Stereoselective Synthesis of 2-Dienyl-Substituted Piperidines using an η^4-Dienetricarbonyliron Complex as the Stereocontrolling Element in a Double Reductive Amination Cascade

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Experimental Section

All reactions were carried out with magnetic stirring using oven- or flame-dried glassware and under an anhydrous N_2 atmosphere, unless stated otherwise. Solvents were degassed where stated: small volumes (<10 mL) were degassed using the 'freeze and thaw' technique (-196 °C to 25 °C, 3 cycles); larger volumes (>10 mL) were degassed by vigorously stirring the solution and alternating between high vacuum (approx. 1 mbar) and purging with N_2 (five cycles), or by purging the solvent with N_2 whilst simultaneously subjecting the solvent to sonication (15 min) using a Clifton Ultrasonic Bath. Analytical TLC was carried out on Merck 60 Å F_{254}, or Whatman 60 Å 0.25 mm pre-coated glass-backed silica gel plates, and visualised using UV light (254/365 nm) and $KMnO_4$ solution or ammonium molybdate(IV)/cerium(IV) sulfate solution staining dip. Column chromatography was performed under gravity or with gentle pressure applied using hand bellows, using Fluka 60 or FluoroChem 60 silica gel (40-60 μm mesh) and laboratory grade solvents. Removal of volatiles was carried out at 40 °C under reduced pressure (50 - 600 mbar) and residual traces of solvent were removed at rt under high vacuum (approx. 1 mbar).

Weinreb amide **10**,[1] 4-(*tert*-butyldimethylsilanyloxy)-1-chlorobutane,[2] and THP ethers, **16a**[3] and **16b**,[3] were prepared according to literature procedures. All solvents were distilled under a N_2 atmosphere. THF and Et_2O were freshly distilled from sodium benzophenone ketyl. CH_2Cl_2 was freshly distilled from CaH_2. Benzene was distilled from CaH_2 and stored over 4 Å MS. DMSO was dried over $MgSO_4$ overnight and then distilled under reduced pressure and stored over 4 Å MS. Et_3N was distilled from KOH pellets and stored over 4 Å MS. All other chemicals were obtained from commercial sources and used

without further purification, unless stated otherwise. All solutions used in work-up procedures were aqueous and saturated, unless stated otherwise. Molecular sieves (MS) were activated by heating with a Bunsen burner under high vacuum (approx. 1 mbar) for 15 min and then allowed to cool to rt before using immediately. *Hazard:* In the synthesis of tricarbonyliron complexes, [$Fe_2(CO)_9$] was used as the $Fe(CO)_3$ source, and [$Fe(CO)_5$] is a by-product from the reaction. Both of these reagents are extremely toxic. All work involving the handling of these species was carried out in a well ventilated hood. All glassware was treated with bleach to destroy any iron carbonyl residues before re-use.

Elemental analyses were recorded on a Carlo Erba EA1110 simultaneous CHNS analyser. Melting points were determined using open glass capillaries on a Stuart Scientific SMP1 apparatus and are uncorrected. IR spectra were recorded either neat, as thin films, as a CH_2Cl_2 film or as a Nujol mull between NaCl plates on a Perkin Elmer 1600 series FTIR or a Perkin Elmer FTIR Paragon 1000 spectrometer. ^{1}H-NMR spectra were recorded at rt on a Bruker AC-300 (300 MHz), a Bruker AV-300 (300 MHz), a Bruker AMX-400 (400 MHz), or a Bruker DRX-500 (500 MHz) spectrometer. The term 'stack' is used to describe a region of the spectrum where resonances arising from non-equivalent nuclei overlap and the corresponding coupling constants associated with the overlapping resonances cannot be accurately determined. The term 'multiplet' or m, is used to describe a region of the spectrum where resonances arising from a single nucleus (or equivalent nuclei) overlap, but where coupling constants cannot be accurately determined. ^{13}C-NMR spectra were recorded at rt on a Bruker AC-300 (75 MHz), a Bruker AV-300 (75 MHz), a Bruker AMX-400 (100 MHz), or a Bruker DRX-500 (125 MHz) spectrometer. Note that the resonances corresponding to the $Fe(CO)_3$ group in ^{13}C-NMR spectra are often of very low intensity, and in most cases were not visible. Mass spectra were recorded on a Micromass LCT spectrometer utilising electrospray (ES) ionisation (and a MeOH mobile phase), or on a VG ProSpec mass spectrometer utilising electron impact (EI) ionisation, and are reported as (*m*/*z* (%)). HRMS were recorded on a Micromass LCT spectrometer using a lock mass incorporated into the mobile phase. Single crystal data for

compounds **(*E*)-7af** and **15** were recorded at rt by Dr Benson Kariuki, at the University of Birmingham, on a Bruker Smart 6000 diffractometer equipped with a CCD detector and a Cu tube source. Structures were solved and refined using SHELXL.[4] Non-hydrogen atoms were refined anisotropically and a riding model was used for C-H hydrogen atoms.

[(2*Z*, 1*S, 4*S**)-1-(*N*-Methylaminocarbonyl)-(1,2,3,4-η)-penta-2-en-1,4-diyl]tricarbonyliron 15.** Mg turnings (114 mg, 4.70 mmol) and 1,2-dibromoethane (12 μL, 0.14 mmol) were added to a stirred solution of 4-(*tert*-butyldimethylsilanyloxy)-1-chlorobutane (630 mg, 2.82 mmol) in THF (30 mL) at 75 °C. The reaction mixture was stirred at this temperature for 27 h, allowed to cool to rt, and subsequently added *via* cannula over 2 min to a stirred solution of Weinreb amide **10** (400 mg, 1.36 mmol) in THF (20 mL) at 0 °C. The reaction mixture was allowed to warm to rt and stirred for a further 36 h and then partitioned between NH_4Cl solution (30 mL) and Et_2O (30 mL). The aqueous phase was extracted with Et_2O (3 x 30 mL). The combined organic phases were washed with brine (50 mL) and dried ($MgSO_4$). Removal of the solvent under reduced pressure and purification of the residue by SiO_2 column chromatography (hexane/Et_2O, 1:1 gradient Et_2O) yielded, in order of elution, unreacted Weinreb amide **10** (219 mg, 55%), and then amide **15** (133 mg, 37%) as a yellow, crystalline solid; R_f (Et_2O) 0.26; υ_{max}(CH_2Cl_2 film)/cm^{-1} 3290s br (N-H), 3060m, 2946m, 2050s (CO), 1974s br (CO), 1633s (C=O), 1556s, 1498m, 1467m, 1445m, 1412s, 1381m, 1349s, 1309m, 1266m, 1233s, 1177m, 1160m; δ_H(300 MHz; $CDCl_3$ – D_2O shake) 0.80 (1H, d, *J* 7.7, C(1)*H*), 1.22-1.32 (1H, m, C(4)*H*), 1.43 (3H, d, *J* 5.9, C(5)H_3), 2.78 (3H, s, NCH_3), 5.18 (1H, dd, *J* 8.5, 5.2, C(3)*H*), 5.81 (1H, dd, *J* 7.7, 5.2, C(2)*H*); δ_C(75 MHz; $CDCl_3$) 19.0 (CH_3, *C*5), 26.5 (CH_3, N*C*H_3), [49.9, 58.3 (2 x CH, *C*1, *C*4)], [82.3, 87.4 (2 x CH, *C*2, *C*3)], 171.2 (C_{quat}, *C*=O); *m/z* (ES) 288.1 [$(M + Na)^+$, 100%], 260.1 (7, M - CO + Na) [Found $[M + Na]^+$ 287.9925. $C_{10}H_{11}FeNNaO_4$ requires *M* + Na, 287.9935].

