7.0 Hz, 3H, C=CH₂CH₃), 0.99 (t, J = 7.5 Hz, 3H, CH₂CH₃).

\(^1^3\)C NMR (100 MHz, CDCl₃): Data for the major isomer only: 141.4 (C=CH), 120.5 (C=CH), 66.9 (CH₂OH), 20.7 (CH₂CH₃), 12.8, 12.7 (CH₂CH₃ and C=CHCH₃).

The spectroscopic properties of this compound were consistent with the data in the literature.\(^{18}\)
(E)-3-(Bromomethyl)pent-2-ene

To a solution of N-bromosuccinimide (3.66 g, 20.56 mmol) in anhydrous CH$_2$Cl$_2$ (50 mL) at 0 °C was added dropwise dimethylsulfide (1.75 mL, 23.86 mmol). The reaction was stirred for 30 minutes and then the reaction was cooled to -20 °C. (E)-2-Ethylbut-2-en-1-ol (1.35 g, 15.70 mmol) was added dropwise and the reaction was stirred for 10 minutes at -20 °C. The reaction was warmed to room temperature and stirred for 1 hour. The reaction was poured into ice (25 g), the organic extract was washed with brine (2 × 30 mL) and the organic phase was carefully concentrated in vacuo. FCC (pentane) afforded the title compound (0.67 g, 26%, 1:0.05 mixture of E:Z isomers) as a colorless oil.

$^1$H NMR (400 MHz, CDCl$_3$): Data for the major isomer only: 5.68 (q, $J$ = 7.0 Hz, 1H, C=C-H), 4.03 (s, 2H, C$_2$H$_4$Br), 2.24 (q, $J$ = 7.5 Hz, 2H, C$_2$H$_5$CH$_3$), 1.65 (d, $J$ = 7.0 Hz, 3H, C=CHC$_3$H$_3$), 1.02 (t, $J$ = 7.5 Hz, 3H, CH$_2$C$_3$H$_7$). Characteristic signals for the minor isomer: 5.50 (q, $J$ = 7.0 Hz, 0.05H, C=C-H).

$^{13}$C NMR (100 MHz, CDCl$_3$): Data for the major isomer only: 138.4 (C=CH), 125.8 (C=C-H), 39.4 (C$_2$H$_4$Br), 21.0 (C$_2$H$_5$CH$_3$), 13.5 (C=CHC$_3$H$_3$), 12.7 (C$_2$H$_5$CH$_3$).

FTIR: 2927, 1660, 1609, 1249 cm$^{-1}$.

MS: Mass spectrometry data was not obtained using either EI, CI and ESI techniques due to high volatility of this bromide.

(E)-4-Ethyl-1-(naphthalen-2-yl)hex-4-en-1-one

General Procedure C: Methyl 3-(naphthalen-2-yl)-3-oxopropanoate (0.83 g, 3.65 mmol) and (E)-3-(bromomethyl)pent-2-ene (0.65 g, 4.01 mmol) were employed. FCC (hexane:EtOAc 50:1) afforded the title compound (0.50 g, 54%, 1:0.05 mixture of E:Z isomers) as a pale yellow oil.

$^1$H NMR (400 MHz, CDCl$_3$): Data for the major isomer: 8.47 (s, 1H, Ar-H), 8.03 (dd, $J$ = 8.0 and 1.5 Hz, 1H, Ar-H), 7.95 (d, $J$ = 8.0 Hz, 1H, Ar-H), 7.90-7.88 (m, 2H, Ar-H), 7.62-7.51 (m, 2H, Ar-H), 5.26 (q, $J$ = 7.0 Hz, 1H, C=CH), 3.21-3.15 (m, 2H, Ar(CO)CH$_2$), 2.51-2.44 (m, 2H, Ar(CO)CH$_2$CH$_3$), 2.13 (q, $J$ = 7.5 Hz, 2H, CH$_2$CH$_3$), 1.62 (d, $J$ = 7.0 Hz, 3H, C=CHCH$_3$), 1.03 (t, $J$ = 7.5 Hz, 3H, CH$_2$CH$_3$).

$^{13}$C NMR (100 MHz, CDCl$_3$): 200.1 (C=O), 140.6 (C=CH), 135.5, 134.4, 132.5 (3 × Ar-C), 129.6, 129.5, 128.4, 128.3, 127.7, 126.7, 123.9 (7 × Ar-CH), 118.4 (C=CH), 37.6 (Ar(CO)CH$_2$), 31.0 (Ar(CO)CH$_2$CH$_3$), 23.1 (CH$_2$CH$_3$), 13.0 (C=CHCH$_3$), 12.8 (CH$_2$CH$_3$).

FTIR: 1682, 1468 cm$^{-1}$.

MS: (ESI$^+$) Found [M+H]$^+$: 253.1584, C$_{18}$H$_{21}$O requires 253.1587.
(4E)-4-Methyl-1-(naphthalen-2-yl)-6-phenylhex-4-en-1-one O-perfluorobenzoyl oxime 2h

**General Procedure D:** Part A: (E)-4-Ethyl-1-(naphthalen-2-yl)hex-4-en-1-one (0.48 g, 1.90 mmol) was used. The reaction was heated at 75 °C for 2 hours to afford the corresponding oxime (0.45 g, 89%) as a colorless solid. Part B: The corresponding oxime (0.45 g, 1.69 mmol) was employed and the reaction was stirred for 2 hours. FCC (hexane: EtOAc 40:1 to EtOAc) afforded the title compound (0.61 g, 79%, 1:0.05 mixture of E:Z isomers) as a colorless solid.

**1H NMR** (400 MHz, CDCl3): Signals for the major isomer: 8.17 (s, 1H, ArH), 7.94-7.83 (m, 4H, ArH), 7.60-7.49 (m, 2H, ArH), 5.22 (q, J = 7.0 Hz, 1H, C=CH), 3.07 (t, J = 7.0 Hz, 2H, Ar(CN)C2H3), 2.30 (t, J = 7.0 Hz, 2H, Ar(CN)CH2C2H3), 2.04 (q, J = 7.5 Hz, 2H, C2H3CH3), 1.57 (d, J = 7.0 Hz, 3H, C=CHCH3), 0.92 (t, J = 7.5 Hz, 3H, CH2C2H3).

**13C NMR** (100 MHz, CDCl3): Signals for the major isomer only: 168.5 (C=N), 139.8 (C=CH), 134.5, 132.9, 130.4 (3 × ArC), 128.8, 128.6, 128.0, 127.7, 126.7, 123.9 (7 × ArCH), 119.6 (C=CH), 33.3 (Ar(CN)CH2C2H3), 28.0 (Ar(CN)C2H3), 22.6 (CH2CH3), 13.0 (C=CHCH3), 12.6 (CH2CH3). Signals corresponding to the perfluorinated benzoyl ester moiety were not resolvable due to their anticipated weak intensity.

**19F NMR** (376 MHz, CDCl3): Signals for the major isomers: -136.9 (2F), -147.5 (1F), -159.7 (2F), Signals for the minor isomer: -137.4 (0.1F), -148.1 (0.05F), -160.0 (0.1F).

**FTIR:** 1755, 1524, 1491, 1324, 1189 cm⁻¹.

**MS:** (ESI⁺) Found [M+Na]⁺: 484.1300, C25H20NO2F5Na requires 484.1306.

(R)-2-Ethyl-5-(naphthalen-2-yl)-2-vinyl-3,4-dihydro-2H-pyrrole 3h

**General Procedure E:** Oxime ester 2h (50.0 mg, 0.108 mmol) was employed and the reaction was heated at 80 °C for 6.5 hours. FCC (toluene:EtOAc 80:1) afforded the title compound (18.5 mg, 68%, 92:8 e.r.) as a pale yellow solid.

\[ [\alpha]_{D}^{22} +38.5 \text{ (c = 0.73, CHCl₃) } \]

**M.P.** 75-77 °C (CH2Cl2-pentane)

**1H NMR** (400 MHz, CDCl3): 8.21 (s, 1H, ArH), 8.14 (dd, J = 8.0 and 1.5 Hz, 1H, ArH), 7.94-7.82 (m, 3H, ArH), 7.56-7.48 (m, 2H, ArH), 6.12 (dd, J = 17.0 and 11.0 Hz, 1H, HC=CH2), 5.12 (dd, J = 17.0 and 1.5 Hz, 1H, HC=CH2), 5.07 (dd, J = 11.0 and 1.5 Hz, 1H, HC=CH2), 3.20-2.98 (m, 2H, Ar(CN)CH2), 2.13-1.91 (m, 2H, Ar(CN)CH2CH3), 1.90-1.75 (m, 2H, (NC)CH2CH3), 0.98 (t, J = 7.5 Hz, 3H, (NC)CH2CH3).
$^{13}$C NMR (100 MHz, CDCl$_3$): 171.2 (C=N), 143.3 (CH=CH$_2$), 134.4, 123.0, 132.3 (3 × ArC), 128.7, 128.0 (2 signals), 127.7, 126.9, 126.3, 124.8 (7 × ArCH), 111.9 (CH=CH$_2$), 80.6 (quaternary C), 35.0 (Ar(CN)CH$_2$), 33.5 ((NCH)$_2$CH$_3$), 31.8 (Ar(CN)CH$_2$CH$_2$), 8.8 ((NCH)$_2$CH$_3$).

FTIR: 2965, 1613 cm$^{-1}$.

MS: (ESI$^+$) Found [M+H]$^+$: 250.1592, C$_{18}$H$_{20}$N requires 250.1590.

The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexane-i-PrOH (99:1, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF$_3$)$_2$C$_6$H$_3$)$_3$ (15 mol%) as ligand; $t_R$ (major) = 12.5 min and $t_R$ (minor) = 13.9 min. The absolute structure of this molecule was confirmed by Vibrational Circular Dichroism (VCD).
Comparison of experimental VCD spectrum of dihydropyrrole 3h (in duplicate, blue) and simulated spectra of the R (red) and S (green) enantiomers. The agreement between the simulated spectrum of the R enantiomer and the experimental spectrum is good, therefore dihydropyrrole 3h has R configuration.

Experimental: A 15.4 mg sample of dihydropyrrole 3h was dissolved in CDCl₃ (150 µL). A VCD spectrum was acquired in 0.100 mm BaF₂ cells for 7 hours each in a BioTools ChiralIR instrument equipped with dual source and dual photoelastic modulator. The resolution was 4 cm⁻¹. The experimental VCD spectrum shows weak characteristic bands.

Computational Spectral Simulations: A Monte Carlo molecular mechanics search for low energy geometries was conducted for full structures of the two enantiomers, R and S. MacroModel within the Maestro graphical interface (Schrödinger Inc.) was used to generate starting coordinates for conformers. All conformers within 5 kcal/mole of the lowest energy conformer were used as starting points for density functional theory (DFT) minimizations within Gaussian09. Optimized structures, harmonic vibrational frequencies/intensities, VCD rotational strengths, and free energies at STP (including zero-point energies) were determined for each conformer. In these calculations, the functional B3LYP and the basis set 6-31G* were used. Simulations of infrared and VCD spectra for each conformation were generated using an in-house built program to fit Lorentzian line shapes (12 cm⁻¹ line width) to the computed spectra thereby allowing direct comparisons between simulated and experimental spectra.

Results: The experimental spectrum was compared with simulated spectra of the two enantiomers based on DFT calculations starting with full structures. The comparison is presented above. The agreement between the simulated spectrum of the R enantiomer and the experimental spectrum is good. It is therefore concluded that dihydropyrrole 3h has R configuration.
Methyl (E)-2-benzylbut-2-enoate

\[
\text{MeO} \quad \text{Ph}
\]

To a solution of methyl 3-hydroxy-2-methylenebutanoate (1.65 g, 12.5 mmol) and phenylboronic acid (3.10 g, 25.1 mmol) in methanol (50 mL), [Rh(COD)Cl]₂ (63.0 mg, 0.125 mmol) was added. The reaction was heated to 55 °C for 20 hours. The solvent was concentrated in vacuo and FCC (hexane:EtOAc 50:1) afforded the title compound (1.89 g, 79%) as a pale yellow oil.

