The Intramolecular Photometathesis of Pyrrole Derivatives

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Supporting Information

Table of Contents

General Details	<i>page S2</i>
General Procedures	<i>page S2 – S4</i>
Compounds	<i>page S5 – S20</i>
Spectra	<i>page S21 – S46</i>
X-Ray Structure	<i>page S47</i>

Experimental

General Details

All reactions were carried out at ambient temperature and under nitrogen atmosphere unless otherwise stated. Reaction glassware was oven-dried as standard, and glassware was flame dried for reactions requiring anhydrous conditions. The dry solvents were obtained from the dry solvent dispenser in the University of Bristol. DMF was stored under nitrogen using 4A molecular sieves. All reactions were stirred magnetically. Brine refers to a saturated solution of sodium chloride in water.

Flash column chromatography was performed using Fluorochem silica gel 60 (0.040 - 0.063). Eluting solvent were as indicated in the text. Thin layer chromatography (TLC) analyses were performed using Merck aluminium sheets covered with a 0.2 mm layer of silica gel 60 F254. Product spots were visualised either with UV light or by staining by potassium manganate (VII) solution, followed by gentle heating. IR spectra were recorded in the range of 4000-6000 cm^{-1} using an IR Perkin-Elmer Spectrum 1 FTIR Spectrophotometer. High resolution mass spectra were recorded with a Fisons/VG Analytical Autospec System. NMR spectra were recorded as solutions in the deuterated solvent stated in the text, and were appropriate using tetramethylsilane as an internal standard. Where necessary, assignments were made with the aid of DEPT and COSY correlation experiments.

Solutions for photochemical reactions were degassed prior to irradiation, followed by thorough mixing to ensure uniformity. Immersion-well photochemical reactions were performed using 125 W medium pressure, and 6 W low pressure mercury lamps in either Pyrex or Vycor glass wells.

General Procedures

Preparation of 4-Acyl-2-(trichloroacetyl)pyrroles¹

A solution of the acyl chloride (1.23 eq) in anhydrous DCM (approx. 0.5 vols) was added to a stirred mixture of 2-(trichloroacetyl)pyrrole (1.0 eq) and AlCl_3 (1.23 eq) in DCM (4.0 vols) and nitromethane (4.0 vols) at -30°C . The mixture was stirred at -30°C for approximately 3 hours during which the reaction followed by TLC. The reaction mixture was poured over ice water and the aqueous phase was extracted (EtOAc). The pooled organic extracts were washed (brine) and dried (MgSO_4) before evaporating to dryness under reduced pressure and the residue was recrystallised from EtOH.

¹ Garrido, D. O. A.; Buldain, G.; Ojea, M. I.; Frydman, B. *J. Org. Chem.* **1988**, 53, 403 – 407

Alcoholysis of 2-(trichloroacetyl)pyrroles²

A thoroughly dry round bottom flask (20 ml) was evacuated and released to nitrogen several times before addition of the required mass of sodium. Anhydrous EtOH was then dispensed into the vessel which was stirred at ambient until all sodium had dissolved. To the NaOEt solution was then added the pyrrole, portionwise over 15 min before stirring at ambient for 1 hour or until all starting material had been consumed. The reaction mixture was then evaporated to dryness before partitioning the residue between Et₂O and 2 N HCl. The aqueous phase was extracted with further Et₂O and the pooled organic extracts were washed (sat. NaHCO₃ (aq)) and dried (MgSO₄) before evaporating to dryness under reduced pressure.

Knorr Pyrrole Synthesis³

To a stirred solution of the appropriate carbonyl compound (15.0 mmol, 1 eq) in glacial acetic acid (5 ml) cooled to 5°C is added dropwise a solution of NaNO₂ (1.0 g, 14.5 mmol, 0.97 eq) in distilled water (1.5 ml) at a rate such that the temperature does not exceed about 7°C. The reaction mixture is stirred at 5°C for about 30 min before allowing to stand at ambient for around 3 hrs. A solution of 95% Zn dust (2.06 g, 30.0 mmol, 2 eq), sodium acetate (4.92 g, 60 mmol, 4 eq) and the appropriate 1, 3-dicarbonyl compound (15 mmol, 1 eq) in glacial acetic acid (9 ml) is then added to the reaction mixture before refluxing the fully charged vessel for approximately 1 hour.

The reaction mixture was then poured over distilled water and, having left to stand overnight, the product was filtered by suction, washed (H₂O) and the product recrystallised from EtOH.

General Mitsunobu Procedure for Alkylation of Pyrroles

A solution of PPh₃ (1.05 eq) in anhydrous THF (approx. 60 vols) was cooled to -78°C with magnetic stirring. DIAD (1.04 eq) was then added dropwise over 10 min. The solution was then stirred at -78°C for 1 hr during which a white ppt formed in the vessel. 4- Penten-1-ol (1.3 eq) was then added dropwise over 10 min before stirring at -78°C for 1 hour. To the pale yellow slurry was then added the pyrrole (1.0 eq) portion-wise over 5 min. The fully charged reaction vessel was removed from cooling and left to stir overnight at room temperature. The clear solutions were evaporated to dryness before loading onto silica for purification by flash chromatography.

² Bailey, D. M.; Johnson, R. E.; Albertson, N. F. *Org. Synth.* CV 6, 618

³ Fischer, H. *Org. Synth.* CV 2, 202

Aminolysis of 2-(trichloroacetyl)pyrroles

To a stirred solution of the 2-(trichloroacetyl)pyrrole, cooled using an appropriate ice bath, was condensed an excess of EtNH₂ from a cylinder. The solution was allowed to stir at ambient for approximately 1 hour or until all starting material had been consumed. Additional EtNH₂ was introduced if necessary. The reaction mixture was evaporated to dryness before purification by column chromatography.

Direct Alkylation of Pyrroles

To a stirred solution of the pyrrole in anhydrous DMF, cooled in ice, is added NaH (1.2 eq). The solution is allowed to warm to ambient temperature and stirred for 15 min before the dropwise addition of 5-iodo-1-pentene. The fully charged reaction vessel is stirred at ambient overnight before the reaction mixture is quenched (water) and the product extracted (DCM). The pooled organic extracts are washed (sat. NaCl) and dried (MgSO₄) before removal of the solvent under reduced pressure. The product is purified using column chromatography.

Compounds

4-Formyl-2-(trichloroacetyl)pyrrole

The general acylation procedure was followed using: 2-(trichloroacetyl) pyrrole (1.0 g, 4.71 mmol, 1.0 eq), AlCl_3 (0.772 g, 5.79 mmol, 1.23 eq) in anhydrous DCM (4 ml) and nitromethane (4 ml), dichloromethyl methyl ether (0.666 g, 5.79 mmol, 1.23 eq) in DCM (0.6 ml). The reaction mixture was purified by flash chromatography (SiO_2 , 40% EtOAc in Pet ether) to give product (0.909 g, 80%) along with a highly colored orange/red impurity: ν_{max} (film)/ cm^{-1} : 3111, 2995, 2881, 1700, 1651 and 1565; δ_{H} (270 MHz, DMSO) 13.19 (1H, s, **NH**), 9.84 (1H, s, **CHO**), 8.10 (1H, m, **Pyr.H**), 7.66 (1H, d, $J=0.9$ Hz, **Pyr.H**); δ_{C} (100 MHz, CDCl_3) 186.8 (**CHO**), 173.7 (C), 134.6 (CH), 127.8 (C), 123.8 (C), 119.7 (CH), 94.9 (C); CI-HRMS: m/z 239.9377 (MH^+ , $\text{C}_7\text{H}_5\text{Cl}_3\text{NO}_2$ requires 239.9386)

4-Acetyl-2-(trichloroacetyl)pyrrole

The general acylation procedure was followed using: 2-(trichloroacetyl) pyrrole (10.00 g, 47.0 mmol, 1 eq), AlCl_3 (8.15 g, 61.1 mmol, 1.3 eq) in DCM (40 ml) and nitromethane (40 ml), acetyl chloride (4.80 g, 61.1 mmol, 1.3 eq) in DCM (6 ml). The product was recrystallised to yield the product as a light brown solid (10.71 g, 89%); ν_{max} (film)/ cm^{-1} 3205, 1652; δ_{H} (400 MHz, DMSO) 13.02 (1H, br. s, **NH**), 8.06 (1H, dd, $J=3.5$ Hz, $J=1.4$ Hz, **Pyr.H**), 7.58 (1H, dd, $J=2.5$ Hz, $J=1.4$ Hz, **Pyr.H**), 2.42 (3H, s, **COCH3**); δ_{C} (100 MHz, DMSO) 192.2 (CO), 172.8 (C), 131.9 (CH), 127.0 (C), 122.5 (C), 119.3 (CH), 94.3 (CCl_3), 27.9 (CH_3)