(2*E*, 4*E*)-6-Hydroxy-10-tetrahydropyranyloxydeca-2,4-diene 17a. A refluxing suspension of Mg turnings (130 mg, 5.20 mmol) in THF (1.5 mL) was treated with a few drops of a solution of chloride **16a** (0.50 g, 2.60 mmol) in THF (4 mL). 1,2-Dibromoethane (5 drops) was added and the remaining solution of chloride **16a** in THF was added dropwise over 2 min. The reaction mixture was stirred at reflux for 1 h and then cooled to 0 °C before a solution of sorbaldehyde (140 μL, 1.30 mmol, ~95:5 mixture of (*E*, *E)*/(*Z*, *E*)-stereoisomers) in THF (5 mL) was added over 2 min. The reaction mixture was allowed to warm to rt and stirred for 16 h and then partitioned between NH_4Cl solution (20 mL) and Et_2O (20 mL). The aqueous phase was extracted with Et_2O (2 x 20 mL). The combined organic phases were washed with brine (20 mL) and dried ($MgSO_4$). Removal of the solvent under reduced pressure yielded an oily yellow residue which was purified by SiO_2 column chromatography (hexane/Et_2O, gradient 3:1 to 1:1) to yield alcohol **17a** as a pale yellow oil (320 mg, 98%, containing ~5% of the (*Z*, *E*)-diene); R_f (hexane/Et_2O, 1:1) 0.26; (Found: C, 70.77; H, 10.26. $C_{15}H_{26}O_3$ requires C, 70.83; H, 10.30%); υ_{max}(film)/cm^{-1} 3420s br (OH), 2940s, 2867s, 1453m, 1441m, 1353m, 1201m, 1138s, 1120s, 1077s, 1024s, 989s; δ_H(300 MHz; $CDCl_3$) 1.37-1.85 (15H, stack, including [1.74 (3H, d, *J* 6.3, C(1)*H*$_3$)], C(7)*H*$_2$, C(8)*H*$_2$, C(9)*H*$_2$, C(12)*H*$_2$, C(13)*H*$_2$, C(14)*H*$_2$, C(1)*H*$_3$), 3.32-3.42 (1H, stack, C(10)*H* or C(15)*H*), 3.44-3.52 (1H, stack, C(10)*H* or C(15)*H*), 3.68-3.77 (1H, stack, C(15)*H* or C(10)*H*), 3.80-3.90 (1H, stack, C(15)*H* or C(10)*H*), 4.11 (1H, apparent q, *J* 6.6, C(6)*H*), 4.52-4.59 (1H, stack, C(11)*H*), 5.54 (1H, dd, *J* 15.1, 7.0, =C*H*), 5.69 (1H, dd, *J* 14.7, 6.2, =C*H*), 5.94-6.08 (1H, m, =C*H*), 6.16 (1H, dd, *J* 14.7, 10.3, =C*H*), resonance for O*H* not observed; selected data for the (*Z*, *E*)-stereoisomer: 6.51 (1H, dd, *J* 15.4, 11.0, =C*H*); δ_C(75 MHz; $CDCl_3$) 17.7 (CH_3, *C*(1)H_3), [19.12, 19.14 (CH_2)], [21.79, 21.83 (CH_2)], 25.1 (CH_2), [29.22, 29.25 (CH_2)], 30.3 (CH_2), [36.76, 36.78 (CH_2)], [61.67, 61.69 (CH_2, *C*10 or *C*15)], [67.04, 67.05 (CH_2, *C*15 or *C*10), [71.91, 71.92 (CH, *C*6)], 98.3 (CH, *C*11), 128.8 (CH), 130.0 (CH), 130.7 (CH), [133.39, 133.40 (CH)]; selected data for the (*Z*, *E*)-stereoisomer: 13.0 (CH_3, *C*1), 21.85 (CH_2), [71.97, 71.99 (CH_2, *C*6)], 124.8 (CH), 125.8 (CH), 128.5 (CH), [135.71, 135.73 (CH)]; *m/z*

(ES) 277.3 [(M + Na)$^+$, 100%] [Found [M + Na]$^+$ 277.1786. $C_{15}H_{26}NaO_3$ requires *M* + Na, 277.1780].

(2*E*, 4*E*)-6-Oxo-10-tetrahydropyranyloxydeca-2,4-diene 18a. MnO_2 (4.80 g, 55 mmol) was added to a stirred solution of allylic alcohol **17a** (0.70 g, 2.75 mmol) in CH_2Cl_2 (30 mL). The mixture was stirred at rt for 15 h and then filtered through a plug of SiO_2, washing with Et_2O (100 mL). Concentration of the filtrate under reduced pressure yielded a yellow oil which was purified by SiO_2 column chromatography (hexane/Et_2O, 2:1) to yield dienone **18a** as a pale yellow oil (0.65 g, 94%); R_f (hexane/Et_2O, 1:1) 0.34; υ_{max}(film)/cm^{-1} 2941s, 2870s, 1687s (C=O), 1663 (C=O), 1640s (C=C), 1596s (C=C), 1442m, 1352m, 1323m, 1200m, 1137s, 1120s; δ_H(300 MHz; $CDCl_3$) 1.43-1.89 (13H, stack, including [1.83 (3H, d, *J* 4.8, C(1)*H*$_3$)], C(8)*H*$_2$, C(9)*H*$_2$, C(12)*H*$_2$, C(13)*H*$_2$, C(14)*H*$_2$, C(1)*H*$_3$), 2.55 (2H, t, *J* 7.2, C(7)*H*$_2$), 3.32-3.41 (1H, stack, C(10)*H* or C(15)*H*), 3.42-3.51 (1H, stack, C(10)*H* or C(15)*H*), 3.68-3.77 (1H, stack, C(15)*H* or C(10)*H*), 3.78-3.87 (1H, stack, C(15)*H* or C(10)*H*), 4.51-4.57 (1H, m, C(11)*H*), 6.03 (1H, d, *J* 15.5, =C*H*), 6.09-6.23 (2H, stack, 2 x =C*H*), 7.02-7.16 (1H, stack, =C*H*); selected data for the (*Z*, *E*)-stereoisomer: 7.49 (1H, dd, *J* 15.4, 11.0, =C*H*); δ_C(75 MHz; $CDCl_3$) 18.5 (CH_3, *C*1), 19.4 (CH_2), 21.0 (CH_2), 25.3 (CH_2), 29.1 (CH_2), 30.5 (CH_2), 39.9 (CH_2, *C*7), [62.0, 66.9 (2 x CH_2, *C*10, *C*15)], 98.5 (CH, *C*11), 127.4 (CH, =*C*H), 130.1 (CH, =*C*H), 139.8 (CH, =*C*H), 142.4 (CH, =*C*H), 200.3 (C_{quat}, *C*=O); selected data for the (*Z*, *E*)-stereoisomer: 13.9 (CH_3, *C*1), 20.9 (CH_2), 40.4 (CH_2, *C*7), 66.7 (CH_2, *C*10 or *C*15), 98.6 (CH, *C*11), 127.6 (CH, =*C*H), 129.1 (CH, =*C*H), 136.3 (CH, =*C*H); *m/z* (ES) 275.2 [(M + Na)$^+$, 100%] [Found [M + Na]$^+$ 275.1619. $C_{15}H_{24}NaO_3$ requires *M* + Na, 275.1623].