\(^1\)H NMR (400 MHz, CDCl₃): 7.30-7.13 (m, 5H, ArH), 7.04 (q, J = 7.0 Hz, 1H, C=CH), 3.72-3.67 (m, 5H, CH₂Ar and OCH₃), 1.89 (d, J = 7.0 Hz, 3H, C=CHCH₃).

\(^1\)C NMR (100 MHz, CDCl₃): 168.0 (C=O), 139.6 (Ar C), 138.9 (C=CH), 131.9 (C=CH), 128.3, 128.2, 125.9 (3 × ArCH), 51.7 (OCH₃), 32.0 (CH₂Ar), 14.7 (C=CHCH₃).

The spectroscopic properties of this compound were consistent with the data in the literature.\(^1\)

(\(E\))-2-Benzylbut-2-en-1-ol

To a solution of methyl (\(E\))-2-benzylbut-2-enoate (1.87 g, 9.84 mmol) in anhydrous THF (35 mL) at -78 °C, was added dropwise diisobutylaluminium hydride (1M in hexane, 20.7 mL, 20.7 mmol). The reaction was stirred for 1 hour. The reaction was quenched with sat. NH₄Cl (50 mL). The precipitate was filtered off and the organic phase was concentrated in vacuo. FCC (hexane:EtOAc 10:1 to 8:1) afforded the title compound (1.18 g, 74%) as a colorless oil.

\(^1\)H NMR (400 MHz, CDCl₃): 7.31-7.14 (m, 5H, ArH), 5.70 (q, J = 7.0 Hz, 1H, C=C), 3.97 (m, 2H, C=CH₂OH), 3.49 (s, 2H, C=CH₂Ar), 1.77 (d, J = 7.0 Hz, 3H, CH₃).

\(^1\)C NMR (100 MHz, CDCl₃): 139.7 (Ar C), 138.4 (HC=C), 128.5, 128.4, 126.0 (3 × ArCH), 122.5 (HC=C), 66.8 (CH₂OH), 33.4 (CH₂Ar), 13.4 (CH₃).

FTIR: 3310, 1494, 1452 cm⁻¹.

MS: (ESI⁺) Found [M+H]⁺: 145.1014, C₁₁H₁₃ requires 145.1012.

(\(E\))-(2-(Bromomethyl)but-2-en-1-yl)benzene

General Procedure B: (\(E\))-2-Benzylbut-2-en-1-ol (0.65 g, 4.01 mmol) was employed to afford the title compound (0.75 g, 83%) as a colorless oil.

\(^1\)H NMR (400 MHz, CDCl₃): 7.32-7.14 (m, 5H, ArH), 5.86 (q, J = 7.0 Hz, 1H, C=CH), 3.88 (s, 2H, CH₂Br), 3.60 (s, 2H, CH₂Ar), 1.79 (d, J = 7.0 Hz, 3H, CH₃).
\[^{13}\text{C NMR}\] (100 MHz, CDCl\(_3\)): 139.0 (Ar\(\text{C}\)), 135.9 (HC=\(\text{C}\)), 128.6, 128.5, 127.2 (3 \times \text{ArCH}), 126.3 (HC=\(\text{C}\)), 39.1 (\text{CH}_2\text{Br}), 33.3 (\text{CH}_2\text{Ar}), 14.1 (\text{CH}_3).

\[^{1}\text{H NMR}\] (400 MHz, CDCl\(_3\)): 8.33 (s, 1H, Ar\(\text{H}\)), 7.95 (dd, \(J = 8.0\) and 2.0 Hz, 1H, Ar\(\text{H}\)), 7.92 (d, \(J = 8.0\) Hz, 1H, Ar\(\text{H}\)), 7.87-7.83 (m, 2H, Ar\(\text{H}\)), 7.62-7.50 (m, 2H, Ar\(\text{H}\)), 7.31-7.14 (m, 5H, Ar\(\text{H}\)), 5.52 (q, \(J = 7.0\) Hz, 1H, C=C\(\text{H}\)), 3.49 (s, 2H, C\(\text{H}_2\)\text{Ar}), 3.15-3.08 (m, 2H, Ar(CO)\(\text{C}\)\(\text{H}_2\)), 2.48-2.40 (m, 2H, Ar(CO)\(\text{CH}_2\text{C}\)\(\text{H}_2\)), 1.75 (d, \(J = 7.0\) Hz, 3H, C\(\text{H}_3\)).

\[^{13}\text{C NMR}\] (100 MHz, CDCl\(_3\)): 199.9 (\(\text{C}=\text{O}\)), 140.0 (Ar\(\text{C}\)), 137.4 (\(\text{C}=\text{CH}\)), 135.5, 134.2, 132.5 (3 \times \text{Ar}\(\text{C}\)), 129.6, 129.5, 128.5, 128.4, 128.3 (2 signals), 127.7, 126.7, 126.0, 123.9 (10 \times \text{ArCH}), 121.0 (\(\text{C}=\text{CH}\)), 37.6 (Ar(CO)\(\text{C}\)\(\text{H}_2\)), 36.1 (\(\text{CH}_2\text{Ar}\)), 31.5 (Ar(CO)\(\text{CH}_2\text{C}\)\(\text{H}_2\)), 13.7 (\(\text{CH}_3\)).

\[^{1}\text{H NMR}\] (400 MHz, CDCl\(_3\)): 8.03 (s, 1H, Ar\(\text{H}\)), 7.88-7.78 (m, 4H, Ar\(\text{H}\)), 7.59-7.49 (m, 2H, Ar\(\text{H}\)), 7.23-7.06 (m, 5H, Ar\(\text{H}\)), 5.49 (q, \(J = 7.0\) Hz, 1H, C=\(\text{CH}\)), 3.40 (s, 2H, C\(\text{H}_2\)\text{Ar}), 3.08-2.98 (m, 2H, Ar(CN)\(\text{CH}_2\)), 2.25 (t, \(J = 7.5\) Hz, 2H, Ar(CN)\(\text{CH}_2\text{CH}_2\)), 1.72 (d, \(J = 7.0\) Hz, 3H, \(\text{CH}_3\)).
$^{13}$C NMR (100 MHz, CDCl$_3$): Signals for the major isomer only: 168.2 (C=N), 139.5 (ArC), 136.7 (C=CH), 134.4, 132.8, 130.3 (3 x ArC), 128.8, 128.5, 128.4, 128.3, 128.0, 127.7, 127.5, 126.6, 126.0, 123.9 (10 x ArCH), 122.1 (C=CH), 35.5 (CH$_2$Ar), 33.5 (Ar(CN)CH$_2$C), 27.9 (Ar(CN)C), 13.6 (CH$_3$). Signals corresponding to the perfluorinated benzyol ester moiety were not resolvable due to their anticipated weak intensity.

$^{19}$F NMR (376 MHz, CDCl$_3$): Signals for the major isomers: -136.9 (2F), -147.5 (1F), -159.6 (2F), Signals for the minor isomer: -137.4 (0.1F), -148.1 (0.05F), -160.0 (0.1F).

FTIR: 1756, 1526, 1492, 1323, 1189 cm$^{-1}$.

MS: (ESI$^+$) Found [M+Na]$^+$: 546.1457, C$_{30}$H$_{22}$NO$_2$F$_5$Na requires 546.1463.

$(S)$-2-Benzyl-5-(naphthalen-2-yl)-2-vinyl-3,4-dihydro-2H-pyrrole 3i

General Procedure E: Oxime ester 2i (55.0 mg, 0.105 mmol) was employed and the reaction was heated at 80 °C for 5.5 hours. FCC (toluene:EtOAc 100:1) afforded the title compound (23 mg, 71%, 93:7 e.r.) as a pale yellow solid.

$\left[\alpha\right]_{D}^{23}$ -118.8 (c = 0.64, CHCl$_3$).

M.P. 89-91 °C (CH$_2$Cl$_2$-pentane).

$^1$H NMR (400 MHz, CDCl$_3$): 8.13-8.06 (m, 2H, ArH), 7.90-7.82 (m, 3H, ArH), 7.55-7.46 (m, 2H, ArH), 7.27-7.12 (m, 5H, ArH), 6.22 (dd, $J = 17.0$ and 10.0 Hz, 1H, HC=CH$_2$), 5.18 (dd, $J = 17.0$ and 1.0 Hz, 1H, HC=CH$_2$), 5.07 (dd, $J = 10.0$ and 1.0 Hz, 1H, HC=CH$_2$), 3.19 (d, $J = 13.0$ Hz, 1H, CH$_2$Ar), 3.01 (d, $J = 13.0$ Hz, 1H, CH$_2$Ar), 2.96-2.83 (m, 1H, Ar(CN)CH$_2$), 2.49-2.38 (m, 1H, Ar(CN)CH$_2$), 2.15-2.04 (m, 1H, Ar(CN)CH$_2$CH$_3$), 2.02-1.92 (m, 1H, Ar(CN)CH$_2$CH$_3$).

$^{13}$C NMR (100 MHz, CDCl$_3$): 172.2 (C=N), 143.8 (CH=CH$_2$), 137.7, 134.4, 132.9, 132.1 (4 x ArC), 130.8 (2 signals), 128.7, 128.0 (2 signals), 127.7 (2 signals), 127.0, 126.3, 126.1 (10 x ArCH), 112.1 (CH=CH$_2$), 80.6 (quaternary C), 46.6 (CH$_2$Ar), 35.1 (Ar(CN)CH$_2$), 31.7 (Ar(CN)CH$_2$CH$_3$).

FTIR: 1613, 1280, 1134 cm$^{-1}$.

MS: (ESI$^+$) Found [M+H]$^+$: 312.1733, C$_{23}$H$_{22}$N requires 312.1747.

The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IA, isocratic hexane-iPrOH (95:5, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF$_3$)$_2$C$_6$H$_3$)$_3$ (15 mol%) as ligand; $t_R$ (major) = 11.4 min and $t_R$ (minor) = 13.0 min.
(E)-2-Isopropylbut-2-en-1-ol

To a solution of 2-butyne-1-ol (2.13 mL, 28.5 mmol) in anhydrous Et₂O (50 mL) was added CuI (5.4 g, 28.5 mmol). The reaction was cooled to 0 °C. Isopropylmagnesium chloride (1.89 M in THF, 45.5 mL, 85.6 mmol) was added dropwise. The reaction was stirred at room temperature for 20 hours. The reaction was quenched with sat. NH₄Cl (100 mL) and extracted with Et₂O (2 × 150 mL). The solvent was carefully distilled off and purification of the residue by FCC (pentane:Et₂O 30:1 to 10:1) afforded the title compound (0.54 g, 17%) as a colorless oil.
$^1$H NMR (400 MHz, CDCl$_3$): 5.49 (q, $J = 7.0$ Hz, 1H, HC=C), 4.09 (s, 2H, CH$_2$OH), 2.86 (sept. $J = 6.5$ Hz, 1H, CH(CH$_3$)$_2$), 1.66 (d, $J = 7.0$ Hz, 3H, CH$_2$(CH=C), 1.07 (d, $J = 6.5$ Hz, 6H, CH(CH$_3$)$_2$).

$^{13}$C NMR (100 MHz, CDCl$_3$): 144.7 (HC=C), 120.5 (H=C=), 124.7 (HC=), 64.6 (CH$_2$OH), 27.6 (CH(CH$_3$)$_2$), 21.2 (CH(CH$_3$)$_2$), 12.7 (CH$_3$CH=C).

The spectroscopic properties of this compound were consistent with the data in the literature.

$(E)$-$(3$-(Bromomethyl)$)-4$-methylpent-2-ene

General Procedure B: $(E)$-2-Isopropylbut-2-en-1-ol (0.53 g, 4.65 mmol) was employed to afford the title compound (0.81 g, 98%) as a colorless oil.