4-(Phenylacetyl)-2-(trichloroacetyl)pyrrole

The general acylation procedure was followed using: 2-(trichloroacetyl) pyrrole (5.00 g, 23.5 mmol, 1 eq), AlCl_3 (3.86 g, 28.9 mmol, 1.23 eq) in DCM (20 ml) and nitromethane (20 ml), phenyl acetyl chloride (4.48 g, 28.9 mmol, 1.23 eq) in DCM (3 ml). The product was recrystallised to yield the product (6.00 g, 77%); ν_{max} (film)/ cm^{-1} 3283, 1682 and 1667; δ_{H} (400 MHz, CDCl_3) 10.01 (1H, br. s, NH), 7.74 (1H, dd, $J=2.5$ Hz, $J=1.4$ Hz, Pyr.H), 7.65 (1H, appt. dm, $J=3.4$ Hz, Pyr.H), 7.35 - 7.22 (5H, m, Ar.H), 4.10 (2H, s, COCH_2Ph); δ_{C} (100 MHz, CDCl_3) 192.8 (C), 173.8 (C), 134.3 (C), 129.9 (CH), 129.4 (2CH), 128.8 (2CH), 127.1 (C), 127.1 (CH), 123.6 (C), 120.4 (CH), 94.2 (CCl_3), 47.1 (CH_2)

Pyrrole-2-carbonitrile⁴

A stirred solution of pyrrole (5.0 g, 5.2 ml, 74.5 mmol, 1 eq) in DMF (25 ml) and MeCN (25 ml) was cooled to -78°C before the dropwise addition of CSI (11.7 g, 7.2 ml, 82.6 mmol, 1.1 eq) over 10 min. The reaction mixture was then warmed to ambient temperature before pouring over NaOH (3 M, 30 ml), NaHCO_3 (5%, 150 ml) and ice. The reaction mixture was extracted (3 $\times$ 200 ml DCM) and the pooled organic extracts washed (3 $\times$ 100 ml H_2O) and dried (MgSO_4). The crude product was purified by flash chromatography to yield the product as a clear oil (4.3 g, 63%); ν_{max} (film)/ cm^{-1} 3297 and 2218; δ_{H} (400 MHz, CDCl_3) 9.59 (1H, br. s., NH), 6.98 (1H, td, $J=2.8$ Hz, $J=1.5$ Hz, Pyr.H), 6.90 (1H, ddd, $J=3.9$ Hz, $J=2.4$ Hz, $J=1.5$ Hz, Pyr.H), 6.28 (1H, ddd, $J=3.8$ Hz, $J=2.6$ Hz, $J=2.4$ Hz, Pyr.H)

⁴ *Can. J. Chem.* **1981**, 59, 2673 - 2679

Ethyl 4-formyl-pyrrole-2-carboxylate

The general alcoholysis procedure was followed using Na (s) (38 mg), EtOH (10 ml), 4-formyl-2-(trichloroacetyl)pyrrole (2.5 g, 10.4 mmol). The combined organic portions were loaded onto silica before purification by flash chromatography (SiO₂, 40% EtOAc in Pet ether) to yield the product as a solid (1.2 g, 71%): $\nu_{\max}$ (film)/cm⁻¹ 3269, 3127, 2985, 1706, 1657, 1560, and 1500; δ_{H} (400 MHz, CDCl₃) 10.45 (1H, s, NH), 9.78 (1H, s, CHO), 7.53 (1H, dd, $J=3.4$ Hz, $J=1.5$ Hz, Pyr.H), 7.26 (1H, m, Pyr.H), 4.29 (2H, q, $J=7.1$ Hz, OCH₂CH₃), 1.30 (3H, t, $J=7.1$ Hz, OCH₂CH₃); δ_{C} (100 MHz, CDCl₃) 185.9 (CH), 161.2 (C), 128.9 (CH), 127.5 (C), 125.2 (C), 114.3 (CH), 61.2 (CH₂), 14.4 (CH₃); EI-HRMS m/z 167.0582 (M⁺, C₈H₉NO₃ requires 167.0582)

Ethyl 4-acetyl-pyrrole-2-carboxylate

The general alcoholysis procedure was followed using Na(s) (20 mg), EtOH (6 ml) and 4-acetyl-2-(trichloroacetyl)pyrrole (1.5 g, 5.89 mmol) to yield product (0.937 g, 87%) as a white solid R_f 0.4 (SiO₂, 50% EtOAc in Pet ether): $\nu_{\max}$ (film)/cm⁻¹ 3257, 3116, 2985, 1683, 1655, 1559, 1483; δ_{H} (400 MHz, CDCl₃) 9.75 (1H, s, NH), 7.55 (1H, dd, $J=3.3$ Hz, $J=1.7$ Hz, Pyr.H), 7.29 (1H, dd, $J=2.4$ Hz, $J=1.7$ Hz, Pyr.H), 4.36 (2H, q, $J=7.1$ Hz, OCH₂CH₃), 2.45 (3H, s, COCH₃), 1.38 (3H, t, $J=7.1$ Hz, OCH₂CH₃); δ_{C} (100 MHz, CDCl₃) 193.5 (C), 161.0 (C), 127.5 (C), 126.2 (CH), 124.3 (C), 114.9 (CH), 61.1 (CH₂), 27.4 (CH₃), 14.4 (CH₃); CI-HRMS m/z 182.0814 (MH⁺, C₉H₁₂NO₃ requires 182.0817)

Ethyl 4-(phenylacetyl)-pyrrole-2-carboxylate

The general alcoholysis procedure was followed using Na(s) (0.10 g), EtOH (30 ml) and 4-(phenylacetyl)-2-(trichloroacetyl)pyrrole (7.0 g, 21.2 mmol) to yield the product (4.90 g, 90%) as a beige powder: $\nu_{\max}$ (film)/cm⁻¹ 3221 and 1668; δ_{H} (400 MHz, CDCl₃) 9.71

(1H, br. s, **NH**), 7.53 (1H, dd, $J=3.3$ Hz, $J=1.6$ Hz, Pyr.**H**), 7.34 - 7.22 (6H, m, 5Ar.**H**, Pyr.**H**), 4.34 (2H, q, $J=7.1$ Hz, OCH_2CH_3), 4.07 (2H, s, COCH_2Ph), 1.37 (3H, t, $J=7.1$ Hz, OCH_2CH_3); δ_{C} (67.5 MHz, CDCl_3) 193.0 (C), 160.8 (C), 134.7 (C), 129.4 (2CH), 128.6 (2CH), 126.8 (CH), 126.6 (CH), 124.2 (C), 115.0 (CH), 61.0 (CH_2), 46.8 (CH_2), 14.3 (CH_3); EI-HRMS m/z 257.1044 (M^+ , $\text{C}_{15}\text{H}_{15}\text{NO}_3$ requires 257.1052)

4-Acetyl-pyrrole-2-carbonitrile

A solution of pyrrole-2-carbonitrile (1.38 g, 15 mmol, 1.0 eq) in anhydrous DCM (20 ml) and nitromethane (20 ml) was added dropwise to a solution of acetyl chloride (2.36 ml, 30 mmol, 2.0 eq) and AlCl_3 (4.0 g, 30 mmol, 2.0 eq) in DCM (40 ml) in an ice bath. After the starting material had been fully consumed (TLC) the reaction mixture was quenched in ice water and the product extracted (EtOAc). The pooled extracts were washed (sat. NaHCO_3 and NaCl solution), dried (MgSO_4) and evaporated under reduced pressure to yield the product as a solid (1.82 g, 90%): ν_{max} (film)/ cm^{-1} 3127, 2223 and 1644; δ_{H} (400 MHz, DMSO) 12.89 (1H, br. s, **NH**), 7.90 (1H, d, $J=1.5$ Hz, Pyr.**H**), 7.32 (1H, d, $J=1.5$ Hz, Pyr.**H**), 2.36 (3H, s, **CH**₃); δ_{C} (100 MHz, DMSO) 191.8 (C), 129.0 (CH), 126.2 (C), 119.2 (CH), 113.7 (C), 101.8 (C), 27.1 (CH_3)