[(3*Z*, 2*S, 5*S**)-6-Oxo-10-tetrahydropyranyloxy-(2,3,4,5-η)-dec-3-en-2,5-diyl]tricarbonyliron 19a.** A solution of dienone **18a** (0.66 g, 2.62 mmol) in degassed Et_2O (5 mL) was added to a stirred suspension of [$Fe_2(CO)_9$] (1.90 g, 5.23 mmol) in degassed Et_2O (25 mL). The mixture was heated at 40 °C for 42 h in the absence of light and then filtered through a short plug of SiO_2. The filtrate was concentrated under reduced pressure to give a dark brown

residue which was purified by SiO_2 column chromatography (hexane/Et_2O, gradient 8:1 to 4:1 to 2:1) to yield iron complex **19a** as an orange oil (0.71 g, 69%); R_f (hexane/Et_2O, 1:1) 0.31; (Found: C, 55.37; H, 6.16. $C_{18}H_{24}FeO_6$ requires C, 55.12; H, 6.17%); υ_{max}(film)/cm^{-1} 2944s, 2870m, 2051s (CO), 1980s br (CO), 1676s (C=O), 1460m, 1441m, 1352m, 1201m, 1174m, 1137s, 1120s, 1033s; δ_H(300 MHz; $CDCl_3$) 1.21 (1H, d, *J* 8.1, C(5)*H*), 1.38-1.87 (14H, stack, C(1)H_3, C(2)*H*, C(8)H_2, C(9)H_2, C(12)H_2, C(13)H_2, C(14)H_2), 2.30-2.47 (2H, m, C(7)H_2), 3.32-3.42 (1H, m, C(10)*H* or C(15)*H*), 3.43-3.53 (1H, m, C(15)*H* or C(10)*H*), 3.68-3.78 (1H, m, C(10)*H* or C(15)*H*), 3.79-3.89 (1H, m, C(15)*H* or C(10)*H*), 4.49-4.59 (1H, m, C(11)*H*), 5.22 (1H, dd, *J* 8.1, 5.2, C(3)*H*), 5.77 (1H, dd, *J* 8.1, 5.2, C(4)*H*); δ_C(100 MHz; $CDCl_3$) 18.7 (CH_3, *C*1), [19.1, 21.0, 25.1, 28.9, 30.3 (5 x CH_2, *C*8, *C*9, *C*12, *C*13, *C*14), [42.01, 42.04 (2 x CH_2, *C*7)], [53.3, 59.0 (2 x CH, *C*2, *C*5)], [62.0, 66.90, 66.92 (2 x CH_2, *C*15, *C*10)], [81.3, 88.6 (2 x CH, *C*3, *C*4), 98.8 (CH, *C*11), 206.0 (C_{quat}, *C*=O); *m/z* (ES) 415.2 [$(M + Na)^+$, 100%], 387.2 (12, M + Na – CO), 359.2 (31, M + Na – 2CO) [Found $[M + Na]^+$ 415.0809. $C_{18}H_{24}FeNaO_6$ requires *M* + Na, 415.0820].

[(3*Z*, 2*S, 5*S**)-10-Hydroxy-6-oxo-(2,3,4,5-η)-dec-3-en-2,5-diyl]tricarbonyliron.** *p*PTS (133 mg, 0.53 mmol) was added to a solution of THP-ether **19a** (516 mg, 1.32 mmol) in EtOH (20 mL) at 40 °C. The reaction mixture was heated at 50 °C for 16 h, and then cooled to rt before being partitioned between EtOAc (50 mL) and H_2O (50 mL). The aqueous phase was extracted with EtOAc (2 x 50 mL) and the combined organic phases were washed with brine (100 mL) and dried ($MgSO_4$). Concentration under reduced pressure yielded a yellow residue which was purified by SiO_2 column chromatography (hexane/Et_2O, 1:1) to provide the corresponding keto-alcohol as an orange oil (350 mg, 86%); R_f (Et_2O) 0.28; υ_{max}(film)/cm^{-1} 3419s br (OH), 2942s, 2870m, 2052s (CO), 1980s br (CO), 1671s (C=O), 1460s, 1440s, 1380m, 1174m, 1062m, 1032s; δ_H(300 MHz; $CDCl_3$) 1.20 (1H, d, *J* 8.1, C(5)*H*), 1.42-1.69 (8H, stack, including [1.46 (3H, d, *J* 5.9, C(1)H_3)], C(2)*H*, C(8)H_2, C(9)H_2, C(1)H_3), 1.85 (1H, s, O*H*), 2.34-2.46 (2H, m, C(7)H_2), 3.61 (2H, t, *J* 6.1, C(10)H_2), 5.23 (1H, dd, *J* 8.5, 5.2, C(3)*H*), 5.77 (1H, dd, *J* 8.1,

5.2, C(4)*H*); δ_C(100 MHz; $CDCl_3$) 18.8 (CH_3, *C*1), 20.0 (CH_2, *C*8), 31.9 (CH_2, *C*9), 41.8 (CH_2, *C*7), [53.2, 59.2 (2 x CH, *C*2, *C*5)], 62.1 (CH_2, *C*10), [81.3, 88.7 (2 x CH, C3, C4)], 206.4 (C_{quat}, *C*=O); *m/z* (ES) 331.0 [$(M + Na)^+$, 100%], 303.0 (28, M + Na - CO), 275.0 (84, M + Na - 2CO) [Found $[M + Na]^+$ 331.0246. $C_{13}H_{16}FeNaO_5$ requires *M* + Na, 331.0245].