$^1$H NMR (400 MHz, CDCl$_3$): 5.71 (q, $J = 7.0$ Hz, 1H, HC=C), 4.02 (s, 2H, CH$_2$Br), 2.86 (sept. $J = 6.5$ Hz, 1H, CH(CH$_3$)$_2$), 1.69 (d, $J = 7.0$ Hz, 3H, CH$_2$(CH=C), 1.16 (d, $J = 6.5$ Hz, 6H, CH(CH$_3$)$_2$).

$^{13}$C NMR (100 MHz, CDCl$_3$): 141.4 (HC=C), 127.6 (HC=), 129.5 (HC=), 36.0 (CH$_2$Br), 28.4 (CH(CH$_3$)$_2$), 21.1 (CH(CH$_3$)$_2$), 13.5 (CH$_3$CH=C).

FTIR: 1460, 1375, 1060 cm$^{-1}$.

MS: Mass Spectrometry data was not obtained by either EI, CI or ESI techniques.

$(Z)$-4-Isopropyl-1-(naphthalene-2-yl)hex-4-en-1-one

General Procedure C: Methyl 3-(naphthalene-2-yl)-3-oxopropanoate (0.86 g, 3.78 mmol) and $(E)$-3-(bromomethyl)$)-4$-methylpent-2-ene (0.80 g, 4.54 mmol) was employed. FCC (hexane:EtOAc 60:1) afforded the target ketone (0.82 g, 82%) as a colorless oil.

$^1$H NMR (400 MHz, CDCl$_3$): 8.49 (s, 1H, ArH), 8.06 (dd, $J = 8.0$ and 1.5 Hz, 1H, ArH), 7.98 (d, $J = 8.0$ Hz, 1H, ArH), 7.90 (t, $J = 8.0$ Hz, 2H, ArH), 7.64-7.52 (m, 2H, ArH), 5.23 (q, $J = 7.0$ Hz, 1H, C=CH), 3.27-3.18 (m, 2H, Ar(CO)CH$_2$), 2.94 (sept. $J = 6.5$ Hz, 1H, CH(CH$_3$)$_2$), 2.45 (t, $J = 7.0$ Hz, 2H, Ar(CO)CH$_2$), 1.65 (d, $J = 7.0$ Hz, 3H, C=CHCH$_3$), 1.06 (d, $J = 6.5$ Hz, 6H, CH(CH$_3$)$_2$).

$^{13}$C NMR (100 MHz, CDCl$_3$): 200.2 (C=O), 144.0 (C=CH), 135.5, 134.4, 132.6 (3 × ArC), 129.6, 129.5, 128.4, 128.3, 127.8, 126.7, 124.0 (7 × ArCH), 117.0 (C=CH), 38.2 (Ar(CO)CH$_2$), 28.6 (CH(CH$_3$)$_2$), 25.4 (Ar(CO)CH$_2$CH$_2$), 20.9 (CH(CH$_3$)$_2$), 12.8 (C=CHCH$_3$).

FTIR: 2960, 1681, 1467, 1360, 1182, 1123 cm$^{-1}$.

MS: (ESI$^+$) Found [M+H]$^+$: 267.1741, C$_{19}$H$_{23}$O requires 267.1743.
(4Z)-4-Isopropyl-1-(naphthalene-2-yl)hex-4-en-1-one O-perfluorobenzoyl oxime 2j

General Procedure D: Part A: (Z)-4-Isopropyl-1-(naphthalene-2-yl)hex-4-en-1-one (0.82 g, 3.08 mmol) was used. The reaction was heated at 75 °C for 2 hours to afford the corresponding oxime (0.81 g, 94%) as a colorless oil. Part B: The corresponding oxime (0.81 g, 2.88 mmol) was employed and the reaction was stirred for 2 hours. FCC (hexane:EtOAc 40:1) afforded the title compound (0.85 g, 62%, 1:0.1 mixture of oxime isomers) as a yellow solid.

1H NMR (400 MHz, CDCl3): Signals for the major isomer: 8.20 (s, 1H, ArH), 7.98-7.85 (m, 4H, ArH), 7.61-7.52 (m, 2H, ArH), 5.26 (q, J = 7.0 Hz, 1H, C=C'H), 3.13-3.07 (m, 2H, Ar(CN)CH2), 2.88 (sept. J = 6.5 Hz, 1H, C'H(CH3)2), 2.24 (t, J = 7.0 Hz, 2H, Ar(CN)CH2CH3), 1.65 (d, J = 7.0 Hz, 3H, C=CHC3H3), 0.94 (d, J = 6.5 Hz, 6H, CH(CH3)2). Characteristic signals only for the minor isomer: 0.91 (d, J = 6.5 Hz, 0.6H, CH(CH3)2).

13C NMR (100 MHz, CDCl3): Signals for the major isomer only: 168.7 (C=N), 143.4 (C=CH), 134.5, 132.9, 130.4 (3 × ArC), 128.8, 128.6, 128.0, 127.7, 126.7, 123.9 (7 × ArCH), 118.1 (C=C'H), 28.8 (Ar(CN)CH2), 28.4 (CH(CH3)2), 28.0 (Ar(CN)CH2CH3), 20.7 (CH(CH3)2), 12.8 (C=CHCH3). Signals corresponding to the perfluorinated benzoyl ester moiety were not resolvable due to their anticipated weak intensity.

19F NMR (376 MHz, CDCl3): Signals for the major isomer: -136.9 (2F), -147.4 (1F), -159.7 (2F). Signals for the minor isomer: -137.4 (0.2F), -148.1 (0.1F), -160.0 (0.2F).

FTIR: 1755, 1524, 1491, 1324, 1190 cm⁻¹.

MS: (ESI⁺) Found [M+Na]+: 498.1461, C26H22NO2F5Na requires 498.1463.

(S)-2-Isopropyl-5-(naphthalene-2-yl)-2-vinyl-3,4-dihydro-2H-pyrrole 3j

General Procedure E: Oxime ester 2j (50.0 mg, 0.105 mmol) was employed and the reaction was heated at 120 °C for 1.75 hours. FCC (hexane:EtOAc 60:1) afforded the title compound (19 mg, 69%, 93:7 e.r.) as a pale yellow solid.

[α]D²⁵ +25.0 (c = 0.40, CHCl3).

M.P. 71-72 °C (CH2Cl2-pentane).

1H NMR (400 MHz, CDCl3): 8.19 (s, 1H, ArH), 8.14 (dd, J = 8.5 and 1.5 Hz, 1H, ArH), 7.94-7.82 (m, 3H, ArH), 7.56-7.48 (m, 2H, ArH), 6.18-6.08 (m, 1H, H=CH2), 5.11-5.04 (m, 2H, H=CH2), 3.13-
2.94 (m, 2H, Ar(CN)CH₂), 2.13-1.90 (m, 3H, Ar(CN)CH₂CH₂ and CH(CH₃)₂), 1.05 (d, J = 6.5 Hz, 3H, CH(CH₃)₂), 0.96 (d, J = 6.5 Hz, 3H, CH(CH₃)₂).

**¹H NMR** (100 MHz, CDCl₃): 170.8 (C=N), 141.8 (H=C=CH₂), 134.3, 133.0, 132.4 (3 × ArC), 128.6, 128.0, 127.9, 127.7, 126.9, 126.3, 124.9 (7 × ArCH), 112.4 (HC=CH₂), 83.7 (quaternary C), 36.9 (CH(CH₃)₂), 34.9 (Ar(CN)CH₂), 28.9 (Ar(CN)CH₂CH₂), 17.9, 17.6 (CH(CH₃)₂).

**¹³C NMR** (100 MHz, CDCl₃): 170.8 (C=N), 141.8 (H=C=CH₂), 134.3, 133.0, 132.4 (3 × ArC), 128.6, 128.0, 127.9, 127.7, 126.9, 126.3, 124.9 (7 × ArCH), 112.4 (HC=CH₂), 83.7 (quaternary C), 36.9 (CH(CH₃)₂), 34.9 (Ar(CN)CH₂), 28.9 (Ar(CN)CH₂CH₂), 17.9, 17.6 (CH(CH₃)₂).

**FTIR**: 1613, 1468, 1363, 1126 cm⁻¹.


The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IA, isocratic hexane-i-PrOH (99:1, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF₃)₂C₆H₃)₃ (15 mol%) as ligand; tᵣ (major) = 10.6 min and tᵣ (minor) = 11.6 min.


**General Procedure C:** Methyl 3-(naphthalen-2-yl)-3-oxopropanoate (0.65 g, 2.84 mmol) and (E)-(4-bromo-3-methylbut-2-en-yl)benzene\(^{13}\) (0.70 g, 3.12 mmol) were employed. FCC (hexane:EtOAc 45:1) afforded the title compound (0.59 g, 66%) as a colorless oil.

\(^{1}H\) NMR (400 MHz, CDCl\(_3\)): 8.48 (s, 1H, ArH), 8.04 (dd, \(J = 8.0\) and 1.5 Hz, 2H, ArH), 7.97 (d, \(J = 8.0\) Hz, 2H, ArH), 7.93-7.86 (m, 2H, ArH), 7.32-7.26 (m, 2H, ArH), 7.22-7.16 (m, 3H, ArH), 5.45 (tq, \(J = 7.5\) and 1.5 Hz, 1H, C=CH), 3.40 (d, \(J = 8.0\) Hz, 2H, C\(_2\)HAr), 3.28-3.21 (t, \(J = 7.0\) Hz, 2H, Ar(CO)CH\(_2\)C\(_2\)H), 2.56 (t, \(J = 7.0\) Hz, 2H, Ar(CO)CH\(_2\)C\(_2\)H), 1.83 (s, 3H, C\(_3\)H).  

\(^{13}C\) NMR (100 MHz, CDCl\(_3\)): 200.0 (C=O), 141.4, 135.5 (2 \(\times\) ArC), 135.1 (C=CH), 134.3, 132.5 (2 \(\times\) ArC), 129.6, 129.5, 128.4 (3 signals), 128.3, 127.8, 126.7, 125.8, 123.9 (10 \(\times\) ArC), 123.7 (C=CH), 37.3 (Ar(CO)CH\(_2\)), 34.2 (CH\(_2\)Ar), 34.1 (Ar(CO)CH\(_2\)C\(_2\)H), 16.5 (CH\(_3\)).  

FTIR: 1680, 1493 cm\(^{-1}\).  

MS: (ESI\(^+\)) Found [M+H]\(^+\): 315.1741, C\(_{23}\)H\(_{23}\)O requires 315.1743.

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**(E)-4-Methyl-1-(naphthalen-2-yl)-6-phenylhex-4-en-1-one**

\[\text{O-}
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**General Procedure D:** Part A: (E)-4-Methyl-1-(naphthalen-2-yl)-6-phenylhex-4-en-1-one (0.58 g, 1.85 mmol) was used. The reaction was heated at 75 °C for 2 hours to afford the corresponding oxime (0.56 g, 92%) as a colorless solid. Part B: The corresponding oxime (0.56 g, 1.70 mmol) was employed and the reaction was stirred for 2 hours. FCC (hexane: EtOAc 50:1 to EtOAc) afforded the title compound (0.70 g, 79%, 1:0.25 mixture of oxime isomers) as a colorless solid.

\(^{1}H\) NMR (400 MHz, CDCl\(_3\)): Signals for both isomers: 8.17 (s, 1H, maj. ArH), 7.92-7.74 (m, 5H, ArH), 7.61-7.49 (m, 2.5H, ArH), 7.36-7.10 (m, 6.5H, ArH), 5.38 (tq, \(J = 7.5\) and 1.0 Hz, 1H, maj. C=CH), 5.29 (tq, \(J = 7.5\) and 1.0 Hz, 0.25H, min. C=CH), 3.37-3.31 (m, 2.5H, min. and maj. CH\(_2\)Ar), 3.16 (t, \(J = 8.0\) Hz, 2H, maj. Ar(CN)CH\(_2\)), 3.02 (t, \(J = 8.0\) Hz, 0.5H, min. Ar(CN)CH\(_2\)), 2.37 (t, \(J = 8.0\) Hz, 2H,
maj. Ar(CN)CH₂CH₂, 2.27 (t, J = 8.0 Hz, 0.5H, maj. Ar(CN)CH₂CH₂), 1.76 (s, 3.75H, min. and maj. CH₃).