Cyclohexenone Pyrrole

The general Knorr pyrrole synthesis was followed using ethylacetoacetate (1.95 g, 15.0 mmol, 1.0 eq) and 1, 3-cyclohexanedione (1.68 g, 15.0 mmol, 1.0 eq). Recrystallisation yielded the product (1.69 g, 7.6 mmol, 50%) as a beige solid: ν_{max} (film)/ cm^{-1} 3158, 1687, 1635; δ_{H} (270 MHz, CDCl_3) 9.59 (1H, s, **NH**), 4.35 (2H, quart, $J=7.1$ Hz, OCH_2CH_3), 2.83 (2H, t, $J=6.2$ Hz, CCH_2CH_2), 2.61 (3H, s, CCH_3), 2.50 - 2.42 (2H, m, COCH_2CH_2), 2.13 (2H, appt. quin, $J=6.1$ Hz, $\text{CH}_2\text{CH}_2\text{CH}_2$), 1.38 (t, 3H, $J=7.1$ Hz OCH_2CH_3)

Ethyl 4-formyl-1-(pent-4-enyl)-pyrrole-2-carboxylate

The general Mitsunobu procedure was followed using: PPh₃ (0.824 g, 3.14 mmol), DIAD (0.628 g, 3.11 mmol), 4-penten-1-ol (0.375 g, 4.35 mmol), ethyl 4-formyl-pyrrole-2-carboxylate (0.5 g, 2.99 mmol). Purification of the reaction mixture by flash chromatography (SiO₂, 30% EtOAc in Pet ether) yielded product (0.469 g, 67%) as a clear oil: $\nu_{\max}$ (film)/cm⁻¹ 3118, 3078, 2980, 1708, 1673, 1641, 1545, 1493 and 1446; δ_{H} (400 MHz, CDCl₃) 9.77 (1H, s, CHO), 7.43 (1H, d, *J*=1.9 Hz, Pyr.H), 7.39 (1H, d, *J*=1.9 Hz, Pyr.H), 5.84 – 5.74 (1H, m, CH₂CH=CH₂), 5.09 – 5.01 (2H, m, CH₂CH=CH₂), 4.36 (2H, m, NCH₂CH₂), 4.31 (2H, q, *J*=7.1 Hz, OCH₂CH₃), 2.08 (2H, q, *J*=6.9 Hz, CH₂CH₂CH), 1.91 (2H, p, *J*=7.3 Hz, CH₂CH₂CH₂), 1.36 (3H, t, *J*=7.1 Hz, OCH₂CH₃); δ_{C} (100MHz, CDCl₃) 185.3 (CH), 160.7 (C), 137.0 (CH), 132.9 (CH), 124.7 (C), 124.3 (C), 118.0 (CH), 115.9 (CH₂), 60.6 (CH₂), 49.6 (CH₂), 30.6 (CH₂), 30.2 (CH₂), 14.4 (CH₃); UV: $\lambda_{\max}$ 227 nm, 272 nm to 300 nm; ESI-HRMS *m/z* 258.1104 (MNa⁺, C₁₃H₁₇NO₃Na requires 258.1101)

Ethyl 4-acetyl-1-(pent-4-enyl)-pyrrole-2-carboxylate

The general Mitsunobu procedure was followed using: PPh₃ (1.293 g, 4.93 mmol), DIAD (0.978 g, 4.84 mmol), 4-penten-1-ol (0.602 g, 6.99 mmol), ethyl 4-acetylpyrrole-2-carboxylate (0.85 g, 4.70 mmol). Purification of the reaction mixture by flash chromatography (SiO₂, 20% EtOAc in Pet ether) yielded the product (0.874 g, 75%) as an off-white solid: $\nu_{\max}$ (film)/cm⁻¹ 3118, 3078, 2980, 2937, 1711, 1663, 1640, 1541; δ_{H} (400 MHz, CDCl₃) 7.41 (1H, d, *J*=1.9 Hz, Pyr.H), 7.34 (1H, d, *J*=1.9 Hz, Pyr.H), 5.84 – 5.74 (1H, m, CH₂CH=CH₂), 5.08 – 4.96 (2H, m, CH₂CH=CH₂), 3.35 – 4.31 (2H, m, NCH₂CH₂), 4.31 (2H, q, *J*=7.3 Hz, OCH₂CH₃), 2.42 (3H, s, COCH₃), 2.07 (2H, m, CH₂CH₂CH), 1.89 (2H, m, CH₂CH₂CH₂), 1.37 (3H, t, *J*=7.3 Hz, OCH₂CH₃); δ_{C} (100 MHz, CDCl₃) 193.2 (C), 160.7 (C), 137.2 (CH), 131.4 (CH), 124.5 (C), 123.3 (C), 118.4 (CH), 115.8 (CH₂), 60.4 (CH₂), 49.4 (CH₂), 30.6 (CH₂), 30.3 (CH₂), 27.2 (CH₃), 14.4 (CH₃); UV: $\lambda_{\max}$ 227 nm, 275 nm to 300 nm; EI-HRMS *m/z* 249.1357 (M⁺, C₁₄H₁₉NO₃ requires 249.1365)

Ethyl 4-(phenylacetyl)-1-(pent-4-enyl)-pyrrole-2-carboxylate

The general Mitsunobu procedure was followed using: Ethyl 4-(2-phenylacetyl)-pyrrole-2-carboxylate (4.5 g, 17.5 mmol, 1.0 eq), PPh_3 (4.8 g, 18.4 mmol, 1.05 eq), DIAD (3.7 g, 18.2 mmol, 1.04 eq), 4-penten-1-ol (2.3 g, 2.7 ml, 26.3 mmol, 1.5 eq) in anhydrous THF (250 ml). The product was purified by flash chromatography (SiO_2 , 20% EtOAc in n-hexane) to yield the product (4.02 g, 71%) as a white solid: ν_{max} (film)/ cm^{-1} 1701 and 1662; δ_{H} (400 MHz, CDCl_3) 7.40 (1H, d, $J=1.9$ Hz, Pyr.**H**), 7.38 (1H, d, $J=1.9$ Hz, Pyr.**H**), 7.34 - 7.21 (5H, m, Ar.**H**), 5.77 (1H, ddt, $J=16.9$ Hz, $J=10.2$ Hz, $J=6.5$ Hz, $\text{CH}_2\text{CH}=\text{CH}_2$), 5.06 - 4.98 (2H, m, $\text{CH}_2\text{CH}=\text{CH}_2$), 4.30 (2H, t, $J=7.2$ Hz, NCH_2CH_2), 4.28 (2H, q, $J=7.1$ Hz, OCH_2CH_3), 4.03 (2H, s, COCH_2Ph), 2.04 (2H, app. q, $J=7.2$ Hz, $\text{CH}_2\text{CH}_2\text{CH}$), 1.86 (2H, quint, $J=7.3$ Hz, $\text{CH}_2\text{CH}_2\text{CH}_2$), 1.35 (3H, t, $J=7.1$ Hz, OCH_2CH_3); δ_{C} (100 MHz, CDCl_3) 192.7 (C), 160.6 (C), 137.0 (CH), 134.9 (C), 131.8 (CH), 129.3 (2CH), 128.6 (2CH), 126.8 (CH), 123.6 (C), 123.3 (C), 118.4 (CH), 115.7 (CH₂), 60.4 (CH₂), 49.3 (CH₂), 46.5 (CH₂), 30.5 (CH₂), 30.1 (CH₂), 14.3 (CH₃); ESI-HRMS m/z 348.1561 (MNa^+ , $\text{C}_{20}\text{H}_{23}\text{NO}_3\text{Na}$ requires 348.1570)