[(3*Z*, 2*S, 5*S**)-6,10-Dioxo-(2,3,4,5-η)-dec-3-en-2,5-diyl]tricarbonyliron 8a.** A solution of DMSO (1.15 mL, 16.20 mmol) in CH_2Cl_2 (20 mL) was added *via* cannula over 5 min to a cold (-78 °C) solution of $(COCl)_2$ (0.71 mL, 8.11 mmol) in CH_2Cl_2 (20 mL). The reaction mixture was stirred at -78 °C for 1 h before a solution of [(3*Z*, 2*S**, 5*S**)-10-hydroxy-6-oxo-(2,3,4,5-η)-dec-3-en-2,5-diyl]tricarbonyliron (1.04 g, 3.38 mmol) in CH_2Cl_2 (20 mL) was added. The reaction mixture was stirred for 1 h at -78 °C, and then Et_3N (4.71 mL, 33.80 mmol) was added dropwise over 5 min. After 1 h, H_2O (75 mL) was added at -78 °C and the reaction mixture then allowed to warm to rt. The two phases were separated, the aqueous phase was extracted with CH_2Cl_2 (3 x 50 mL), and the combined organic phases were dried ($MgSO_4$) and then concentrated under reduced pressure. Purification of the residue by SiO_2 column chromatography (hexane/Et_2O, 3:2) provided keto-aldehyde **8a** as an orange oil (0.80 g, 77%); R_f (Et_2O) 0.52; υ_{max}(film)/cm^{-1} 2950m, 2724w, 2050s (CO), 1977s br (CO), 1723s (C=O), 1674s (C=O), 1494m, 1461m, 1441m, 1380m, 1174m, 1109m, 1033m; δ_H(300 MHz; $CDCl_3$) 1.19 (1H, d, *J* 8.1, C(5)*H*), 1.43-1.59 (4H, stack, C(1)H_3, C(2)*H*), 1.82-1.96 (2H, m, C(8)H_2), 2.35-2.52 (4H, stack, C(7)H_2, C(9)H_2), 5.24 (1H, dd, *J* 8.5, 5.2, C(3)*H*), 5.78 (1H, dd, *J* 8.1, 5.2, C(4)*H*), 9.75 (1H, s, C*H*O); δ_C(75 MHz; $CDCl_3$) 16.7 (CH_2, *C*8), 19.1 (CH_3, *C*1), [41.0, 42.9 (2 x CH_2, *C*7, *C*9)], [53.3, 59.5 (2 x CH, *C*2, *C*5)], [81.1, 88.7 (2 x CH, *C*3, *C*4)], 201.7 (CH, *C*HO), 204.4 (C_{quat}, *C*=O); *m/z* (ES) 329.1 [$(M + Na)^+$, 50%], 301.1 (9, M + Na – CO), 277.1 (49), 273.1 (13, M + Na – 2CO), 245.1 (100, M + Na – 3CO) [Found $[M + Na]^+$ 329.0094. $C_{13}H_{14}FeNaO_5$ requires *M* + Na, 329.0088].

(2*E*, 4*E*)-6-Hydroxy-11-tetrahydropyranyloxyundeca-2,4-diene 17b. A refluxing suspension of Mg turnings (0.47 g, 19.40 mmol) in THF (5 mL) was treated with a few drops of a solution of chloride **16b** (2.00 g, 9.68 mmol) in THF (15 mL). 1,2-Dibromoethane (5 drops) was added and the remaining solution of chloride **16b** in THF was added dropwise over 2 min. The reaction mixture was stirred at reflux for 1 h and then cooled to 0 °C before a solution of sorbaldehyde (0.96 mL, 8.71 mmol, ~95:5 mixture of (*E*, *E)*/(*Z*, *E*)-stereoisomers) in THF (20 mL) was added over 2 min. The reaction mixture was warmed to rt. After 16 h, the reaction mixture was partitioned between NH_4Cl solution (40 mL) and Et_2O (40 mL), and the aqueous phase extracted with Et_2O (2 x 40 mL). The combined organic phases were washed with brine (100 mL) and dried ($MgSO_4$). Removal of the solvent under reduced pressure yielded an oily yellow residue which was purified by SiO_2 column chromatography (hexane/Et_2O, gradient 3:1 to 1:1) to afford alcohol **17b** as a pale yellow oil (2.11 g, 90%, containing ~5% of the (*Z*, *E)*-diene); R_f (hexane/Et_2O, 1:1) 0.29; (Found: C, 71.73; H, 10.65. $C_{16}H_{28}O_3$ requires C, 71.60; H, 10.52%); υ_{max}(film)/cm^{-1} 3422s br (OH), 2938s, 2859s, 1453m, 1441m, 1353m, 1201m, 1138s, 1120s, 1077s, 1024s, 988s; δ_H(300 MHz; $CDCl_3$) 1.28-1.85 (17H, stack, including [1.75 (3H, d, *J* 6.3, C(1)H_3)], C(7)H_2, C(8)H_2, C(9)H_2, C(10)H_2, C(13)H_2, C(14)H_2, C(15)H_2, C(1)H_3), 3.32-3.42 (1H, m, C(11)H_a or C(16)H_a), 3.44-3.53 (1H, m, C(16)H_a or C(11)H_a), 3.67-3.77 (1H, m, C(11)H_b or C(16)H_b), 3.80-3.91 (1H, m, C(16)H_b or C(11)H_b), 4.09 (1H, apparent q, *J* 6.6, C(6)*H*), 4.51-4.59 (1H, m, C(12)*H*), 5.54 (1H, dd, *J* 14.7, 7.0, =C*H*), 5.61-5.77 (1H, m, =C*H*), 5.95-6.21 (2H, stack, 2 x =C*H*), resonance for O*H* not observed; selected data for the (*Z*, *E*)-stereoisomer: 6.50 (1H, dd, *J* 15.1, 11.0, =C*H*); δ_C(75 MHz; $CDCl_3$) 17.7 (CH_3, *C*1), [19.17, 19.19, 24.95, 24.98, 25.2, 25.89, 25.93, 29.33, 29.34, 30.4 (6 x CH_2, *C*8, *C*9, *C*10, *C*13, *C*14, *C*15)], 37.0 (CH_2, *C*7), [61.69, 61.72, 67.12, 67.15 (2 x CH_2, *C*11, *C*16)], [72.02, 72.04 (CH, *C*6)], [98.27, 98.28 (CH, *C*12)], [128.9, 130.1, 130.7, 133.5 (4 x CH, =*C*H)], selected data for the (*Z*, *E*)-stereoisomer: 13.0 (CH_3, *C*1), [72.07, 72.09 (CH_2, *C*6)], [124.8, 125.9, 128.6, 135.8 (4 x CH, =*C*H)]; *m/z* (ES) 291.1 [$(M + Na)^+$, 100%] [Found $[M + Na]^+$ 291.1941. $C_{16}H_{28}NaO_3$ requires *M* + Na, 291.1936].