¹³C NMR (100 MHz, CDCl₃): Signals for the major isomer only: 168.4 (C≡N), 141.1, 134.5 (2 × ArC), 134.0 (C=CH), 132.9, 130.4 (2 × ArC), 128.8, 128.6, 128.4, 128.2, 128.0, 127.7, 127.6, 126.7, 125.9 (9 × ArCH), 125.0 (C=CH), 124.0 (ArCH), 36.5 (Ar(CN)CH₂CH₂), 34.2 (CH₂Ar), 27.6 (Ar(CN)CH₂), 16.0 (CH₃). Signals corresponding to the perfluorinated benzoyl ester moiety were not resolvable due to their anticipated weak intensity.

¹⁹F NMR (376 MHz, CDCl₃): Signals for the major isomers: -136.9 (2F), -147.3 (1F), -159.6 (2F), Signals for the minor isomer: -137.2 (0.5F), -148.0 (0.25F), -159.9 (0.5F).

FTIR: 1754, 1524, 1492, 1321, 1190 cm⁻¹.

MS: (ESI⁺) Found [M+Na]⁺: 546.1464, C₃₀H₂₂NO₂F₅Na requires 546.1463.

(R,E)-2-Methyl-5-(naphthalen-2-yl)-2-styryl-3,4-dihydro-2H-pyrrole 3k

General Procedure E: Oxime ester 2k (55.0 mg, 0.105 mmol) was employed and the reaction was heated at 120 °C for 2 hours. FCC (toluene:EtOAc 80:1) afforded the title compound (25 mg, 76%, 94:6 e.r.) as a pale yellow solid.

[α]D²⁰⁺33.3 (c = 0.51, CHCl₃).

M.P. 112-113 °C (CH₂Cl₂-pentane).

¹H NMR (400 MHz, CDCl₃): 8.24 (s, 1H, ArH), 8.16 (d, J = 8.0 Hz, 1H, ArH), 7.95-7.82 (m, 3H, ArH), 7.57-7.48 (m, 2H, ArH), 7.44-7.17 (m, 5H, ArH), 6.54 (d, J = 16.0 Hz, 1H, HC=CHAr), 6.49 (d, J = 16.0 Hz, 1H, HC=CHAr), 3.28-3.10 (m, 2H, Ar(CN)CH₂), 2.30-2.19 (m, 1H, (CN)CH₂), 2.11-2.00 (m, 1H, (CN)CH₂), 1.59 (s, 3H, CH₃).

¹³C NMR (100 MHz, CDCl₃): 171.5 (C≡N), 137.4 (ArC), 136.4 (HC=CHAr), 134.4, 133.0, 132.2 (3 × ArC), 128.7, 128.5, 128.2, 128.1, 127.8, 127.1 (2 signals) (7 × ArCH), 126.6 (HC=CHAr), 126.4 (2 signals), 124.8 (3 × ArCH), 76.6 (quaternary C), 36.1 (Ar(CN)CH₂CH₂), 35.0 (Ar(CN)CH₂), 27.6 (CH₃).

FTIR: 1611, 1279, 1132 cm⁻¹.

MS: (ESI⁺) Found [M+H]⁺: 312.1745, C₂₃H₂₂N requires 312.1747.

The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexane-i-PrOH (90:10, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF₃)₂C₆H₃)_3 (15 mol%) as ligand; tᵣ (minor) = 10.1 min and tᵣ (major) = 11.0 min.
Methyl 3-oxo-3-(4-(trifluoromethyl)phenyl)propanoate and Methyl (Z)-3-hydroxy-3-(4-(trifluoromethyl)phenyl)acrylate

To a suspension of NaH (0.34 g, 8.55 mmol) in THF (10 mL) at room temperature was added dimethyl carbonate (0.61 mL, 7.20 mmol). 1-(4-(Trifluoromethyl)phenyl)ethan-1-one (1.34 g, 7.13 mmol) was added and the reaction was heated at 75 °C for 16 hours. The reaction was cooled to room temperature and then concentrated in vacuo. To the residue was added ice-cold water (30 mL) and aq. 1M HCl (30
mL) and the mixture was extracted with EtOAc (2 x 50 mL). The organic extracts were combined, dried (Na₂SO₄) and concentrated in vacuo. The residue was purified by FCC (hexane:EtOAc 30:1) to afford the title compound (1.37 g, 78%, 1:0.5 mixture of keto and enol tautomers) as a pale yellow oil.

**1H NMR** (400 MHz, CDCl₃): Signals for both tautomers: 12.47 (s, 0.5H, B-OH), 8.05 (d, J = 8.0 Hz, 2H, A-ArH), 7.88 (d, J = 8.0 Hz, 1H, B-ArH), 7.75 (d, J = 8.0 Hz, 2H, A-ArH), 7.67 (d, J = 8.0 Hz, 1H, B-ArH), 5.72 (s, 0.5H, B-C=CH), 4.02 (s, 2H, A-CH₂), 3.82 (s, 1.5H, B-OCH₃), 3.75 (s, 3H, A-OCH₃).

**13C NMR** (100 MHz, CDCl₃): Signals for both tautomers: 191.4 (A-Ar(CO)), 173.2 (B-(CO)OCH₃), 169.6 (B-(O)OH), 167.4 (A-(CO)OCH₃), 138.5 (A-Ar(C(CO))), 136.7 (B-Ar(C(CO))), 135.0 (q, J = 33.5 Hz, A-F₃C-), 125.7 (q, J = 33.0 Hz, B-F₃C-), 128.9 (A-ArCH), 126.4 (B-ArCH), 125.9 (q, J = 4.0 Hz, A-ArCH), 125.6 (q, J = 4.0 Hz, B-ArCH), 123.8 (q, J = 272.0 Hz, B-CF₃), 123.5 (q, J = 272.0 Hz, A-CF₃), 88.7 (B-C=CH), 52.7 (A-OCH₃), 51.7 (B-OCH₃), 45.8 (A-CH₂).

**19F NMR** (376 MHz, CDCl₃): -62.9 (1.5F), -63.1 (3F).

**FTIR**: 1744, 1694, 1321, 1125, 1112, 1067 cm⁻¹.

**MS**: (ESI⁺) Found [M+H]+: 269.0391, C₁₁H₁₂F₃NaO₃ requires 269.0396.

**(E)-4-Methyl-6-phenyl-1-(4-(trifluoromethyl)phenyl)hex-4-en-1-one**

General Procedure C: Methyl 3-oxo-3-(4-(trifluoromethyl)phenyl)propanoate (0.60 g, 2.44 mmol) and (E)-(4-bromo-3-methylbut-2-en-yl)benzene¹³ (0.60 g, 2.67 mmol) were employed. FCC (hexane:EtOAc 30:1) afforded the title compound (0.20 g, 25%) as a pale yellow oil.

**1H NMR** (400 MHz, CDCl₃): 8.03 (d, J = 8.0 Hz, 2H, ArH), 7.71 (d, J = 8.0 Hz, 2H, ArH), 7.30-7.23 (m, 2H, ArH), 7.24-7.11 (m, 3H, ArH), 5.38 (t, J = 7.5 Hz, 1H, C=CH), 3.35 (d, J = 7.5 Hz, 2H, C=CH₂CH₂), 3.15-3.08 (m, 2H, Ar(CO)CH₂), 2.48 (t, J = 7.0 Hz, 2H, Ar(CO)CH₂CH₂), 1.78 (s, 3H, CH₃).

**13C NMR** (100 MHz, CDCl₃): 198.9 (C=O), 141.3 (ArC), 139.6 (Ar(C(CO))), 134.6 (C=CH), 134.3 (q, J = 33.5 Hz, F₃CC), 128.4 (2 signals), 128.3, 125.8 (4 × ArCH), 125.7 (q, J = 4.0 Hz, ArCH₂), 124.0 (C=CH), 123.6 (q, J = 275.0 Hz, CF₃), 37.5 (Ar(CO)CH₂), 34.2 (C=CH₂Ar), 33.7 (Ar(CO)CH₂CH₂), 16.4 (CH₂).

**19F NMR** (376 MHz, CDCl₃): -63.0.

**FTIR**: 1692, 1325, 1129, 1066 cm⁻¹.

**MS**: (ESI⁺) Found [M+H]+: 333.1449, C₂₀H₂₀F₃O requires 333.1461.

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¹³The starting material was prepared according to the procedure described in reference 13.
(E)-4-Methyl-6-phenyl-1-(4-(trifluoromethyl)phenyl)hex-4-en-1-one O-perfluorobenzoyl oxime 21

\[
\begin{align*}
\text{C}_6\text{H}_5 & \quad \text{Ph} \\
\text{O} & \quad \text{O} \\
\text{Me} & \quad \text{Me}
\end{align*}
\]

General Procedure D: Part A: (E)-4-Methyl-6-phenyl-1-(4-(trifluoromethyl)phenyl)hex-4-en-1-one (0.19 g, 0.572 mmol) was used. The reaction was heated at 75 °C for 2 hours to afford the corresponding oxime (0.16 g, 81%) as a colorless solid. Part B: The corresponding oxime (0.16 g, 0.46 mmol) was employed and the reaction was stirred for 2 hours. FCC (hexane: EtOAc 50:1 to 40:1) afforded the title compound (0.16 g, 64%) as a colorless oil.

\[
\begin{align*}
\text{H NMR} & \ (400 \text{ MHz, CDCl}_3): \text{7.79 (d, } J = 8.0 \text{ Hz, 2H, Ar-H), 7.66 (d, } J = 8.0 \text{ Hz, 2H, Ar-H), 7.29-7.24 \text{ (m, 2H, Ar-H), 7.21-7.08 (m, 3H, Ar-H), 5.30 (t, } J = 7.5 \text{ Hz, 1H, C=CH), 3.30 (d, } J = 7.5 \text{ Hz, 2H, C=CHC}_2H_5, 3.08-3.01 (m, 2H, Ar(CN)C}_2H_5, 2.28 (t, } J = 7.0 \text{ Hz, 2H, Ar(CN)CH}_2C_2H_5, 1.71 (s, 3H, C}_3H_3). \\
\text{C NMR} & \ (100 \text{ MHz, CDCl}_3): 167.5 (C=N), 156.3 (C=O), 140.9 (ArC), 136.7 (ArC(CN)), 133.5 (C=CH), 132.8 (q, } J = 34.0 \text{ Hz, F}_3C_C, 128.5, 128.2, 127.9, 126.0 (4 \times \text{ArCH}), 125.8 (q, } J = 4.0 \text{ Hz, ArCH), 125.4 (C=CH), 123.7 (q, } J = 275.0 \text{ Hz, CF}_3, 36.1 (\text{ArCNCH}_2C_2H_5, 34.2 (C=CHCH}_2Ar), 27.7 (\text{ArCNCH}_2), 16.0 (\text{CH}_3). \\
\text{F NMR} & \ (376 \text{ MHz, CDCl}_3): -62.9 (3F), -136.8 (2F), -146.8 (1F), -159.4 (2F). \\
\text{FTIR} : 1767, 1497, 1323, 1191 \text{ cm}^{-1}. \\
\text{MS} : (\text{ESI}^+) \text{ Found [M+Na]}^+: 564.1177, C_{27}H_{19}F_8NNaO_2 \text{ requires 564.1180.}
\end{align*}
\]

(R,E)-2-Methyl-2-styril-5-(4-(trifluoromethyl)phenyl)-3,4-dihydro-2H-pyrrole 31

\[
\begin{align*}
\text{F}_3C & \quad \text{Ph} \\
\text{N} & \quad \text{N} \\
\text{Me} & \quad \text{Me}
\end{align*}
\]