4-Acetyl-1-(pent-4-enyl)-2-(trichloroacetyl)-pyrrole

The general Mitsunobu procedure was followed using: 4-acetyl-2-(trichloroacetyl)pyrrole (4.5 g, 17.7 mmol, 1.0 eq), PPh_3 (4.9 g, 18.6 mmol, 1.05 eq), DIAD (3.7 g, 3.6 ml, 18.4 mmol, 1.04 eq), 4-penten-1-ol (2.0 g, 2.4 ml, 23.0 mmol, 1.3 eq) in anhydrous THF (300 ml). The product was purified by flash chromatography (SiO_2 , 20% EtOAc in n-hexane) to yield product (4.45 g, 78%) as a white solid: ν_{max} (film)/ cm^{-1} 1680 and 1655; δ_{H} (400 MHz, CDCl_3) 7.87 (1H, d, $J=1.7$ Hz, Pyr.**H**), 7.56 (1H, d, $J=1.7$ Hz, Pyr.**H**), 5.81 (1H, ddt, $J=16.9$ Hz, $J=10.2$ Hz, $J=6.6$ Hz, $\text{CH}_2\text{CH}=\text{CH}_2$), 5.11-5.03 (2H, m, $\text{CH}_2\text{CH}=\text{CH}_2$), 4.35 (2H, t, $J=7.3$ Hz, NCH_2CH_2), 2.45 (3H, s, COCH_3), 2.12 (2H, app. q, $J=6.9$ Hz, $\text{CH}_2\text{CH}_2\text{CH}$), 1.89 (2H, quint, $J=7.3$ Hz, $\text{CH}_2\text{CH}_2\text{CH}_2$); δ_{C} (100 MHz, CDCl_3) 192.1 (C), 173.4 (C), 136.7 (CH), 134.4 (CH), 125.0 (C), 123.5 (CH), 122.1 (C), 115.9 (CH₂), 95.8 (C), 50.7 (CH₂), 30.4 (CH₂), 29.9 (CH₂), 27.1 (CH₃); CI-HRMS m/z 322.0168 (MH^+ , $\text{C}_{13}\text{H}_{15}\text{Cl}_3\text{NO}_2$ requires 322.0168)

4-Acetyl-1-(hex-4-enyl)-2-(trichloroacetyl)-pyrrole

The general Mitsunobu procedure was followed using: 4-acetyl-2-(trichloroacetyl)pyrrole (7.8 g, 30.6 mmol, 1.0 eq), PPh₃ (8.4 g, 32.2 mmol, 1.05 eq), DIAD (6.5 g, 6.2 ml, 32.0 mmol, 1.04 eq), 4-hexen-1-ol (4.0 g, 4.7 ml, 39.8 mmol, 1.3 eq) in anhydrous THF (300 ml). The product was purified by flash chromatography (SiO₂, 20% EtOAc in n-hexane) to yield product (7.9 g, 76%) as a waxy solid: $\nu_{\max}$ (film)/cm⁻¹ 1668 and 1541; δ_{H} (400 MHz, CDCl₃) 7.86 (1H, d, $J=1.7$ Hz, Pyr.**H**), 7.55 (1H, d, $J=1.7$ Hz, Pyr.**H**), 5.52 - 5.34 (2H, m, CH₂CH=CHCH₃), 4.36 - 4.30 (2H, m, NCH₂CH₂), 2.45 (3H, s, COCH₃), 2.04 (2H, q, $J=6.8$ Hz, CH₂CH₂CH), 1.88 - 1.79 (2H, m, CH₂CH₂CH₂), 1.66 (3H, dd, $J=6.0$ Hz, $J=1.1$ Hz, CH=CHCH₃); δ_{C} (100 MHz, CDCl₃) 192.4 (C), 173.3 (C), 134.6 (CH), 129.3 (CH), 126.5 (CH), 124.8 (C), 123.6 (CH), 121.9 (C), 95.7 (C), 50.8 (CH₂), 30.4 (CH₂), 29.3 (CH₂), 27.2 (CH₃), 17.9 (CH₃); CI-HRMS m/z 336.0325 (MH⁺, C₁₄H₁₇Cl₃NO₂ requires 336.0325)

N-Ethyl-4-acetyl-1-(pent-4-enyl)-pyrrole-2-carboxamide

The general aminolysis procedure was followed using 4-acetyl-1-(pent-4-enyl)-2-(trichloroacetyl)pyrrole (1.0 g, 3.1 mmol). The product was purified by flash chromatography (SiO₂, 40% EtOAc in n-hexane) to yield product (0.69 g, 90%) as a white solid: $\nu_{\max}$ (film)/cm⁻¹ 3296, 1667, 1631 and 1532; δ_{H} (400 MHz, CDCl₃) 7.33 (1H, d, $J=1.7$ Hz, Pyr.**H**), 7.02 (1H, d, $J=1.8$ Hz, Pyr.**H**), 6.25 (1H, br. s, NH₂), 5.79 (1H, ddt, $J=16.8$ Hz, $J=10.2$ Hz, $J=6.6$ Hz, CH₂CH=CH₂), 5.07-4.99 (2H, m, CH₂CH=CH₂), 4.36 (2H, t, $J=7.2$ Hz, NCH₂CH₂), 3.42 (2H, app. quint, $J=6.8$ Hz, NHCH₂CH₃), 2.40 (3H, s, COCH₃), 2.07 (2H, app. q, $J=6.7$ Hz, CH₂CH₂CH), 1.90 (2H, quint, $J=7.3$ Hz, CH₂CH₂CH₂), 1.23 (3H, t, $J=7.2$ Hz, NHCH₂CH₃); δ_{C} (100 MHz, CDCl₃) 192.9 (C), 161.1 (C), 137.3 (CH), 130.5 (CH), 127.3 (C), 124.1 (C), 115.6 (CH₂), 111.5 (CH), 49.1 (CH₂), 34.4 (CH₂), 30.7 (CH₂), 30.6 (CH₂), 27.1 (CH₃), 15.0 (CH₃); CI-HRMS m/z 249.1592 (MH⁺, C₁₄H₂₁N₂O₂ requires 249.1603)

N-Ethyl-4-acetyl-1-(hex-4-enyl)-pyrrole-2-carboxamide

The general aminolysis procedure was followed using 4-acetyl-1-(hex-4-enyl)-2-(trichloroacetyl)pyrrole (2.74 g, 8.1 mmol). The product was purified by flash chromatography (SiO₂, 40% EtOAc in n-hexane) to yield product (1.47 g, 69%) as a white solid: ν_{max} (film)/cm⁻¹ 3354, 1636, 1549 and 1526; δ_{H} (400 MHz, CDCl₃) 7.31 (1H, d, $J=1.9$ Hz, Pyr.**H**), 7.02 (1H, d, $J=1.7$ Hz, Pyr.**H**), 6.33 (1H, br. s., NH₂Et), 5.49 - 5.32 (2H, m, CH₂CH=CHCH₂), 4.35 - 4.31 (2H, m, NCH₂CH₂), 3.45 - 3.36 (2H, m, NHCH₂CH₃), 2.38 (3H, s, COCH₃), 2.02 - 1.93 (2H, m, CH₂CH₂CH), 1.88 - 1.78 (2H, m, CH₂CH₂CH₂), 1.63 (3H, app. d, $J=5.4$ Hz, CH=CHCH₃), 1.21 (3H, t, $J=7.3$ Hz, NHCH₂CH₃); δ_{C} (100 MHz, CDCl₃) 192.9 (C), 161.1 (C), 130.4 (CH), 129.7 (CH), 127.2 (C), 126.0 (CH), 123.9 (C), 111.4 (CH), 49.1 (CH₂), 34.2 (CH₂), 31.1 (CH₂), 29.4 (CH₂), 26.9 (CH₃), 17.9 (CH₃), 14.8 (CH₃); CI-HRMS m/z 263.1750 (MH⁺, C₁₅H₂₃N₂O₂ requires 263.1760)