(2*E*, 4*E*)-6-Oxo-11-tetrahydropyranyloxyundeca-2,4-diene 18b. MnO_2 (3.24 g, 37.20 mmol) was added to a stirred solution of alcohol **17b** (0.50 g, 1.86 mmol) in CH_2Cl_2 (25 mL). The mixture was stirred at rt for 15 h and then filtered through a plug of SiO_2, washing with Et_2O (100 mL). Concentration under reduced pressure yielded a yellow oil, which was purified by SiO_2 column chromatography (hexane/Et_2O, 2:1) to provide dienone **18b** as a pale yellow oil (0.45 g, 91%); R_f (hexane/Et_2O, 1:1) 0.38; (Found: C, 72.29; H, 10.06. $C_{16}H_{26}O_3$ requires C, 72.14; H, 9.84%); υ_{max}(film)/cm^{-1} 2941s, 2870m, 1688m (C=O), 1662s (C=C), 1640s (C=C), 1596s, 1442m, 1352m, 1200m, 1137m, 1120m, 1034s; δ_H(300 MHz; $CDCl_3$) 1.31-1.92 (15H, stack, including [1.89 (3H, d, *J* 4.8, C(1)*H*$_3$)], C(8)*H*$_2$, C(9)*H*$_2$, C(10)*H*$_2$, C(13)*H*$_2$, C(14)*H*$_2$, C(15)*H*$_2$, C(1)*H*$_3$), 2.54 (2H, t, *J* 7.5, C(7)*H*$_2$), 3.31-3.42 (1H, m, C(11)*H*$_a$ or C(16)*H*$_a$), 3.43-3.54 (1H, m, C(16)*H*$_a$ or C(11)*H*$_a$), 3.66-3.77 (1H, m, C(11)*H*$_b$ or C(16)*H*$_b$), 3.79-3.91 (1H, m, C(16)*H*$_b$ or C(11)*H*$_b$), 4.49-4.59 (1H, m, C(12)*H*), 6.05 (1H, d, *J* 15.1, =C*H*), 6.10-6.25 (2H, stack, 2 x =C*H*), 7.04-7.18 (1H, m, =C*H*); selected data for the (*Z*, *E*)-stereoisomer: 7.50 (1H, dd, *J* 14.7, 11.0, =C*H*); δ_C(75 MHz; $CDCl_3$) 18.4 (CH_3, *C*1), [19.3, 23.8, 25.2, 25.7, 29.2, 30.4 (6 x CH_2, *C*8, *C*9, *C*10, *C*13, *C*14, *C*15)], 40.0 (CH_2, *C*7), [61.9, 67.0 (2 x CH_2, *C*11, *C*16)], 98.4 (CH, *C*12), [127.3, 130.0, 139.6, 142.3 (4 x CH, =*C*H), 200.2 (C_{quat}, *C*=O), selected data for the (*Z*, *E*)-stereoisomer: 13.8 (CH_3, *C*1), 40.5 (CH_2, *C*7), [127.6, 129.0, 136.1, 136.2 (4 x CH_2, =*C*H)]; *m/z* (ES) 289.1 [(M + Na)$^+$, 100%] [Found [M + Na]$^+$ 289.1777. $C_{16}H_{26}NaO_3$ requires *M* + Na, 289.1780].

[(3*Z*, 2*S, 5*S**)-6-Oxo-11-tetrahydropyranyloxy-(2,3,4,5-η)-undec-3-en-2,5-diyl]tricarbonyliron 19b.** A solution of dienone **18b** (0.60 g, 2.25 mmol) in degassed Et_2O (10 mL) was added to a stirred suspension of [$Fe_2(CO)_9$] (2.05 g, 5.63 mmol) in degassed Et_2O (30 mL). The mixture was heated at 40 °C for 42 h in the absence of light and then filtered through a short plug of SiO_2. Concentration of the filtrate under reduced pressure gave a dark brown residue, which was purified by SiO_2 column chromatography (hexane/Et_2O, gradient 8:1 to 4:1 to 2:1), to yield iron complex **19b** as an orange oil (0.59 g, 64%); R_f (hexane/Et_2O, 1:1) 0.34; υ_{max}(film)/cm^{-1} 2943s, 2866m, 2051s (CO),

1976s br (CO), 1675s (C=O), 1461m, 1441m, 1353m, 1201m, 1174m, 1137s, 1120s, 1077s, 1034s; δ_H(300 MHz; $CDCl_3$) 1.21 (1H, d, *J* 8.1, C(5)*H*), 1.31-1.85 (16H, stack, including [1.46 (3H, d, *J* 5.5, C(1)H_3)], C(2)*H*, C(8)H_2, C(9)H_2, C(10)H_2, C(13)H_2, C(14)H_2, C(15)H_2, C(1)H_3), 2.30-2.42 (2H, m, C(7)H_2), 3.31-3.42 (1H, m, C(11)H_a or C(16)H_a), 3.43-3.54 (1H, m, C(16)H_a or C(11)H_a), 3.67-3.77 (1H, m, C(11)H_b or C(16)H_b), 3.80-3.90 (1H, m, C(16)H_b or C(11)H_b), 4.52-4.59 (1H, m, C(12)*H*), 5.23 (1H, dd, *J* 8.1, 5.2, C(3)*H*), 5.77 (1H, dd, *J* 8.1, 5.2, C(4)*H*); δ_C(75 MHz; $CDCl_3$) 18.9 (CH_3, *C*1), [19.4, 24.3, 25.3, 25.7, 29.3, 30.5 (6 x CH_2, *C*8, *C*9, *C*10, *C*13, *C*14, *C*15)], 42.4 (CH_2, *C*7), [53.3, 59.1 (2 x CH, *C*2, *C*5)], [62.02, 62.03, 67.1 (CH_2, *C*16, *C*11)], [81.1, 88.4 (2 x CH, *C*3, *C*4)], 98.6 (CH, *C*12), 205.1 (C_{quat}, *C*=O); *m/z* (ES) 429.1 [$(M + Na)^+$, 100%] [Found $[M + Na]^+$ 429.0970. $C_{19}H_{26}FeNaO_6$ requires *M* + Na, 429.0976].

[(3*Z*, 2*S, 5*S**)-11-Hydroxy-6-oxo-(2,3,4,5-η)-undec-3-en-2,5-diyl]tricarbonyliron.** *p*PTS (60 mg, 0.22 mmol) was added to a solution of THP-ether **19b** (300 mg, 0.74 mmol) in absolute EtOH (10 mL) at 40 °C. The reaction mixture was warmed to 50 °C. After 16 h at this temperature, the reaction mixture was cooled to rt before being partitioned between EtOAc (40 mL) and H_2O (40 mL). The aqueous phase was extracted with EtOAc (2 x 50 mL) and the combined organic phases were washed with brine (50 mL) and dried ($MgSO_4$). Concentration under reduced pressure yielded a yellow residue, which was purified by SiO_2 column chromatography (hexane/Et_2O, 1:1), to provide [(3*Z*, 2*S**, 5*S**)-11-hydroxy-6-oxo-(2,3,4,5-η)-undec-3-en-2,5-diyl]tricarbonyliron as a yellow oil (0.22 g, 93%); R_f (Et_2O) 0.30; υ_{max}(film)/cm^{-1} 3406s br (OH), 2938s, 2862m, 2050s (CO), 1980s br (CO), 1668s (C=O), 1494m, 1461s, 1440s, 1380m, 1339m, 1299m, 1174m, 1073m, 1052m; δ_H(300 MHz; $CDCl_3$) 1.21 (1H, d, *J* 8.1, C(5)*H*), 1.28-1.67 (10H, stack, C(1)H_3, C(2)*H*, C(8)H_2, C(9)H_2, C(10)H_2), 2.29-2.47 (2H, m, C(7)H_2), 3.57-3.73 (2H, m, C(11)H_2), 5.17-5.30 (1H, m, C(3)*H*), 5.72-5.84 (1H, m, C(4)*H*), resonance for O*H* not observed; δ_C(75 MHz; $CDCl_3$) 18.9 (CH_3, *C*1), [24.1, 25.2, 32.2 (3 x CH_2, *C*8, *C*9, *C*10)], 42.3 (CH_2, *C*7), [53.3, 59.2 (2 x CH, *C*2, *C*5)], 62.1 (CH_2, *C*11), [81.1, 88.5 (2 x CH, *C*3, *C*4)], 205.7 (C_{quat}, *C*=O); *m/z* (ES) 345.0 [(M +