General Procedure E: Oxime ester 2l (46.0 mg, 0.085 mmol) was employed and the reaction was heated at 120 °C for 1 hour. FCC (toluene:EtOAc 60:1) afforded the title compound (19 mg, 70%, 93:7 e.r.) as a pale yellow oil.

\[
\alpha_D^{23} +35.7 (c = 0.62, \text{CHCl}_3).
\]

\[
\begin{align*}
\text{H NMR} & \ (400 \text{ MHz, CDCl}_3): 8.00 (d, } J = 8.0 \text{ Hz, 2H, Ar-H), 7.68 (d, } J = 8.0 \text{ Hz, 2H, Ar-H), 7.37 (d, } J = 7.5 \text{ Hz, 2H, Ar-H), 7.32-7.16 (m, 3H, Ar-H), 6.48 (d, } J = 16.0 \text{ Hz, 1H, HC=CH), 6.44 (d, } J = 16.0 \text{ Hz, 1H, HC=CH), 3.14-2.97 (m, 2H, Ar(CN)CH)_2C_2H_5, 2.26-2.15 (m, 1H, Ar(CN)CH}_2C_2H_5, 2.07-1.96 (m, 1H, Ar(CN)CH}_2C_2H_5, 1.54 (s, 3H, CH}_3). \\
\text{C NMR} & \ (100 \text{ MHz, CDCl}_3): 170.3 (C=N), 137.9 (ArC(CN)), 137.2 (ArC), 135.9 (HC=CHAr), 132.1 (q, } J = 33.5 \text{ Hz, F}_3C_C, 128.5, 128.1, 127.2 (3 \times \text{ArCH), 126.8 (HC=CHAr), 126.3 (ArCH), 125.4 (q,}
\]
J = 4.0 Hz, ArCH), 124.0 (q, J = 275.0 Hz, CF₃), 76.8 (quaternary C), 35.9 (Ar(CN)CH₂CH₃), 35.0 (Ar(CN)CH₂), 27.5 (CH₃).

¹⁹F NMR (376 MHz, CDCl₃): -62.6.

FTIR: 1323, 1273, 1132 cm⁻¹.


The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexane-i-PrOH (95:5, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF₃)₂C₆H₃)(15 mol%) as ligand; tᵣ (major) = 8.3 min and tᵣ (minor) = 9.5 min.
Methyl 3-(4-methoxyphenyl)-3-oxopropanoate and Methyl (Z)-3-hydroxy-3-(4-methoxyphenyl)acrylate

To a suspension of NaH (1.27 g, 31.92 mmol) in THF (40 mL) at room temperature was added dimethyl carbonate (2.27 mL, 26.87 mmol). 1-(4-methoxyphenyl)ethan-1-one (4.00 g, 26.60 mmol) was added and the reaction was heated at 75 °C for 16 hours. The reaction was cooled to room temperature and then concentrated in vacuo. To the residue was added ice-cold water (50 mL) and aq. 1M HCl (50 mL) and the mixture was extracted with EtOAc (2 × 100 mL). The organic extracts were combined, dried (Na₂SO₄) and concentrated in vacuo. The residue was purified by FCC (hexane:EtOAc 50:1 to 10:1) to afford the title compound (4.02 g, 72%, 1:0.1 mixture of keto and enol tautomers) as a pale yellow oil.

1H NMR (400 MHz, CDCl₃): Signals for both tautomers: 12.53 (s, 0.1H, B-OH), 7.91 (d, J = 8.0 Hz, 2H, A-ArH), 7.75-7.70 (m, 0.2H, B-ArH), 6.97-6.88 (m, 2.2H, A-ArH and B-ArH), 5.58 (s, 0.1H, B=C=CH₂), 3.95 (s, 2H, A-CH₂), 3.86 (s, 3H, A-Ar-OC₃H₃), 3.84 (s, 0.3H, B-OC₃H₃), 3.78 (s, 0.3H, B-OC₃H₃), 3.74 (s, 3H, A-(CO)OCH₃).

13C NMR (100 MHz, CDCl₃): Signals for the keto tautomer: 190.8 (Ar(C=O)), 168.1 ((CO)OCH₃), 164.0 (ArC(OCH₃)), 130.9 (ArCH), 129.0 (ArC(CO)), 114.0 (ArCH), 55.5 (Ar(OCH₃)), 45.5 (CH₃).

The spectroscopic properties of this compound were consistent with the data in the literature.²¹

(E)-1-(4-Methoxyphenyl)-4-methyl-6-phenylhex-4-en-1-one

General Procedure C: Methyl 3-(4-methoxyphenyl)-3-oxopropanoate (0.46 g, 2.23 mmol) and (E)-(4-bromo-3-methylbut-2-en-yl)benzene¹³ (0.55 g, 2.45 mmol) were employed. FCC (hexane:EtOAc 50:1 to 30:1) afforded the title compound (0.58 g, 89%) as a pale yellow oil.

1H NMR (400 MHz, CDCl₃): 7.94 (d, J = 8.0 Hz, 2H, ArH), 7.31-7.12 (m, 5H, ArH), 6.92 (d, J = 8.0 Hz, 2H, ArH), 5.40 (t, J = 7.5 Hz, 1H, C=CH), 3.86 (s, 3H, OCH₃), 3.63 (d, J = 7.5 Hz, 2H, C=CH₂Ar), 3.04 (t, J = 7.5 Hz, 2H, Ar(CO)CH₃), 2.46 (t, J = 7.5 Hz, 2H, Ar(CO)CH₂CH₂), 1.78 (s, 3H, CH₃).

13C NMR (100 MHz, CDCl₃): 198.6 (C=O), 163.3 (ArC(OCH₃)), 141.5 (ArC), 135.2 (C=CH), 130.3 (ArCH), 130.1 (ArC(CO)), 128.4, 128.3, 125.7 (3 × ArCH), 123.5 (C=CH), 113.7 (ArCH), 55.4 (Ar(OCH₃)), 37.0 (Ar(CO)CH₂), 34.2 (2 signals) ((C=CH₂Ar and Ar(CO)CH₂CH₂), 16.4 (CH₃).

FTIR: 1675, 1599, 1256, 1169 cm⁻¹.

(4E)-1-(4-methoxyphenyl)-4-methyl-6-phenylhex-4-en-1-one O-perfluorobenzoyl oxime 2m

![Chemical structure of 2m]

**General Procedure D:** Part A: (E)-1-(4-Methoxyphenyl)-4-methyl-6-phenylhex-4-en-1-one (0.57 g, 1.93 mmol) was used. The reaction was heated at 75 °C for 2 hours to afford the corresponding oxime (0.55 g, 92%) as a colorless solid. Part B: The corresponding oxime (0.55 g, 1.78 mmol) was employed and the reaction was stirred for 2 hours. FCC (hexane: EtOAc 40:1) afforded the title compound (0.65 g, 73%, 1:0.1 mixture of oxime isomers) as a colorless solid.

**1H NMR** (400 MHz, CDCl$_3$): Data for the major isomer: 7.68 (d, $J = 8.0$ Hz, 2H, ArH), 7.30-7.08 (m, 5H, ArH), 6.91 (d, $J = 8.0$ Hz, 2H, ArH), 5.33 (t, $J = 7.5$ Hz, 1H, C=CH), 3.84 (s, 3H, OC$_3$H$_3$), 3.32 (d, $J = 7.5$ Hz, 2H, C=CH$_2$Ar), 2.99 (t, $J = 7.5$ Hz, 2H, Ar(CN)C$_2$H$_2$), 2.28 (t, $J = 7.5$ Hz, 2H, Ar(CN)CH$_2$C$_2$H$_2$), 1.72 (s, 3H, CH$_3$). Characteristic signals for the minor isomer: 5.24 (t, $J = 7.5$ Hz, 0.1H, C=CH), 3.82 (s, 0.3H, OC$_3$H$_3$), 2.87 (t, $J = 7.5$ Hz, 0.2H, Ar(CN)C$_2$H$_2$), 2.20 (t, $J = 7.5$ Hz, 0.2H, Ar(CN)CH$_2$C$_2$H$_2$), 1.52 (s, 3H, CH$_3$).

**13C NMR** (100 MHz, CDCl$_3$): 167.8 (C=N), 161.9 (ArC(OCH$_3$)), 141.1 (ArC), 134.1 (C=CH), 129.0, 128.4, 128.2, 125.8 (4 × ArCH), 125.2 (ArC(CN)), 124.8 (C=CH), 114.2 (ArCH), 55.4 (ArOCH$_3$), 36.5 (Ar(CN)CH$_2$C$_2$H$_2$), 34.2 (C=CH$_2$Ar), 27.5 (Ar(CN)CH$_2$H), 16.0 (CH$_3$).

**19F NMR** (376 MHz, CDCl$_3$): Data for the major isomer: -137.1 (2F), -147.6 (1F), -159.7 (2F). Data for the minor isomer: -137.2 (0.2F), -148.1 (0.1F), -160.0 (0.2F).

**FTIR**: 1760, 1495, 1325, 1193, 1180 cm$^{-1}$.

**MS**: (ESI$^+$) Found [M+Na]$^+$: 526.1405, C$_{27}$H$_{22}$F$_5$NNaO$_3$ requires 526.1412.

(R,E)-5-(4-Methoxyphenyl)-2-methyl-2-styryl-3,4-dihydro-2H-pyrrole 3m

![Chemical structure of 3m]

**General Procedure E:** Oxime ester 2m (55 mg, 0.11 mmol) was employed and the reaction was heated at 120 °C for 1.25 hours. FCC (toluene:EtOAc 60:1) afforded the title compound (18 mg, 56%, 94:6 e.r.) as a pale yellow oil.

[α]$^D_{	ext{D}}$ +80.6 (c = 0.53, CHCl$_3$).

**1H NMR** (400 MHz, CDCl$_3$): 7.85 (d, $J = 8.0$ Hz, 2H, ArH), 7.37 (d, $J = 8.0$ Hz, 2H, ArH), 7.31-7.14 (m, 3H, ArH), 6.93 (d, $J = 8.0$ Hz, 2H, ArH), 6.48 (d, $J = 16.0$ Hz, 1H, HC=CH), 6.44 (d, $J = 16.0$ Hz, 1H, HC=CH), 3.84 (s, 3H, OCH$_3$), 3.10-2.90 (m, 2H, Ar(CN)CH$_2$), 2.20-2.09 (m, 1H, Ar(CN)CH$_2$CH$_2$), 2.01-1.90 (m, 1H, Ar(CN)CH$_2$CH$_2$), 1.52 (s, 3H, CH$_3$).
$^{13}$C NMR (100 MHz, CDCl$_3$): 170.8 (C=\(\text{N}\)), 161.4 (Ar\(\text{C}(\text{OCH}_3)\)), 137.5 (Ar\(\text{C}\)), 136.6 (HC=CHAr), 129.4, 128.4 (2 \times \text{ArCH}), 127.5 (Ar\(\text{C}(\text{CN})\)), 127.0 (Ar\(\text{CH}\)), 126.4, 126.3 (Ar\(\text{CH}\) and HC=CHAr), 113.7 (Ar\(\text{CH}\)), 76.2 (quaternary \(\text{C}\)), 55.3 (Ar\(\text{O(\text{CH}_3)}\)), 36.0 (Ar\(\text{(CN)CH}_2\)), 34.9 (Ar\(\text{(CN)CH}_2\text{CH}_2\)), 27.6 (CH$_3$).

FTIR: 1605, 1514, 1251, 1172 cm$^{-1}$.

MS: (ESI$^+$) Found [M+H]$^+$: 292.1707, $C_{20}H_{22}NO$ requires 292.1696.