4-Acetyl-1-(pent-4-enyl)-pyrrole-2-carbonitrile

The standard alkylation procedure followed using 4-acetyl-pyrrole-2-carbonitrile (3.5 g, 26.1 mmol, 1.0 eq), NaH (0.75 g, 31.3 mmol, 1.2 eq), 5-bromo-1-pentene (4.67 g, 31.3 mmol, 1.2 eq) in DMF. The product was purified by flash chromatography (SiO₂, 40% EtOAc in n-hexane) to yield product (4.33 g, 82%) as an oil: ν_{max} (film)/cm⁻¹ 2222 and 1666; δ_{H} (400 MHz, CDCl₃) 7.43 (1H, d, $J=1.7$ Hz, Pyr.**H**), 7.19 (1H, d, $J=1.7$ Hz, Pyr.**H**), 5.78 (1H, ddt, $J=17.6$ Hz, $J=10.1$ Hz, $J=6.4$ Hz, CH₂CH=CH₂), 5.12 - 5.04 (2H, m, CH₂CH=CH₂), 4.09 (2H, t, $J=7.0$ Hz, NCH₂CH₂), 2.41 (3H, s, COCH₃), 2.10 (2H, app. dq, $J=6.7$ Hz, $J=1.2$ Hz, CH₂CH₂CH), 1.98 (2H, app. d. quint, $J=7.0$ Hz, $J=1.4$ Hz, CH₂CH₂CH₂); δ_{C} (100 MHz, CDCl₃) 191.7 (C), 136.1 (CH), 129.2 (CH), 126.1 (C), 120.1 (CH), 116.4 (CH₂), 112.3 (C), 105.6 (C), 48.9 (CH₂), 30.2 (CH₂), 29.7 (CH₂), 27.1 (CH₃); CI-HRMS m/z 203.1182 (MH⁺, C₁₂H₁₅N₂O requires 203.1184)

Ethyl 4,5,6,7-tetrahydro-3-methyl-4-oxo-1-(pent-4-enyl)-indole-2-carboxylate

The standard alkylation procedure was followed using the cyclohexenone pyrrole (1.3 g, 5.9 mmol, 1.0 eq), NaH (0.18 g, 7.6 mmol, 1.3 eq), 5-iodo-1-pentene (1.7 g, 8.8 mmol, 1.5 eq) in anhydrous DMF (30 ml). The product was purified by flash chromatography (SiO₂, 30% EtOAc in n-hexane) to yield product (1.40 g, 82%) as a white solid: $\nu_{\max}$ (film)/cm⁻¹ 2948, 1687 and 1644; δ_{H} (400 MHz, CDCl₃) 5.79 (1H, ddt, $J=16.8$ Hz, $J=10.2$ Hz, $J=6.6$ Hz, CH₂CH=CH₂), 5.06 - 4.96 (2H, m, CH₂CH=CH₂), 4.29 (2H, q, $J=7.1$ Hz, OCH₂CH₃), 4.23 - 4.17 (2H, m, NCH₂CH₂), 2.73 (2H, t, $J=6.3$ Hz, CCH₂CH₂), 2.59 (3H, s, CCH₃), 2.46 - 2.42 (2H, m, COCH₂CH₂), 2.14 - 2.04 (4H, m, CH₂CH₂CH₂CH₂CH), 1.76 (2H, quint, CH₂CH₂CH₂, $J=7.6$ Hz), 1.35 (3H, t, $J=7.1$ Hz, OCH₂CH₃); δ_{C} (100 MHz; CDCl₃) 194.9 (C), 162.0 (C), 146.8 (C), 137.2 (CH), 130.4 (C), 120.6 (C), 118.8 (C), 115.4 (CH₂), 59.9 (CH₂), 45.4 (CH₂), 38.9 (CH₂), 30.7 (CH₂), 30.0 (CH₂), 22.9 (CH₂), 22.3 (CH₂), 14.3 (CH₃), 12.2 (CH₃); CI-HRMS m/z 290.1751 (MH⁺, C₁₇H₂₄NO₃ requires 290.1756)

Ethyl 1-((E)-2-formylbuta-1,3-dienyl)-1,4,5,6-tetrahydropyridine-2-carboxylate

Ethyl 4-formyl-1-(pent-4-enyl)-pyrrole-2-carboxylate (0.235 g, 1 mmol) was dissolved in MeCN (100 ml). The colourless solution was passed through a Vycor flow reactor with an internal volume of 90 ml, equipped with a 400 W medium pressure Hg lamp at a flow rate of 1 ml min⁻¹. Full consumption of starting material was observed by TLC after the 90 min residence time. The solution was evaporated under reduced pressure to give a dark orange/brown oil which was subsequently purified by flash chromatography (SiO₂, 60% EtOAc in Pet ether) to yield the product (105 mg, 45%) as an orange oil: $\nu_{\max}$ (film)/cm⁻¹ 3330, 2980, 2936, 2874, 2718, 1717, 1662, 1628, 1598 and 1580; δ_{H} (400 MHz, CDCl₃) 9.15 (1H, d, $J=1.4$ Hz, CHO), 6.80 (1H, s, NCH=C), 6.48 (1H, t, $J=4.1$ Hz, C=CHCH₂), 6.37 (1H, ddd, $J=17.7$ Hz, $J=11.4$ Hz, $J=1.3$ Hz, CCH=CH₂), 5.68 (1H, dd, $J=17.7$ Hz, $J=2.2$ Hz, CCH=CHH), 5.31 (1H, ddd, $J=11.5$ Hz, $J=2.2$ Hz, $J=0.7$ Hz, CCH=CHH), 4.23 (2H, q, $J=7.1$ Hz, OCH₂CH₃), 3.67 (1H, m, NCH₂CH₂), 2.35 (td, 2H, $J=6.6$ Hz, $J=4.1$ Hz, CHCH₂CH₂), 1.92 (2H, m, CH₂CH₂CH₂), 1.30 (3H, t, $J=7.1$ Hz, OCH₂CH₃); δ_{C} (100 MHz, CDCl₃) 190.9 (CH), 163.0 (C), 154.6 (CH), 133.8 (C), 127.2

(CH), 125.1 (CH), 117.8 (CH₂), 116.1 (C), 61.6 (CH₂), 50.6 (CH₂), 22.9 (2CH₂), 14.0 (CH₃); ESI-HRMS m/z 258.1100 (MNa⁺, C₁₃H₁₇NO₃Na requires 258.1101)

Ethyl 1-((E)-2-acetylbuta-1,3-dienyl)-1,4,5,6-tetrahydropyridine-2-carboxylate

A solution of ethyl 4-acetyl-1-(pent-4-enyl)-pyrrole-2-carboxylate (249 mg, 1 mmol) in MeCN (150 ml) was degassed before irradiating using a Vycor immersion well reactor and a 125 W Hg lamp for 1 hour 20 minutes. The major product was isolated by flash chromatography (30% EtOAc in n-hexane) to yield product (111 mg, 45%) as a yellow oil: $\nu_{\max}$ (film)/cm⁻¹ 3413, 2980, 2935, 1717, 1626, 1575, 1546, 1448; δ_{H} (400 MHz, CDCl₃) 7.23 (1H, s, NCH=C), 6.35 (1H, dd, $J=17.8$ Hz, $J=11.2$ Hz, CCH=CH₂), 6.29 (1H, t, $J=4.1$ Hz, C=CHCH₂), 5.25 (1H, ddd, $J=11.2$ Hz, $J=2.1$ Hz, $J=0.5$ Hz, CCH=CHH), 5.15 (1H, dd, $J=17.8$ Hz, $J=2.1$ Hz, CCH=CHH), 4.14 (2H, q, $J=7.1$ Hz, OCH₂CH₃), 3.46 (2H, m, NCH₂CH₂), 2.22 (2H, td, $J=6.6$ Hz, $J=4.1$ Hz, CHCH₂CH₂), 2.16 (3H, s, COCH₃), 1.78 (2H, m, CH₂CH₂CH₂), 1.22 (3H, t, $J=7.1$ Hz, OCH₂CH₃); δ_{C} (100 MHz, CDCl₃) 197.2 (C), 163.4 (C), 146.6 (CH), 134.4 (C), 130.6 (CH), 123.0 (CH), 118.3 (CH₂), 115.8 (C), 61.4 (CH₂), 50.4 (CH₂), 26.9 (CH₃), 22.9 (CH₂), 22.7 (CH₂), 14.1 (CH₃); ESI-HRMS m/z 246.1359 (M⁺, C₁₄H₁₉NO₃ requires 249.1365)

Ethyl 1,4,5,6-tetrahydro-1-(2-(2-phenylacetyl)buta-1,3-dienyl)pyridine-2-carboxylate