Na)$^+$, 100%] [Found [M + Na]$^+$ 345.0413. $C_{14}H_{18}FeNaO_5$ requires *M* + Na, 345.0401].

[(3*Z*, 2*S, 5*S**)-6,11-Dioxo-(2,3,4,5-η)-undec-3-en-2,5-diyl]tricarbonyliron 8b.** A solution of DMSO (210 μL, 2.98 mmol) in CH_2Cl_2 (3 mL) was added *via* cannula over 5 min to a cold (-78 °C) solution of $(COCl)_2$ (13 μL, 1.49 mmol) in CH_2Cl_2 (4 mL). The reaction mixture was stirred at -78 °C for 1 h before a solution of [(3*Z*, 2*S**, 5*S**)-11-hydroxy-6-oxo-(2,3,4,5-η)-undec-3-en-2,5-diyl]tricarbonyliron (200 mg, 0.62 mmol) in CH_2Cl_2 (3 mL) was added. The reaction mixture was stirred for 1 h at -78 °C, and then Et_3N (87 μL, 6.21 mmol) was added dropwise over 5 min. After 1 h, H_2O (10 mL) was added at -78 °C and the reaction mixture then allowed to warm to rt. The two phases were separated, and the aqueous phase was extracted with CH_2Cl_2 (3 x 10 mL). The combined organic phases were dried ($MgSO_4$) and then concentrated under reduced pressure. Purification of the residue by SiO_2 column chromatography (hexane/Et_2O, 3:2) provided keto-aldehyde **8b** as an orange oil (170 mg, 86%); R_f (Et_2O) 0.56; (Found: C, 52.36; H, 4.79. $C_{14}H_{16}FeO_5$ requires C, 52.53; H, 5.04%); υ_{max}(film)/cm^{-1} 2947m, 2863m, 2724m, 2051s (CO), 1980s br (CO), 1724s (C=O), 1673s (C=O), 1494m, 1461s, 1441s, 1380m, 1364m, 1174s, 1111m, 1033m; δ_H(300 MHz; $CDCl_3$) 1.20 (1H, d, *J* 7.9, C(5)*H*), 1.41-1.68 (8H, stack, including [1.47 (3H, d, *J* 5.9, C(1)H_3)], C(2)*H*, C(8)H_2, C(9)H_2, C(1)H_3), 2.33-2.50 (4H, stack, C(7)H_2, C(10)H_2), 5.24 (1H, dd, *J* 8.1, 5.2, C(3)*H*), 5.78 (1H, dd, *J* 7.9, 5.2, C(4)*H*), 9.76 (1H, s, C*H*O); δ_C(75 MHz; $CDCl_3$) 19.0 (CH_3, *C*1), [21.4, 23.7 (2 x CH_2, *C*8, *C*9)], [41.9, 43.4 (2 x CH_2, *C*7, *C*10)], [53.2, 59.3 (2 x CH, *C*2, *C*5)], [81.1, 88.6 (2 x CH, *C*3, *C*4)], 202.0 (CH, *C*=O), 204.7 (C_{quat}, *C*=O); *m/z* (ES) 359.1 [(M + K)$^+$, 14%], 343.1 (100, M + Na) [Found [M + Na]$^+$ 343.0238. $C_{14}H_{16}FeNaO_5$ requires *M* + Na, 343.0245].

[(2*Z*, 1*S, 4*S**, 2'*R**)-1-[(*N*-Benzyl)piperidin-2'-yl]-(1,2,3,4-η)-penta-2-en-1,4-diyl]tricarbonyliron 7aa.** A solution of keto-aldehyde **8a** (57 mg, 0.186 mmol) in THF (1 mL) was added to a stirred suspension of $BnNH_2$ (24 μL, 0.223 mmol) and $NaBH(OAc)_3$ (158 mg, 0.744 mmol) in THF (2 mL). The

reaction mixture was stirred at rt for 12 h, and then partitioned between Et_2O (5 mL) and $NaHCO_3$ solution (5 mL). The aqueous phase was extracted with Et_2O (3 x 5 mL), and the combined organic phases were washed with brine (10 mL), dried ($MgSO_4$) and the solvent removed under reduced pressure. Purification of the residue by SiO_2 column chromatography (hexane/Et_2O, 6:1 plus 1% Et_3N) yielded piperidine **7aa** as a yellow oil (60 mg, 85%); R_f (hexane/Et_2O, 4:1) 0.44; (Found: C, 63.23; H, 5.93; N, 3.79. $C_{20}H_{23}FeNO_3$ requires C, 63.01; H, 6.08; N, 3.67%); υ_{max}(film)/cm^{-1} 3027w, 2934s, 2856m, 2788m, 2039s (CO), 1962s br (CO), 1494w, 1442m, 1380w, 1366w, 1029w; δ_H(300 MHz; $CDCl_3$) 1.05-1.17 (1H, m, C(1)*H*), 1.31-1.55 (6H, stack, including [1.40 (3H, d, *J* 6.3, C(5)H_3], C(4)*H*, CH_2CH$_2$CHN, C(5)H_3), 1.58-1.78 (3H, stack, CH_aH$_b$CHN, CH_2CH$_2$N), 1.83-2.08 (3H, stack, CH$_a$$H_b$C*H*N, C$H_aH_b$N), 2.60-2.74 (1H, m, CH$_a$$H_b$N), 3.06-3.21 (1H, m, C$H_aH_b$Ph), 4.20-4.37 (1H, m, CH$_a$$H_b$Ph), 4.98 (1H, dd, *J* 8.5, 4.8, C(2)*H* or C(3)*H*), 5.03-5.13 (1H, m, C(3)*H* or C(2)*H*), 7.17-7.39 (5H, stack, Ph*H*); δ_C(100 MHz; $CDCl_3$) 18.8 (CH_3, *C*5), 23.3 (CH_2, *C*H$_2$CH$_2$CHN), 25.2 (CH_2, *C*H$_2$CH$_2$N), 35.6 (CH_2, *C*H$_2$CHN), 50.7 (CH_2, *C*H$_2$N), 58.0 (CH, *C*4), 58.8 (CH_2, *C*H$_2$Ph), 65.2 (2 x CH, *C*1, *C*HN, overlapping resonances), 84.2 (CH, *C*3), 84.5 (CH, *C*2), 127.0 (CH, *p*-Ph), 128.5 (CH, *m*-Ph), 129.0 (CH, *o*-Ph), (C_{quat}, *ipso*-Ph) not observed; *m/z* (ES) 382.0 [$(M + H)^+$, 98%], 298.0 (100, M + H - 3CO) [Found $[M + H]^+$ 382.1116. $C_{20}H_{24}FeNO_3$ requires *M* + H, 382.1106].