The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexane-i-PrOH (90:10, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF$_3$)$_2$C$_6$H$_3$)$_3$ (15 mol%) as ligand; \(t_R\) (minor) = 10.7 min and \(t_R\) (major) = 13.8 min.
Methyl 3-(3-ethylphenyl)-3-oxopropanoate (A) and Methyl (Z)-3-(3-ethylphenyl)-3-hydroxyacrylate (B).

To a suspension of NaH (0.72 g, 18.20 mmol) in THF (30 mL) at room temperature was added dimethyl carbonate (1.30 mL, 15.4 mmol). 1-(3-Ethylphenyl)ethan-1-one (2.25 g, 15.2 mmol) was added and the reaction was heated at 75 °C for 16 hours. The reaction was cooled to room temperature and then concentrated in vacuo. To the residue was added ice-cold water (40 mL) and aq. 1M HCl (40 mL) and the mixture was extracted with EtOAc (2 × 80 mL). The organic extracts were combined, dried (Na₂SO₄) and concentrated in vacuo. The residue was purified by FCC (hexane:EtOAc 40:1) to afford the title compound (1.85 g, 59%, 1:0.3 mixture of keto and enol tautomers) as a pale yellow oil.

**1H NMR (400 MHz, CDCl₃):** Signals for both tautomers: 12.49 (s, 0.3H, B-OH), 7.80-7.71 (m, 2H, A-ArH), 7.63-7.55 (m, 0.6H, B-ArH), 7.46-7.27 (m, 2.6H, A-ArH and B-ArH), 5.66 (s, 0.3H, B-C=CH), 4.00 (s, 2H, A-CH₂), 3.79 (s, 0.9H, B-(CO)OCH₃), 3.74 (s, 3H, A-(CO)OCH₃), 2.75-2.64 (m, 2.6H, A and B CH₂CH₃), 1.28-1.22 (m, 3.9H, A and B CH₂CH₃).

**13C NMR (100 MHz, CDCl₃):** Signals for the keto tautomer: 192.5 (Ar(C=O)), 168.0 ((CO)OCH₃), 145.0 (ArCH₂CH₂), 136.0 (Ar(C=O)), 133.5, 128.7, 127.8, 126.0 (ArCH), 52.4 ((CO)OCH₃), 45.8 ((CO)CH₂(C=O)), 28.7 (CH₂CH₃), 15.4 (CH₂CH₃).

**FTIR:** 2966, 1743, 1684, 1436, 1212 cm⁻¹.

**MS:** (ESI⁺) Found [M+Na]⁺: 229.0839, C₁₂H₁₄NaO₃ requires 229.0835.

**(E)-1-(3-Ethylphenyl)-4-methyl-6-phenylhex-4-en-1-one**

**General Procedure C:** Methyl 3-(3-ethylphenyl)-3-oxopropanoate (0.84 g, 4.05 mmol) and (E)-(4-bromo-3-methylbut-2-en-yl)benzene¹³ (1.00 g, 4.46 mmol) were employed. FCC (hexane:EtOAc 50:1) afforded the title compound (1.00 g, 85%) as a pale yellow oil.

**1H NMR (400 MHz, CDCl₃):** 7.80-7.73 (m, 2H, ArH), 7.42-7.13 (m, 7H, ArH), 5.40 (t, J = 7.5 Hz, 1H, C=CH), 3.36 (d, J = 7.5 Hz, 2H, C=CHCH₂Ar), 3.09 (t, J = 8.0 Hz, 2H, Ar(C=O)CH₂), 2.70 (q, J = 7.5 Hz, 2H, CH₃CH₂), 2.47 (t, J = 8.0 Hz, 2H, Ar(C=O)CH₂CH₂), 1.78 (s, 3H, H(CC=CH)), 1.25 (t, J = 7.5 Hz, 3H, CH₃CH₂).

**13C NMR (100 MHz, CDCl₃):** 202.0 (CO), 144.7 (ArCH₂CH₂), 141.4 (ArC), 137.1 (Ar(C=O)), 135.1 (C=CH), 132.6, 128.5, 128.4, 128.3, 127.4, 125.8, 125.6 (7 × ArCH), 123.6 (C=CH), 37.3 (Ar(C=O)CH₂), 34.2, 34.0 (C=CHCH₂Ar and Ar(C=O)CH₂CH₂), 28.8 (CH₃CH₂), 16.4 (H(CC=CH)), 15.5 (CH₂CH₃).

55
FTIR: 1683, 1452, 1157 cm$^{-1}$.

MS: (ESI$^+$) Found [M+H]$^+$: 293.1909, C$_{21}$H$_{25}$O requires 293.1900.

(E)-1-(3-Ethylphenyl)-4-methyl-6-phenylhex-4-en-1-one O-perfluorobenzoyl oxime 2n

![Chemical Structure]

General Procedure D: Part A: (E)-1-(3-ethylphenyl)-4-methyl-6-phenylhex-4-en-1-one (0.25 g, 0.85 mmol) was used. The reaction was heated at 75 °C for 2 hours to afford the corresponding oxime (0.24 g, 92%) as a colorless solid. Part B: The corresponding oxime (0.24 g, 0.78 mmol) was employed and the reaction was stirred for 2 hours. FCC (hexane: EtOAc 50:1) afforded the title compound (0.37 g, 94%, 1:0.05 mixture of oxime isomers) as a colorless solid.

$^1$H NMR (400 MHz, CDCl$_3$): Data for the major isomer: 7.56-7.45 (m, 2H, ArH), 7.36-7.09 (m, 7H, ArH), 5.33 (t, $J = 7.5$ Hz, 1H, C=C=CH$_2$), 3.31 (d, $J = 7.5$ Hz, 2H, C=CHC$_2$H$_5$), 3.02 (t, $J = 8.0$ Hz, 2H, Ar(CN)CH$_2$C$_6$H$_5$), 2.67 (q, $J = 7.5$ Hz, 2H, C$_3$H$_7$), 2.28 (t, $J = 8.0$ Hz, 2H, Ar(CN)CH$_2$C$_2$H$_5$), 1.71 (s, 3H, H$_3$C=CH), 1.23 (t, $J = 7.5$ Hz, 3H, CH$_3$C$_2$H$_5$). Characteristic signals for the minor isomer: 2.91-2.84 (m, 0.1H, Ar(CN)C$_6$H$_5$), 2.61 (q, $J = 7.5$ Hz, 0.1H, C$_3$H$_7$), 1.18 (t, $J = 7.5$ Hz, 0.15H, CH$_3$C$_2$H$_5$).

$^{13}$C NMR (100 MHz, CDCl$_3$): 168.9 (C=O), 144.8 (ArC=CH$_2$), 141.1 (ArC), 134.0 (ArC(CN)), 130.6, 128.7, 128.4, 128.2, 126.9, 125.8 (6 × ArCH), 124.9, 124.8 (ArCH and C=CH), 36.3 (Ar(CN)CH$_2$C$_2$H$_5$), 34.2 (C=CHC$_2$Ar), 28.8 (CH$_2$C$_6$H$_5$), 27.9 (Ar(CN)CH$_2$), 16.0 (H$_3$CC=CH), 15.5 (CH$_2$C$_2$H$_5$).

$^{19}$F NMR (376 MHz, CDCl$_3$): Data for the major isomer: -137.0 (2F), -147.5 (1F), -159.7 (2F). Data for the minor isomer: -137.2 (0.1F), -148.1 (0.05F), -160.1 (0.1F).

FTIR: 1764, 1523, 1497, 1325, 1190 cm$^{-1}$.

MS: (ESI$^+$) Found [M+Na]$^+$: 524.1624, C$_{28}$H$_{24}$F$_5$NNaO$_2$ requires 524.1619.

(R,E)-5-(3-Ethylphenyl)-2-methyl-2-styryl-3,4-dihydro-2H-pyrrole 3n

![Chemical Structure]

General Procedure E: Oxime ester 2n (50.0 mg, 0.100 mmol) was employed and the reaction was heated at 120 °C for 1 hour. FCC (toluene to toluene:EtOAc 80:1) afforded the title compound (18.5 mg, 64%, 93:7 e.r.) as a pale yellow oil.

$[^{13}]$D $^*+52.5$ (c = 0.53, CHCl$_3$).

$^1$H NMR (400 MHz, CDCl$_3$): 7.80 (s, 1H, ArH), 7.66 (dt, $J = 7.5$ and 1.5 Hz, 1H, ArH), 7.41-7.15 (m, 7H, ArH), 6.49 (d, $J = 16.0$ Hz, 1H, HC=CH), 6.44 (d, $J = 16.0$ Hz, 1H, HC=CH), 3.14-2.92 (m, 2H,
Ar(CN)CH₂, 2.69 (q, J = 7.5 Hz, 2H, CH₂CH₃), 2.22-2.10 (m, 1H, Ar(CN)CH₂CH₂), 2.03-1.92 (m, 1H, Ar(CN)CH₂CH₂), 1.53 (s, 3H, H₃CC=CH), 1.26 (t, J = 7.5 Hz, 3H, CH₂CH₃).

¹³C NMR (100 MHz, CDCl₃): 171.7 (C=N), 144.5 (ArCCH₂CH₃), 137.4 (ArC), 136.5 (C=CH), 134.6 (ArC(CN)), 130.1, 128.4 (2 signals), 127.2, 127.1 (5 × ArCH), 126.5 (C=CH), 126.3, 125.4 (2 × ArCH), 76.4 (quaternary C), 36.0 (Ar(CN)CH₂CH₂), 35.1 (Ar(CN)CCH₂), 28.8 (CH₂CH₃), 27.5 (H₃CC=CH), 15.7 (CH₂CH₃).

FTIR: 1615, 1600, 1581 cm⁻¹.


The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IB, isocratic hexane-i-PrOH (90:10, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF₃)₂C₆H₃)₃ (15 mol%) as ligand; tᵣ (minor) = 8.0 min and tᵣ (major) = 11.9 min.
Methyl (E)-2-(cyclopropanecarbonyl)-4-methyl-6-phenylhex-4-enoate

General Procedure C: Part A: Methyl 3-cyclopropyl-3-oxopropanoate (0.52 g, 3.65 mmol) and (E)-(4-bromo-3-methylbut-2-en-yl)benzene\textsuperscript{13} (0.90 g, 4.01 mmol) were employed. FCC (toluene:hexane 5:2) afforded the title compound (0.55 g, 53%) as a colorless oil.

\textbf{\textsuperscript{1}H NMR} (400 MHz, CDCl\textsubscript{3}): 7.31-7.23 (m, 2H, ArH), 7.24-7.10 (m, 3H, ArH), 5.41 (t, J = 7.5 Hz, 1H, C=CH), 3.83 (t, J = 7.5 Hz, 1H, (CO)CH=CH), 3.67 (s, 3H, (CO)OCH\textsubscript{3}), 3.34 (d, J = 7.5 Hz, 2H, (CO)CHC\textsubscript{6}H\textsubscript{5}), 2.65 (d, J = 7.5 Hz, 2H, (CO)CHCH\textsubscript{3}=CH), 2.10-2.02 (m, 1H, CH(CH\textsubscript{2})\textsubscript{2}), 1.75 (s, 3H, CH\textsubscript{3}C=CH), 1.07-1.01 (m, 2H, CH(C\textsubscript{6}H\textsubscript{5})\textsubscript{2}), 0.93-0.86 (m, 2H, CH(CH\textsubscript{2})\textsubscript{2}).

\textbf{\textsuperscript{13}C NMR} (100 MHz, CDCl\textsubscript{3}): 204.8 (C=O), 170.1 (C=OCH\textsubscript{3}), 141.0 (ArC), 132.1 (C=CH), 128.4, 128.3 (2 × ArCH), 125.9 (C=CH), 125.8 (ArCH), 58.5 ((CO)CHCH\textsubscript{3}=CH), 52.3 ((CO)OCH\textsubscript{3}), 38.0 ((CO)CHCH\textsubscript{3}=CH), 34.2 (C=CHCH\textsubscript{3}=CH), 19.7 (CH(CH\textsubscript{2})\textsubscript{2}), 16.1 (CH\textsubscript{3}C=CH), 11.9, 11.7 (CH(CH\textsubscript{2})\textsubscript{2}).