A solution of ethyl 4-(phenylacetyl)-1-(pent-4-enyl)-pyrrole-2-carboxylate (487 mg, 1.5 mmol) in MeCN (150 ml) was irradiated using a Vycor immersion well reactor and a 125 W Hg lamp for 1 hour. The reaction mixture was evaporated to dryness and the product purified by flash chromatography (20% EtOAc in n-hexane) to yield product (92 mg, 19%) as an orange oil: $\nu_{\max}$ /cm⁻¹ (film) 2933, 1716 and 1628; δ_{H} (400 MHz, CDCl₃) 7.31 (1H, s, NCH=C), 7.23 - 7.09 (5H, m, Ar.H), 6.34 (1H, dd, $J=17.7$ Hz, $J=11.2$ Hz, CCH=CH₂), 6.26 (1H, t, $J=4.0$ Hz, C=CHCH₂), 5.25 (1H, dd, $J=11.2$ Hz, $J=2.1$ Hz, CCH=CHH), 5.15 (1H, dd, $J=17.7$ Hz, $J=2.1$ Hz, CCH=CHH), 4.07 (2H, q, $J=7.1$ Hz, OCH₂CH₃), 3.79 (2H, s, COCH₂Ph), 3.44 - 3.40 (2H, m, NCH₂CH₂), 2.22 - 2.15 (2H, m, CHCH₂CH₂), 1.73 (2H, m, CH₂CH₂CH₂), 1.15 (3H, t, $J=7.1$ Hz, OCH₂CH₃); δ_{C} (100 MHz, CDCl₃) 196.6 (C), 163.3 (C), 146.8 (CH), 136.1 (C), 134.4 (C), 130.6 (CH), 129.2

(CH), 128.2 (CH), 126.2 (CH), 123.1 (CH), 118.7 (CH₂), 114.8 (C), 61.3 (CH₂), 50.4 (CH₂), 45.6 (CH₂), 22.8 (CH₂), 22.6 (CH₂), 13.9 (CH₃); ESI-HRMS m/z 326.1744 (MH⁺, C₂₀H₂₄NO₃ requires 326.1751)

1-((E)-2-acetylbuta-1,3-dienyl)-N-ethyl-1,4,5,6-tetrahydropyridine-2-carboxamide

A solution of N-ethyl-4-acetyl-1-(pent-4-enyl)-pyrrole-2-carboxamide (248 mg, 1 mmol) in MeCN (150 ml) was degassed before irradiating using a Vycor immersion well reactor and a 125 W Hg lamp for 3 hours. The product was isolated by flash chromatography (3% MeOH in EtOAc) to yield product (100 mg, 40%) as a yellow oil: δ_H (400 MHz, CDCl₃) 7.21 (1H, s, NCH=C), 6.45 (1H, dd, $J=17.7$ Hz, $J=11.2$ Hz, CCH=CH₂), 5.97 (1H, t, $J=3.9$ Hz, C=CHCH₂), 5.93 (1H, br. s, NHEt), 5.37 (1H, ddd, $J=11.2$ Hz, $J=2.0$ Hz, $J=0.7$ Hz, CCH=CHH), 5.21 (1H, dd, $J=17.7$ Hz, $J=2.0$ Hz, CCH=CHH), 3.56-3.52 (2H, m, NCH₂CH₂), 3.33 (2H, app. dq, $J=7.3$ Hz, $J=5.8$ Hz, NHCH₂CH₃), 2.25 (2H, td, $J=6.6$ Hz, $J=4.0$ Hz, CHCH₂CH₂), 2.22 (3H, s, COCH₃), 1.88-1.81 (2H, m, CH₂CH₂CH₂), 1.15 (3H, t, $J=7.3$ Hz, NHCH₂CH₃); δ_C (100 MHz, CDCl₃) 197.4 (C), 164.1 (C), 145.2 (CH), 138.2 (C), 130.3 (CH), 118.9 (CH₂), 117.5 (CH), 116.5 (C), 50.5 (CH₂), 34.5 (CH₂), 27.1 (CH₃), 22.7 (CH₂), 22.4 (CH₂), 14.6 (CH₃); CI-HRMS m/z 249.1612 (MH⁺, C₁₄H₂₁N₂O₂ requires 249.1603)

1-((1E,3E)-2-acetylpenta-1,3-dienyl)-N-ethyl-1,4,5,6-tetrahydropyridine-2-carboxamide

A solution of N-ethyl-4-acetyl-1-(hex-4-enyl)-pyrrole-2-carboxamide (262 mg, 1 mmol) in MeCN (150 ml) was degassed before irradiating using a Vycor immersion well reactor and a 125 W Hg lamp for 50 min. The minor product was isolated by flash chromatography (100% EtOAc) to yield **X** (50 mg, 19%) as an orange oil: δ_H (400 MHz, CDCl₃) 7.1 (1H, s, NCH=C), 5.99 (1H, dq, $J=15.9$ Hz, $J=1.7$ Hz, CCH=CHCH₃), 5.93 (2H, t, $J=4.0$ Hz, C=CHCH₂), 5.57 (1H, dq, $J=15.9$ Hz, $J=6.6$ Hz, CCH=CHCH₃), 3.45 - 3.49 (2H, m, NCH₂CH₂), 3.27 (2H, app. dq, $J=7.3$ Hz, $J=5.9$ Hz, NHCH₂CH₃), 2.20 (2H, td, $J=6.6$ Hz, $J=3.9$ Hz, CHCH₂CH₂), 2.14 (3H, s, COCH₃), 1.83 - 1.75 (2H, m, CH₂CH₂CH₂), 1.77 (3H, dd, $J=6.6$ Hz, $J=1.7$ Hz, CH=CHCH₃), 1.10 (3H, t, $J=7.3$ Hz, NHCH₂CH₃); δ_C (100 MHz, CDCl₃) 197.9 (C), 163.8 (C), 144.3 (CH), 138.3 (C), 130.7

(CH), 123.7 (CH), 117.4 (CH), 116.7 (C), 50.3 (CH₂), 34.4 (CH₂), 27.1 (CH₃), 22.7 (CH₂), 22.4 (CH₂), 18.6 (CH₃), 14.6 (CH₃); CI-HRMS m/z 263.1750 (MH⁺, C₁₅H₂₃N₂O₂ requires 263.1760)

1-((E)-2-acetylbuta-1,3-dienyl)-1,4,5,6-tetrahydropyridine-2-carbonitrile

A solution of 4-acetyl-1-(pent-4-enyl)-pyrrole-2-carbonitrile (202 mg, 1 mmol) in MeCN (150 ml) was degassed before irradiating using a Vycor immersion well reactor and a 125 W Hg lamp for 2 hours. The product was isolated by flash chromatography (30% EtOAc in n-hexane) to yield product (50 mg, 25%) as an orange oil: δ_H (400 MHz, CDCl₃) 7.59 (1H, s, NCH=C), 6.48 (1H, dd, $J=17.7$ Hz, $J=11.1$ Hz, CCH=CH₂), 5.89 (1H, t, $J=4.4$ Hz, C=CHCH₂), 5.41 (1H, dd, $J=11.2$ Hz, $J=2.0$ Hz, CCH=CHH), 5.16 (1H, dd, $J=17.8$ Hz, $J=2.0$ Hz, CCH=CHH), 3.56 - 3.52 (2H, m, NCH₂CH₂), 2.26 (3H, s, COCH₃), 2.25 (2H, td, $J=6.4$ Hz, $J=4.4$ Hz, CHCH₂CH₂), 1.88 - 1.81 (2H, m, CH₂CH₂CH₂); δ_C (100 MHz, CDCl₃) 197.0 (C), 141.5 (CH), 131.1 (CH), 122.9 (CH), 119.5 (CH₂), 118.1 (C), 116.7 (C), 114.3 (C), 48.5 (CH₂), 26.8 (CH₃), 22.4 (CH₂), 20.8 (CH₂); CI-HRMS m/z 203.1181 (MH⁺, C₁₂H₁₅N₂O requires 203.1184)

Ethyl 1,4,5,6-tetrahydro-1-(3-oxo-2-(prop-1-en-2-yl)cyclohex-1-enyl)pyridine-2-carboxylate