[(2*Z*, 1*S, 4*S**, 2'*R**)-1-[*N*-(*para*-Methoxybenzyl)piperidin-2'-yl]-(1,2,3,4-η)-penta-2-en-1,4-diyl]tricarbonyliron 7ab.** Keto-aldehyde **8a** (57 mg, 0.186 mmol), *p*-methoxybenzylamine (29 μL, 0.223 mmol) and $NaBH(OAc)_3$ (158 mg, 0.744 mmol) were reacted as detailed for **7aa**. After 12 h, work up and purification by SiO_2 column chromatography (hexane/Et_2O, 4:1 plus 1% Et_3N) afforded piperidine **7ab** as a yellow oil (63 mg, 82%); R_f (hexane/Et_2O, 4:1) 0.24; (Found: C, 61.16; H, 6.29; N, 3.55. $C_{21}H_{25}FeNO_4$ requires C, 61.33; H, 6.13; N, 3.41%); ν_{max}(film)/cm^{-1} 2998w, 2934s, 2856m, 2835m, 2786m, 2714w, 2038s (CO), 1962s br (CO), 1612m, 1585w, 1511s, 1464m, 1442m, 1300m, 1248s, 1180m, 1171m, 1037s; δ_H(300 MHz; $CDCl_3$) 1.10 (1H, app t, *J* 9.0, C(1)*H*), 1.18-1.27 (1H, m, C(4)*H*), 1.29-1.50 (6H, stack, including [1.41

(3H, d, *J* 6.3, C(5)H_3)] CH_2CH_aH$_b$CH$_2$N, C(5)H_3), 1.57-1.75 (2H, stack, CH$_a$$H_bCH_2N, CH_aH_b$CHN), 1.83-2.01 (3H, stack, CH$_a$$H_bCHN, CH_aH_b$N), 2.57-2.69 (1H, m, CH$_a$$H_b$N), 3.04 (1H, d, *J* 12.9, CH_aH$_b$Ar), 3.79 (3H, s, OCH_3), 4.19 (1H, d, *J* 12.9, CH$_a$$H_b$Ar), 4.98 (1H, dd, *J* 8.5, 4.8, C(3)*H*), 5.06 (1H, dd, *J* 9.0, 4.8, C(2)*H*), 6.83 (2H, d, *J* 8.3, CH_{Ar}), 7.20 (2H, d, *J* 8.3, CH_{Ar}); δ_C(100 MHz; $CDCl_3$) 18.8 (CH_3, *C*5), 23.3 (CH_2, *C*H_2CH_2CHN), 25.2 (CH_2, *C*H_2CH_2N), 35.5 (CH_2, *C*H_2CHN), 50.4 (CH_2, *C*H_2N), 55.1 (CH_3, O*C*H_3), 58.0 (CH, *C*4), 58.2 (CH_2, *C*H_2Ar), [64.9, 65.1 (2 x CH, *C*1, *C*HN)], 84.2 (CH, *C*3), 84.6 (CH, *C*2), 113.8 (CH, *C*H_{Ar}), 130.1 (CH, *C*H_{Ar}), 132.1 (C_{quat}, *ipso*-C), 159.0 (C_{quat}, *C*OMe); *m/z* (ES) 412.0 [$(M + H)^+$, 100%], 328.1 (43, M + H - 3CO) [Found [M + H]$^+$ 412.1226. $C_{21}H_{26}FeNO_4$ requires *M* + H, 412.1211].

[(2*Z*, 1*S, 4*S**, 2'*R**)-1-[(*N*-Butyl)piperidin-2'-yl]-(1,2,3,4-η)-penta-2-en-1,4-diyl]tricarbonyliron 7ac.** Keto-aldehyde **8a** (50 mg, 0.163 mmol), $BuNH_2$ (19 μL, 0.196 mmol) and $NaBH(OAc)_3$ (138 mg, 0.652 mmol) were reacted as detailed for **7aa**. After 12 h, work up and purification by SiO_2 column chromatography (hexane/Et_2O, 2:1 plus 1% Et_3N) afforded piperidine **7ac** as a yellow oil (46 mg, 81%); R_f (hexane/Et_2O, 2:1) 0.20; υ_{max}(film)/cm^{-1} 2933s, 2860s, 2788m, 2039s (CO), 1962s br (CO), 1442m, 1379m, 1364w, 1264w, 1236w, 1189w, 1139w, 1087w; δ_H(300 MHz; $CDCl_3$) 0.83-1.02 (4H, stack, including [0.91 (3H, t, *J* 7.0, CH_2C*H*$_3$), 0.97 (1H, apparent t, *J* 9.0, C(1)*H*)], CH_2C*H*$_3$, C(1)*H*), 1.14-1.63 (12H, stack, including [1.39 (3H, d, *J* 6.3, C(5)H_3)], C(4)*H*, CH_2CH_2CH$_2$NBu, CH_2CH_2CH$_3$, C(5)H_3), 1.65-1.75 (1H, m, CH_aH$_b$CHN), 1.78-1.94 (2H, stack, CH$_a$$H_bCH$N), 2.00-2.13 (1H, m, C$H_aH_b$NBu), 2.22-2.35 (1H, m, CH_aH$_b$Pr), 2.76-2.93 (2H, stack, CH$_a$$H_bNBu, CH_a$$H_b$Pr), 4.96 (1H, dd, *J* 8.5, 4.8, C(3)*H*), 5.04 (1H, dd, *J* 9.0, 4.8, C(2)*H*); δ_C(75 MHz; $CDCl_3$) 14.1 (CH_3, CH_2*C*H_3), 19.2 (CH_3, *C*5), 20.9 (CH_2, *C*$H_2$$CH_3$), 23.8 ($CH_2$, *C*$H_2CH_2$CHN), 25.7 ($CH_2$, *C*$H_2CH_2$NBu), 28.5 ($CH_2$, *C*$H_2CH_2$$CH_3$), 36.0 ($CH_2$, *C*$H_2$CHN), [51.0, 54.0 (2 x CH_2, 2 x CH_2N)], 58.1 (CH, *C*4), 64.5 (CH, *C*1), 65.3 (CH, *C*HN), 84.1 (CH, *C*3), 84.2 (CH, *C*2); *m/z* (ES) 348.1 [$(M + H)^+$, 100%], 264.2 (17, M + H - 3CO) [Found [M + H]$^+$ 348.1266. $C_{17}H_{26}FeNO_3$ requires *M* + H, 348.1262].