\textbf{FTIR}: 1741, 1702 cm\textsuperscript{-1}.

\textbf{MS}: (ESI\textsuperscript{+}) Found [M+Na]\textsuperscript{+}: 309.1474, C\textsubscript{18}H\textsubscript{22}O\textsubscript{3}Na requires 309.1461.

\textbf{(E)-1-Cyclopropyl-4-methyl-6-phenylhex-4-en-1-one}

General Procedure C: Part B: Methyl (E)-2-(cyclopropanecarbonyl)-4-methyl-6-phenylhex-4-enoate (0.50 g, 1.76 mmol) was employed. FCC (hexane:EtOAc 30:1) afforded the title compound (0.37 g, 92%) as a colorless oil.

\textbf{\textsuperscript{1}H NMR} (400 MHz, CDCl\textsubscript{3}): 7.32-7.25 (m, 2H, ArH), 7.22-7.14 (m, 3H, ArH), 5.41-5.34 (m, 1H, C=CH), 3.36 (d, J = 7.5 Hz, 2H, C=CHCH\textsubscript{3}), 2.69 (t, J = 7.5 Hz, 2H, (CO)C\textsubscript{6}H\textsubscript{5}CH\textsubscript{2}), 2.36 (t, J = 7.5 Hz, 2H, (CO)CH\textsubscript{3}CH\textsubscript{2}), 1.97-1.88 (m, 1H, CH(CH\textsubscript{2})\textsubscript{2}), 1.74 (s, 3H, CH\textsubscript{3}C=CH), 1.04-0.97 (m, 2H, CH(CH\textsubscript{2})\textsubscript{2}), 0.88-0.81 (m, 2H, CH(CH\textsubscript{2})\textsubscript{2}).

\textbf{\textsuperscript{13}C NMR} (100 MHz, CDCl\textsubscript{3}): 210.6 (C=O), 141.5 (ArC), 134.9 (C=CH), 128.4, 128.3, 125.8 (3 × ArCH), 123.5 (C=CH), 42.1 ((CO)C\textsubscript{6}H\textsubscript{5}CH\textsubscript{2}), 34.2 (C=CHCH\textsubscript{3}), 33.7 ((CO)CH\textsubscript{3}CH\textsubscript{2}), 20.4 (CH(CH\textsubscript{2})\textsubscript{2}), 16.3 (CH\textsubscript{3}C=CH), 10.7 (CH(CH\textsubscript{2})\textsubscript{2}).

\textbf{FTIR}: 1698, 1385, 1083 cm\textsuperscript{-1}.
General Procedure D: Part A: (E)-1-Cyclopropyl-4-methyl-6-phenylhex-4-en-1-one (0.36 g, 1.58 mmol) was used. The reaction was heated at 75 °C for 1 hour to afford the corresponding oxime (0.35 g, 91%) as a colorless oil. Part B: The corresponding oxime (0.35 g, 1.44 mmol) was employed and the reaction was stirred for 2 hours. FCC (hexane:EtOAc 40:1) afforded the title compound (0.51 g, 81%, 1:0.5 mixture of oxime isomers) as a yellow oil.

\[ \text{General Procedure E: Oxime ester } 2o \text{ (50.0 mg, 0.114 mmol) was employed and the reaction was heated at 120 °C for 3 hours. FCC (hexane:EtOAc 4:1 to 2:1) afforded the title compound (15.5 mg, 61%, 90:10 e.r.) as a pale yellow oil.} \]

\[ [\alpha]_D^{23} +81.0 \text{ (c = 0.33, CHCl}_3) \]
^1^H NMR (400 MHz, CDCl$_3$): 7.39-7.34 (m, 2H, ArH), 7.31-7.35 (m, 2H, ArH), 7.19 (tt, $J = 8.0$ and 1.5 Hz, 1H, ArH), 6.41 (d, $J = 16.0$ Hz, 1H, CH=CHAr), 6.34 (d, $J = 16.0$ Hz, 1H, CH=CHAr), 2.47-2.32 (m, 2H, (CN)CH$_2$), 2.02-1.92 (m, 1H, (CN)CH$_2$CH$_2$), 1.88-1.72 (m, 2H, (CN)CH$_2$CH$_2$ and CH$_2$(CH$_2$)$_2$), 1.39 (s, 3H, (NC)C$_3$H$_3$), 0.93-0.80 (m, 4H, CH(CH$_2$)$_2$).

^1^C NMR (100 MHz, CDCl$_3$): 177.8 (C=N), 137.5 (ArC), 136.6 (CH=CHAr), 128.4, 127.0, 126.3 (3 × ArCH), 126.1 (CH=CHAr), 75.4 (quaternary C), 35.6 ((CN)CH$_2$CH$_2$), 34.2 ((CN)CH$_2$), 27.4 ((NC)CH$_3$), 14.4 (CH(CH$_2$)$_2$), 7.4, 7.2 (CH(CH$_2$)$_2$).

FTIR: 1631, 1448 cm$^{-1}$.

MS: (ESI$^-$) Found [M+H]$^-$: 226.1590, C$_{16}$H$_{20}$N requires 226.1590.

The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IA, isocratic hexane-$i$-PrOH-diethylamine (100:1:0.1, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF$_3$)$_2$C$_6$H$_3$)$_3$ (15 mol%) as ligand; $t_R$ (major) = 12.4 min and $t_R$ (minor) = 18.8 min.
Methyl 3-cyclohexyl-3-oxopropanoate (A) and methyl (Z)-3-cyclohexyl-3-hydroxyacrylate (B).

To a solution of diisopropylamine (6.18 mL, 44.2 mmol) in THF (30 mL) at -78 °C was added n-BuLi (1M in hexane, 44.2 mL, 44.2 mmol) dropwise. The reaction was stirred for 30 minutes. Methyl acetate was added slowly (3.50 mL, 44.17 mmol) at -78 °C and the reaction was stirred for 30 minutes. Cyclohexanecarbonyl chloride (1.99 mL, 14.70 mmol) was added and the reaction was warmed to room temperature over ~ 30 minutes. The reaction was stirred for a further 2 hours. To the reaction 1M HCl (50 mL) was added. The organic phase was extracted with EtOAc (3 × 100 mL). The organic extracts were combined, dried (Na₂SO₄) and concentrated in vacuo. The residue was purified by FCC (hexane:EtOAc 20:1) to afford the title compound (2.51 g, 93%, 1:0.2 mixture of keto and enol tautomers) as a pale yellow oil.

1H NMR (400 MHz, CDCl₃): Signals for both tautomers: 12.02 (s, 0.2H, B-OH), 4.94 (s, 0.2H, B-C=CH), 3.72 (s, 2H, A-(CO)OCH₃), 3.70 (s, 0.6H, B-(CO)OCH₃), 3.48 (s, 2H, A-(CO)CH₂(CO)), 2.49-2.39 (m, 1H, A-CH(CO)), 2.13-2.02 (m, 0.2H, B-CH(CO)), 1.95-1.56 (m, 6H, A and B 2.5 × CH₂), 1.41-1.11 (m, 6H, A and B 2.5 × CH₃).

13C NMR (100 MHz, CDCl₃): Signals for the keto tautomer: 205.7 (CH(CO)), 167.9 ((CO)OCH₃), 52.3 ((CO)OCH₃), 50.9 (CH(CO)), 47.0 ((CO)CH₂(CO)), 28.2, 25.7, 25.4 (3 × CH₃).

The spectroscopic properties of this compound were consistent with the data in the literature.²²

(E)-1-Cyclohexyl-4-methyl-6-phenylhex-4-en-1-one

General Procedure C: Methyl 3-cyclohexyl-3-oxopropanoate (0.41 g, 2.23 mmol) and (E)-(4-bromo-3-methylbut-2-en-yl)benzene¹³ (0.55 g, 2.45 mmol) were employed. FCC (hexane:EtOAc 40:1 to 35:1) afforded the title compound (0.35 g, 58%) as a pale yellow oil.

1H NMR (400 MHz, CDCl₃): 7.30-7.12 (m, 5H, ArH), 5.33 (t, J = 7.5 Hz, 1H, C=CH), 3.34 (d, J = 7.5 Hz, 2H, C=CHCH₂Ar), 2.55 (t, J = 8.0 Hz, 2H, Ar(CO)CH₃), 2.37-2.24 (m, 3H, Ar(CO)CH₂CH₂ and CH(CO)), 1.85-1.60 (m, 8H, CH₂ and 2.5 × CH₃), 1.38-1.11 (m, 5H, 2.5 × CH₃).
$^{13}$C NMR (100 MHz, CDCl$_3$): 213.7 (C=O), 141.5 (ArC), 135.1 (C=CH), 128.3 (2 signals), 125.7 (3 × ArCH), 123.3 (C=CH), 50.9 (CH(CO)), 39.2 (Ar(CO)CH$_2$), 34.2 (C=CHCH$_2$Ar), 33.3 (Ar(CO)CH$_2$CH$_2$), 28.5, 25.8, 25.7 (3 × CH$_2$), 16.4 (CH$_3$).

FTIR: 2928, 1707, 1450 cm$^{-1}$.

MS: (ESI$^+$) Found [M+H]$^+$: 271.2060, C$_{19}$H$_{27}$O requires 271.2056.

$^{19}$F NMR (376 MHz, CDCl$_3$): Data for the major isomer: -137.3 (2F), -147.9 (1F), -159.9 (2F). Data for the minor isomer: -137.4 (0.2F), -148.0 (0.1F), -159.9 (0.2F).

FTIR: 2928, 1707, 1450 cm$^{-1}$.

MS: (ESI$^+$) Found [M+Na]$^+$: 502.1770, C$_{26}$H$_{26}$F$_5$NNaO$_2$ requires 502.1776.

$^{1}$H NMR (400 MHz, CDCl$_3$): Data for the major isomer: 7.33-7.11 (m, 5H, ArH), 5.35 (t, $J = 7.5$ Hz, 1H, C=CH), 3.33 (d, $J = 7.5$ Hz, 2H, C=CHC$_{2}$Ar), 2.52-2.45 (m, 2H, Ar(CN)C$_{2}$H$_2$), 2.44-2.33 (m, 1H, CH(CN)), 2.27-2.20 (m, 2H, Ar(CN)CH$_2$CH$_2$), 1.89-1.65 (m, 8H, C$_3$H$_2$ and 2 × CH$_2$), 1.48-1.11 (m, 5H, 2 × CH$_2$). Characteristic signals for the minor isomer: 5.43-5.38 (m, 0.1H, C=CH), 3.37-3.35 (m, 0.2H, C=CHC$_{2}$Ar).

$^{13}$C NMR (100 MHz, CDCl$_3$): Signals for the major isomer: 174.8 (C=N), 141.1 (ArC), 134.4 (C=CH), 128.4, 128.2, 125.9 (3 × ArCH), 124.5 (C=CH), 44.1 (CH(CN)), 35.9 (Ar(CN)CH$_2$CH$_2$), 34.2 (C=CHCH$_2$Ar), 30.0 (CH$_2$), 29.1 (Ar(CN)CH$_2$), 25.9, 25.7 (2 × CH$_2$), 15.9 (CH$_3$).

$^{19}$F NMR (376 MHz, CDCl$_3$): Data for the major isomer: -137.3 (2F), -147.9 (1F), -159.9 (2F). Data for the minor isomer: -137.4 (0.2F), -148.0 (0.1F), -159.9 (0.2F).

FTIR: 1760, 1523, 1496, 1324, 1194 cm$^{-1}$.

MS: (ESI$^+$) Found [M+Na]$^+$: 502.1770, C$_{26}$H$_{26}$F$_5$NNaO$_2$ requires 502.1776.