A solution of ethyl 4,5,6,7-tetrahydro-3-methyl-4-oxo-1-(pent-4-enyl)-indole-2-carboxylate (289 mg, 1.0 mmol) in MeCN (150 ml) was degassed before irradiating using a Vycor immersion well reactor and a 125 W Hg lamp for 40 minutes. The reaction mixture was evaporated to dryness and the product purified by flash chromatography (35% EtOAc in n-hexane) to yield **X** (198 mg, 69%) as a yellow oil: $\nu_{\max}$ (film)/cm⁻¹ 2940, 1769, 1716, 1628 and 1558; δ_H (400 MHz, CDCl₃) 6.31 (1H, t, $J=4.0$ Hz, C=CHCH₂), 5.24 - 5.22 (1H, m, C=CHH), 4.92 (1H, dd, $J=2.5$ Hz, $J=0.8$ Hz, C=CHH), 4.19 (2H, q, $J=7.1$ Hz, OCH₂CH₃), 3.36 (2H, br. t, COCH₂CH₂), 2.39 (2H, t, $J=6.6$ Hz, NCH₂CH₂), 2.35 (2H, t, $J=6.1$ Hz, CCH₂CH₂), 2.28 (2H, td, $J=6.6$ Hz, $J=4.0$ Hz, NCH₂CH₂), 1.90 (3H, m, CCH₃), 1.90-1.80 (4H, m, 2CH₂CH₂CH₂), 1.28 (3H, t, $J=7.2$ Hz, OCH₂CH₃); δ_C (100 MHz; CDCl₃) 196.9 (C), 164.2 (C), 162.3 (C), 140.0 (C), 134.2

(C), 125.1 (C), 122.5 (CH), 118.0 (CH₂), 61.2 (CH₂), 50.5 (CH₂), 37.9 (CH₂), 32.3 (CH₂), 23.4 (CH₂), 23.0 (CH₂), 22.4 (CH₃), 21.2 (CH₂), 14.1 (CH₃); CI-HRMS *m/z* 290.1745 (MH⁺, C₁₇H₂₄NO₃ requires 290.1756)

Ethyl 1-acetyl-5,6,6a,7,7a-pentahydro-4H-cyclobuta[hi]indolizine-4-carboxylate

A solution of ethyl 4-acetyl-1-(pent-4-enyl)-pyrrole-2-carboxylate (249 mg, 1 mmol) in MeCN (150 ml) was degassed before irradiating using a Vycor immersion well reactor and a 125 W Hg lamp for 1 hour 20 minutes. The minor product was isolated by flash chromatography (60% EtOAc in n-hexane) to yield the cycloadduct (50 mg, 25%): $\nu_{\max}$ (film)/cm⁻¹ 2936, 1725, 1613 and 1561; δ_{H} (400MHz, CDCl₃) 7.11 (1H, s, NCH=C), 4.18 (2H, m, OCH₂CH₃), 3.82 (1H, dd, *J*=8.1 Hz, *J*=6.4 Hz, NCH=CCH), 3.47 (1H, app. dt. *J*=13.6 Hz, *J*=3.3 Hz, NCHHCH₂), 3.23 – 3.12 (2H, m, NCHHCH₂, CH₂CHCH₂), 2.52 (1H, ddd, *J*=12.0 Hz, *J*=10.3 Hz, *J*=8.2 Hz, CHCHHCH), 2.21 (3H, s, COCH₃), 1.78 (1H, ddd, *J*=12.2 Hz, *J*=8.9 Hz, *J*=6.4 Hz, CHCHHCH), 1.76 – 1.55 (4H, m, NCH₂CH₂CH₂, CH₂CH₂CH), 1.28 (3H, t, *J*=7.1 Hz, OCH₂CH₃); δ_{C} (100MHz, CDCl₃) 190.6 (C), 171.2 (C), 154.0 (CH), 122.7 (C), 67.3 (C), 61.1 (CH₂), 45.8 (CH₂), 41.6 (CH), 36.2 (CH), 31.6 (CH₂), 25.6 (CH₃), 24.2 (CH₂), 22.1 (CH₂), 14.2 (CH₃); CI-HRMS *m/z* 250.1432 (MH⁺, C₁₄H₂₀NO₃ requires 250.1443)

1-Acetyl-N-ethyl-5,6,6a,7,7a-pentahydro-4H-cyclobuta[hi]indolizine-4-carboxamide

A solution of N-ethyl-4-acetyl-1-(pent-4-enyl)-pyrrole-2-carboxamide (248 mg, 1 mmol) in MeCN (150 ml) was degassed before irradiating using a Vycor immersion well reactor and a 125 W Hg lamp for 3 hours. The product was isolated by column chromatography (10% MeOH in EtOAc) to yield the cycloadduct (28 mg, 11%) as solid, the structure of which was confirmed by X-ray crystallography (see below): $\nu_{\max}$ (film)/cm⁻¹ 3317, 2934, 1647, 1608, 1565 and 1514; δ_{H} (400 MHz, CDCl₃) 7.10 (1H, s, NCH=C), 6.45 (1H, br. s, NH₂Et), 3.64 (1H, dd, *J*=7.8 Hz, *J*=6.8 Hz, NCH=CCH), 3.62 – 3.57 (1H, m, CH₂CHCH₂), 3.48 (1H, dm, *J*=13.7 Hz, NCHHCH₂), 3.33 – 3.24 (2H, m, NHCH₂CH₃), 2.89 – 2.82 (1H, m, NCHHCH₂), 2.55 – 2.47 (1H, m, CHCHHCH), 2.15 (3H, s, COCH₃), 1.78 – 1.52 (5H, m, CHCHHCH, NCH₂CH₂CH₂, CH₂CH₂CH), 1.13 (3H, t, *J*=7.3 Hz, NHCH₂CH₃); δ_{C} (100 MHz; CDCl₃) 191.5 (C), 170.3 (C), 153.0 (CH), 125.2

(C), 67.9 (C), 46.4 (CH₂), 43.2 (CH), 34.2 (CH₂), 33.2 (CH), 31.3 (CH₂), 26.1 (CH₃), 24.1 (CH₂), 21.5 (CH₂), 14.8 (CH₃); CI-HRMS m/z 249.1594 (MH⁺, C₁₄H₂₁N₂O₂ requires 249.1603)

1-Acetyl-N-ethyl-5,6,6a,7,7a-pentahydro-7-methyl-4H-cyclobuta[hi]indolizine-4-carboxamide

A solution of N-ethyl-4-acetyl-1-(hex-4-enyl)-pyrrole-2-carboxamide (262 mg, 1 mmol) in MeCN (150 ml) was degassed before irradiating using a Vycor immersion well reactor and a 125 W Hg lamp for 50 minutes. The major product was isolated by flash chromatography (30% EtOAc in n-hexane) to yield the cycloadduct (75 mg, 29%) as a solid: $\nu_{\max}$ (film)/cm⁻¹ 3318, 2932, 1650, 1615, 1569 and 1517; d_H (400 MHz, CDCl₃) 7.03 (1H, s, NCH=C), 6.47 (1H, br. s, NHEt), 3.43 (1H, dm, $J=13.4$ Hz, NCHHCH₂), 3.30 - 3.21 (2H, m, NHCH₂CH₃), 3.13 (1H, d, $J=5.6$ Hz, NCH=CCH), 3.07 - 3.02 (1H, m, CHCHMeCH), 2.82 (1H, ddd, $J=13.7$ Hz, $J=10.0$ Hz, $J=4.2$ Hz, NCHHCH₂), 2.12 (3H, s, COCH₃), 2.01 (1H, app. ddd, $J=8.1$, $J=6.8$, $J=5.9$ Hz, CHMeCHCH₂), 1.67 - 1.48 (4H, m, NCH₂CH₂CH₂, CH₂CH₂CH), 1.17 (3H, d, $J=6.8$ Hz, CHCH₃), 1.10 (3H, t, $J=7.2$ Hz, NHCH₂CH₃) d_C (100 MHz, CDCl₃) 191.7 (CO), 170.6 (CO), 152.6 (CH), 125.0 (C), 64.9 (C), 50.8 (CH), 46.5 (CH₂), 41.7 (CH), 40.3 (CH), 34.3 (CH₂), 26.2 (CH₃), 23.0 (CH₂), 21.9 (CH₂), 19.5 (CH₃), 14.8 (CH₃); CI-HRMS m/z 263.1756 (MH⁺, C₁₅H₂₃N₂O₂ requires 263.1760)