General Procedure D: Part A: (E)-1-cyclohexyl-4-methyl-6-phenylhex-4-en-1-one O-perfluorobenzoyl oxime 2p

General Procedure E: Oxime ester 2p (50.0 mg, 0.104 mmol) was employed and the reaction was heated at 120 °C for 1.3 hours. FCC (toluene:EtOAc 30:1 to 8:1) afforded the title compound (19.5 mg, 71%, 93:7 e.r.) as a pale yellow oil.

$[\alpha]_{D}^{22}$ -14.8 (c = 0.61, CHCl$_3$).
\( ^1H \text{NMR} \) (400 MHz, CDCl\(_3\)): 7.37-7.32 (m, 2H, Ar-H), 7.30-7.24 (m, 2H, Ar-H), 7.18 (tt, \( J = 7.5 \) and 2.0 Hz, 1H, Ar-H), 6.40 (d, \( J = 16.0 \) Hz, 1H, HC=CH), 6.34 (d, \( J = 16.0 \) Hz, 1H, HC=CH), 2.62-2.46 (m, 2H, Ar(CN)CH\(_2\)), 2.42-2.32 (m, 1H, CH(CN)), 2.01-1.64 (m, 7H, Ar(CN)CH\(_2\)CH\(_2\) and 2.5 \times CH\(_2\)), 1.44-1.16m (m, 8H, CH\(_3\)) and 2.5 \times CH\(_2\)).

\( ^{13}C \text{NMR} \) (100 MHz, CDCl\(_3\)): 180.6 (C=O), 137.5 (Ar-C), 136.7 (HC=CHAr), 128.4, 127.0, 126.3 (3 \times ArCH), 126.1 (HC=CHAr), 75.2 (quaternary C), 42.7 (CH(CN)), 35.7 (Ar(CN)CH\(_2\)CH\(_2\)), 34.6 (Ar(CN)CH\(_2\)), 30.6 (CH\(_3\)), 27.6 (CH\(_3\)), 26.1, 26.0 (2 \times CH\(_2\)).

FTIR: 2925, 1633, 1448 cm\(^{-1}\).

MS: (ESI\(^+\)) Found [M+H]\(^+\): 268.2057, C\(_{19}\)H\(_{26}\)N requires 268.2060.

The enantiomeric purity of this compound was determined by chiral HPLC (Chiralpak IA, isocratic hexane-i-PrOH (99:1, 0.5 mL/min, 20 °C) against a racemic standard prepared under similar conditions using P(3,5-(CF\(_3\))\(_2\)C\(_6\)H\(_3\))\(_3\) (15 mol%) as ligand; \( t_R \) (major) = 14.2 min and \( t_R \) (minor) = 16.0 min. The absolute structure of this molecule was confirmed by Vibrational Circular Dichroism (VCD).
Comparison of experimental VCD spectrum of dihydropyrrole 3p (in duplicate, purple) and simulated spectra of the R (red) and S (green) enantiomers. The agreement between the simulated spectrum of the R enantiomer and the experimental spectrum is good, therefore dihydropyrrole 3p has R configuration.

Experimental: A 11.9 mg sample of dihydropyrrole 3p was dissolved in CDCl$_3$ (110 µL). A VCD spectrum was acquired in 0.100 mm BaF$_2$ cells for 7 hours each in a BioTools ChiralIR instrument equipped with dual source and dual photoelastic modulator. The resolution was 4 cm$^{-1}$. The experimental VCD spectrum shows weak characteristic bands.

Computational Spectral Simulations: A Monte Carlo molecular mechanics search for low energy geometries was conducted for full structures of the two enantiomers, R and S. MacroModel within the Maestro graphical interface (Schrödinger Inc.) was used to generate starting coordinates for conformers. All conformers within 5 kcal/mole of the lowest energy conformer were used as starting points for density functional theory (DFT) minimizations within Gaussian09. Optimized structures, harmonic vibrational frequencies/intensities, VCD rotational strengths, and free energies at STP (including zero-point energies) were determined for each conformer. In these calculations, the functional B3LYP and the basis set 6-31G* were used. Simulations of infrared and VCD spectra for each conformation were generated using an in-house built program to fit Lorentzian line shapes (12 cm$^{-1}$ line width) to the computed spectra thereby allowing direct comparisons between simulated and experimental spectra.

Results: The experimental spectrum was compared with simulated spectra of the two enantiomers based on DFT calculations starting with full structures. The comparison is presented above. The agreement between the simulated spectrum of the R enantiomer and the experimental spectrum is good. It is therefore concluded that dihydropyrrole 3p has R configuration.
Dichloro[(S)-2-((S)-7’-(Bis(3,5-dimethylphenyl)phosphanyl)-2,2',3,3’-tetrahydro-1,1’-spirobi[inden]-7-yl)-4-phenyl-4,5-dihydrooxazole]palladium [(S,S)-L-2f]PdCl₂

A solution of (COD)PdCl₂ (4.6 mg, 0.016 mmol) and (Sₐ,S)⁻L-2f (10.0 mg, 0.016 mmol) in CH₂Cl₂ (0.7 mL) was stirred at room temperature for 90 minutes, after which time it was carefully concentrated in vacuo. The resulting yellow residue was washed with pentane (2 mL) and dried under vacuum to give the title compound (10.0 mg, 78%) as a yellow solid. Crystals suitable for X-ray diffraction were grown from slow evaporation of CDCl₃ (0.3 mL) layered with hexane (0.5 mL) at 20 °C. δH (400 MHz, CDCl₃) 8.12 (1H, d, J = 7.5 Hz, ArCH), 7.63-7.53 (4H, m, ArCH), 7.50-7.37 (5H, m, ArCH), 7.34 (1H, d, J = 7.5 Hz, ArCH), 7.29-7.15 (4H, m, ArCH), 7.10 (1H, s, ArCH), 7.02 (1H, s, ArCH), 4.32 (1H, dd, J = 12.0 and 9.0 Hz, CH₂CHPh), (1H, dd, J = 10.0 and 9.0 Hz, CH₂CHPh), 3.61 (1H, dd, J = 12.0 and 10.0 Hz, CH₂CHPh), 3.05-2.85 (2H, m, CH), 2.67-2.53 (1H, m, CH), 2.35-2.13 (13H, m, 4 × CH₃ and CH), 2.10-1.90 (2H, m, CH), 1.69-1.58 (1H, m, CH), 0.83-0.69 (1H, m, CH); δP (162 MHz, CDCl₃) 28.6 (s).

The structure of this compound was determined unambiguously by X-ray crystallography.
(S)-3-Methyl-6-phenylhexan-3-amine 5

A pressure vessel, fitted with magnetic stirrer, was charged with 10% Pd/C (13.5 mg, 0.13 mmol), MeOH (6 mL), H₂O (1 mL) and (R)-3a (50 mg, 0.27 mmol). The vessel was pressurised with H₂ (6 atm) and vigorously stirred at room temperature for 4 days. The reaction vessel was depressurised and the mixture was filtered through a pad of celite, washing with EtOAc (25 mL). The filtrate was concentrated in vacuo to afford amine 5 (50.1 mg, 97%) as a colourless oil.

[α]D⁺¹⁷.5 (c = 0.5, CHCl₃).

¹H NMR (400 MHz, CDCl₃): 7.29-7.23 (m, 2H, ArH), 7.20-7.13 (m, 3H, ArH), 6.67-5.91 (br s, 2H, NH₂), 2.62 (t, J = 7.5 Hz, 2H, ArCH₂), 1.79-1.60 (m, 6H, ArCH₂CH₂CH₂ and CH₂CH₃), 1.28 (s, 3H, CCH₃), 0.92 (t, J = 7.5 Hz, 3H, CH₂CH₃).

¹³C NMR (100 MHz, CDCl₃): 141.7 (ArC), 128.3 (2 signals), 125.9 (3 × ArCH), 56.9 (CNH₂), 37.9 (ArCH₂CH₂CH₂), 35.8 (ArCH₂), 31.5 (CH₂CH₃), 25.0 (ArCH₂CH₂), 24.0 (CCH₃), 7.9 (CH₃CH₃).

FTIR 2886, 1601, 1508, 1460, 1383 cm⁻¹.

MS (Cl⁺) Found [M+H⁺]: 192.1758, C₁₃H₂₂N requires 192.1752.

The enantiospecificity of the process was determined to be >95% by analysis of the Mosher’s amide derivatives of compound 5.

(2S*,5R*)-2-isopropyl-5-(naphthalen-2-yl)-2-vinylpyrrolidine 6

To a solution of imine rac-3j (60 mg, 0.23 mmol) in dry toluene (1.5 mL), stirring under nitrogen at -78 °C, was added a solution of DIBAL-H (1.43 mmol, 6.2 eq) dropwise. The reaction mixture was stirred at -78 °C for 6 hours then warmed to 0 °C and quenched with saturated Rochelle’s Salt solution (5 mL). The phases were separated and the aqueous layer was extracted with Et₂O (5 x 10 mL). The organic layers united were washed with water (30 mL), dried over MgSO₄ and the solvents removed in
The crude product was purified by FCC (5 to 10% EtOAc in hexane) and preparative TLC (2 runs in 3% EtOAc in hexane) to yield the title compound 6 (43 mg, 0.16 mmol, 70%, 5:1 d.r.).

\[ ^1H \text{ NMR} \ (400 \text{ MHz, CDCl}_3): \text{ Data for the major diastereomer:} \ 7.88 - 7.80 \ (m, 4H), 7.56 \ (dd, J = 8.5, 1.7 \text{ Hz}, 1H), 7.52 - 7.37 \ (m, 2H), 5.89 \ (dd, J = 17.4, 10.7 \text{ Hz}, 1H), 5.21 \ (dd, J = 10.7, 1.3 \text{ Hz}, 1H), 5.15 \ (dd, J = 17.4, 1.3 \text{ Hz}, 1H), 4.40 \ (tt, J = 7.5 \text{ Hz}, 1H), 2.35 - 2.15 \ (m, 1H), 1.99 - 1.71 \ (m, 5H), 0.99 \ (d, J = 6.9 \text{ Hz}, 6H). A signal corresponding to NH was not observed. Characteristic signals for the minor diastereomer: 5.99 \ (dd, J = 17.1, 10.6 \text{ Hz}, 1H), 5.42 \ (dd, J = 17.2, 2.0 \text{ Hz}, 1H), 4.47 \ (dd, J = 10.0, 5.7 \text{ Hz}, 1H). \]

\[ ^{13}\text{C NMR} \ (100 \text{ MHz, CDCl}_3): \text{ Signals for the major diastereomer only:} \ 143.4, 142.5, 133.4, 132.7, 128.0, 127.8, 127.6, 125.8, 125.4, 125.3, 124.8, 112.3, 69.5, 60.6, 38.3, 34.0, 33.9, 18.5, 18.0. \]

\[ \text{FTIR:} \ 2960, 2878 \text{ cm}^{-1}. \]

\[ \text{MS: (ESI\textsuperscript{*}) Found [M+H]\textsuperscript{+}:} \ 266.1906, \text{ C}_{19}\text{H}_{24}\text{N} \text{ requires} \ 266.1903. \]

The relative stereochemistry of this compound was assigned on the basis of nOe experiments as indicated on the compound structure.
X-ray Crystallography Experimental Details

X-ray diffraction data for 3b was collected at 100K on a Bruker Microstar rotating anode diffractometer using Cu-Kα (λ = 1.54178 Å), while data for 4 were collected at 100 K on a Bruker APEX II diffractometer using Mo-Kα radiation (λ = 0.71073 Å). Data collections were performed using a CCD area detector from a single crystal mounted on a glass fibre. Intensities were integrated in SAINT and absorption corrections were based on equivalent reflections using SADABS. The structures were solved using Superflip and all of the structures were refined against F^2 in SHELXL using Olex2. All of the non-hydrogen atoms were refined anisotropically. While all of the hydrogen atoms were located geometrically and refined using a riding model.
References

23. Sheldrick, G. M. SADABS V2012/1, University of Götingen, Germany.
O

N

Ph

Me

C₆F₅

single pulse decoupled gated NOE