Ethyl 5,6,6a,7,7a-pentahydro-1-(2-phenylacetyl)-4H-cyclobuta[hi]indolizine-4-carboxylate

A solution of ethyl 4-(phenylacetyl)-1-(pent-4-enyl)-pyrrole-2-carboxylate (325 mg, 1 mmol) in MeCN (150 ml) was degassed before irradiating using a Vycor immersion well reactor and a 125 W Hg lamp for 40 minutes. The reaction mixture was purified by flash chromatography (30% EtOAc in n-hexane) to yield the cycloadduct (80 mg, 25%) as the major product: $\nu_{\max}$ (film)/cm⁻¹ 2935, 1725, 1612, 1598 and 1557; d_H (400 MHz, CDCl₃) 7.25 - 7.10 (6H, m, 5PhH, NCH=C), 4.18 - 4.05 (2H, m, OCH₂CH₃), 3.76 (1H, dd, $J=8.2$ Hz, $J=6.4$ Hz, NCH=CCH), 3.65 (2H, s, COCH₂Ph), 3.39 (1H, app. dt, $J=13.6$ Hz, $J=3.4$

Hz, NCH $\overline{H}$ HCH $\overline{2}$), 3.16 - 3.06 (2H, m, NCH $\overline{H}$ HCH $\overline{2}$, CH $\overline{2}$ CH $\overline{H}$ CH $\overline{2}$), 2.41 (1H, ddd, J =12.2 Hz, J =10.3 Hz, J =8.3 Hz, CHCH $\overline{H}$ HCH), 1.68 (1H, ddd, J =12.3 Hz, J =8.8 Hz, J =6.4 Hz, CHCH $\overline{H}$ HCH), 1.63 - 1.47 (4H, m, NCH $\overline{2}$ CH $\overline{2}$ CH $\overline{2}$, CH $\overline{2}$ CH $\overline{2}$ CH), 1.21 (3H, t, J =7.1 Hz, OCH $\overline{2}$ CH $\overline{3}$); δ_C (100 MHz, CDCl $\overline{3}$) 190.5 (CO), 171.2 (CO), 154.1 (CH), 136.5 (C), 129.0 (2CH), 128.4 (2CH), 126.3 (CH), 121.9 (C), 67.3 (CH $\overline{2}$), 61.2 (C), 45.9 (CH $\overline{2}$), 45.5 (CH $\overline{2}$), 41.8 (CH), 36.4 (CH), 31.7 (CH $\overline{2}$), 24.2 (CH $\overline{2}$), 22.3 (CH $\overline{2}$), 14.2 (CH $\overline{3}$); CI-HRMS m/z 326.1752 (MH $^+$, C $\overline{20}$ H $\overline{24}$ NO $\overline{3}$ requires 326.1756)

1-Acetyl-5,6,6a,7,7a-pentahydro-4H-cyclobuta[hi]indolizine-4-carbonitrile

A solution of 4-acetyl-1-(pent-4-enyl)-pyrrole-2-carbonitrile (202 mg, 1 mmol) in MeCN (150 ml) was degassed before irradiating using a Vycor immersion well reactor and a 125 W Hg lamp for 2 hours. The product was isolated by flash chromatography (70% EtOAc in n-hexane) to yield the cycloadduct (57 mg, 28%) as a yellow solid: $\nu_{\max}$ (film)/cm $^{-1}$ 3049, 2924, 2230, 1619 and 1579; δ_H (400 MHz, CDCl $\overline{3}$) 6.99 (1H, s, NCH=C), 3.93 (1H, dd, J =8.3 Hz, J =6.6 Hz, NCH=CCH), 3.45 (1H, dm, J =14.4 Hz, NCH $\overline{H}$ HCH $\overline{2}$), 3.25 - 3.16 (1H, m, CH $\overline{2}$ CH $\overline{H}$ CH $\overline{2}$), 3.10 - 3.02 (1H, m, NCH $\overline{H}$ HCH $\overline{2}$), 2.58 (1H, ddd, J =12.4 Hz, J =10.6 Hz, J =8.5 Hz, CHCH $\overline{H}$ HCH), 2.13 (3H, s, COCH $\overline{3}$), 1.84 (1H, ddd, J =12.5 Hz, J =9.0 Hz, J =6.6 Hz, CHCH $\overline{H}$ HCH), 1.79 - 1.62 (4H, m, NCH $\overline{2}$ CH $\overline{2}$ CH $\overline{2}$, CH $\overline{2}$ CH $\overline{2}$ CH); δ_C (100 MHz, CDCl $\overline{3}$) 190.6 (CO), 152.0 (CH), 123.6 (C), 117.7 (C), 56.0 (C), 45.1 (CH $\overline{2}$), 44.1 (CH), 38.1 (CH), 32.5 (CH $\overline{2}$), 25.7 (CH $\overline{3}$), 23.6 (CH $\overline{2}$), 21.4 (CH $\overline{2}$); CI-HRMS m/z 203.1179 (MH $^+$, C $\overline{12}$ H $\overline{15}$ N $\overline{2}$ O requires 203.1184)

Cyclohexenone Cyclobutane

A solution of ethyl 4,5,6,7-tetrahydro-3-methyl-4-oxo-1-(pent-4-enyl)-indole-2-carboxylate (289 mg, 1 mmol) in MeCN (150 ml) was degassed before irradiating using a Quartz immersion well reactor and a 6 W l.p. Hg lamp for 10 hours. The major product was isolated by flash chromatography (100% EtOAc) to yield the cycloadduct (124 mg, 43%) as a solid: $\nu_{\max}$ (film)/cm $^{-1}$ 2934, 1722, 1610 and 1563; δ_H (400 MHz, CDCl $\overline{3}$) 4.26 - 4.18 (2H, m, OCH $\overline{2}$ CH $\overline{3}$), 3.53 (1H, app. dt, J =14.1 Hz, J =4.5 Hz, NCH $\overline{H}$ HCH $\overline{2}$), 3.31 - 3.23 (1H, m, CH $\overline{2}$ CH $\overline{H}$ CH $\overline{2}$), 2.92 (1H, ddd, J =13.7 Hz, J =9.7 Hz, J =4.2 Hz, NCH $\overline{H}$ HCH $\overline{2}$),

2.44 - 2.34 (2H, m, COCH₂CH₂), 2.33 - 2.22 (2H, m, COCH₂CH₂CH₂C), 2.15 (1H, dd, $J=11.9$ Hz, $J=10.4$ Hz, CCH₂CH), 2.03 - 1.96 (2H, m, COCH₂CH₂CH₂), 1.93 (1H, dd, $J=12.0$ Hz, $J=8.6$ Hz, CCH₂CH), 1.74 - 1.58 (2H, m, NCH₂CH₂CH₂), 1.53 (3H, s, CCH₃), 1.57 - 1.42 (2H, m, CH₂CH₂CH), 1.29 (3H, t, $J=7.1$ Hz, OCH₂CH₃); d_C (100 MHz, CDCl₃) 191.1 (C), 170.4 (C), 169.9 (C), 119.8 (C), 71.4 (C), 61.0 (CH₂), 49.8 (C), 42.3 (CH₂), 38.2 (CH₂), 36.7 (CH₂), 32.1 (CH), 23.9 (CH₂), 23.1 (CH₂), 22.0 (CH₂), 22.0 (CH₂), 18.0 (CH₃), 14.3 (CH₃); CI-HRMS m/z 290.1742 (MH⁺, C₁₇H₂₄NO₃ requires 290.1756)

le7814H.3

le7821C.3

le8112H.1

le8112C.1

le0412H.2

le0412C.1

le2264H.3

le2264C.3

le6500H.3

le6500C.3

le1931H.3

le1967C.3

le1366H.1

le1366C.1

le8614H.3

le8628C.3

le4319H.3

le4319C.3

le7185H.3

le7216C.3

le8441H.3

le7337C.3

le1933H.3

le1933C.3

le7857H.3

le7482C.3

X-Ray Structure of Cycloadduct

For X-ray structure with full coordinates see accompanying .cif file.