[(2*Z*, 1*S, 4*S**, 2'*R**)-1-[*N*-(*tert*-Butyldimethylsilanyloxyethyl)piperidin-2'-yl]-(1,2,3,4-η)-penta-2-en-1,4-diyl]tricarbonyliron 7ad.** Glacial AcOH was added dropwise to a stirred solution of ethanolamine (13 μL, 0.223 mmol) in THF (3 mL) until the mixture reached pH 6. A solution of keto-aldehyde **8a** (57 mg, 0.186 mmol) in THF (2 mL) and $NaBH(OAc)_3$ (158 mg, 0.744 mmol) were then added. After 12 h, work up as detailed for **7aa** yielded a yellow oil. This was dissolved in CH_2Cl_2 (2 mL) and treated with imidazole (51 mg, 0.744 mmol) and $^tBuMe_2SiCl$ (56 mg, 0.372 mmol). The reaction mixture was stirred for 16 h and then partitioned between H_2O (8 mL) and CH_2Cl_2 (8 mL). The aqueous phase was extracted with CH_2Cl_2 (2 x 8 mL), the combined organic phases were dried ($MgSO_4$) and the solvent removed under reduced pressure. The residue was purified by SiO_2 column chromatography (hexane/Et_2O, 2:1 plus 1% Et_3N) to afford piperidine **7ad** as a yellow oil (0.059 g, 71%); R_f (hexane/Et_2O, 1:1) 0.36; υ_{max}(film)/cm^{-1} 2931s, 2857s, 2041s (CO), 1962s br (CO), 1472m, 1463m, 1442m, 1380w, 1362w, 1256s, 1095s, 1033m; δ_H(300 MHz; $CDCl_3$) 0.05 (6H, s, Si(C*H*$_3$)$_2$), 0.88 (9H, s, SiC(C*H*$_3$)$_3$), 0.96 (1H, apparent t, *J* 9.2, C(1)*H*), 1.21-1.43 (5H, stack, including [1.39 (3H, d, *J* 5.9, C(5)*H*$_3$], C(4)*H*, C*H*$_a$H$_b$CH$_2$CHN, C(5)*H*$_3$), 1.46-1.59 (3H, stack, C*H*$_2$CH$_a$*H*$_b$CH$_2$CHN), 1.64-1.75 (1H, m, C*H*$_a$H$_b$CHN), 1.77-1.87 (1H, m, CH$_a$*H*$_b$CHN), 1.92-2.03 (1H, m, C*H*N), 2.15-2.27 (1H, m, C*H*$_a$H$_b$N), 2.45-2.57 (1H, m, C*H*$_a$H$_b$CH$_2$O), 2.79-2.90 (1H, m, CH$_a$*H*$_b$N), 2.95-3.05 (1H, m, CH$_a$*H*$_b$CH$_2$O), 3.60-3.78 (2H, m, C*H*$_2$OSi), 4.98 (1H, dd, *J* 9.2, 5.2, C(2)*H*), 5.13 (1H, dd, *J* 8.8, 5.2, C(3)*H*); δ_C(100 MHz; $CDCl_3$) -5.7 (CH_3, Si(*C*H$_3$)$_2$), 18.0 (C_{quat}, Si*C*(CH$_3$)$_3$), 18.8 (CH_3, *C*5), 23.4 (CH_2, *C*H$_2$CH$_2$CHN), 25.3 (CH_2, *C*H$_2$CH$_2$N), 25.7 (CH_3, SiC(*C*H$_3$)$_3$), 35.7 (CH_2, *C*H$_2$CHN), [52.1, 55.7 (2 x CH_2, 2 x *C*H$_2$N)], 58.0 (CH, *C*4), 61.6 (CH_2, *C*H$_2$OSi), [64.7, 65.3 (2 x CH, *C*1, *C*HN)], 84.2 (CH, *C*3), 84.6 (CH, *C*2); *m/z* (ES) 450.3 [$(M + H)^+$, 100%], 366.3 (49, M + H - 3CO), 310.3 (16, M + H - $Fe(CO)_3$) [Found $[M + H]^+$ 450.1748. $C_{21}H_{36}FeNO_4Si$ requires *M* + H, 450.1763].

[(2*Z*, 1*S, 4*S**, 2'*R**)-1-[*N*-(Prop-2''-enyl)piperidin-2'-yl]-(1,2,3,4-η)-penta-2-en-1,4-diyl]tricarbonyliron 7ae.** Keto-aldehyde **8a** (100 mg, 0.327 mmol), allylamine (30 μL, 0.392 mmol) and $NaBH(OAc)_3$ (280 mg, 1.308 mmol) were reacted as detailed for **7aa**. After 12 h, work up and purification by SiO_2 column chromatography (hexane/Et_2O, 1:2 plus 1% Et_3N) afforded piperidine **7ae** as a yellow oil (87 mg, 80%); R_f (Et_2O) 0.24; (Found: C, 58.07; H, 6.44; N, 4.38. $C_{16}H_{21}FeNO_3$ requires C, 58.02; H, 6.39; N, 4.23%); υ_{max}(film)/cm^{-1} 2934m, 2856m, 2785m, 2039s (CO), 1962s br (CO), 1642w, 1442m, 1379w, 1364w, 1126w; δ_H(300 MHz; $CDCl_3$) 0.97 (1H, apparent t, *J* 9.4, C(1)*H*), 1.16-2.06 (12H, stack, including [1.39 (3H, d, *J* 6.3, C(5)H_3)], C*H*NCH_2CH_2CH_2C$H_a$$H_b$, C(4)*H*, C(5)$H_3$), 2.77-2.93 (2H, stack, CH_aH_bN, C$H_a$$H_b$CH=$CH_2$), 3.65 (1H, dd, *J* 13.4, 5.0, CH_aH_bCH=CH_2), 4.97 (1H, dd, *J* 8.8, 5.2, C(2)*H* or C(3)*H*), 5.06 (1H, dd, *J* 8.8, 4.8, C(3)*H* or C(2)*H*), 5.10-5.24 (2H, stack, CH=CH_2), 5.76-5.92 (1H, m, C*H*=CH_2); δ_C(75 MHz; $CDCl_3$) 19.1 (CH_3, *C*5), 23.9 (CH_2, *C*$H_2$$CH_2$CHN), 25.7 ($CH_2$, *C*$H_2$$CH_2$N), 36.1 ($CH_2$, *C*$H_2$CHN), 51.2 ($CH_2$, *C*$H_2$N), 57.8 ($CH_2$, *C*$H_2$CH=$CH_2$), 58.1 (CH, *C*4), 64.6 (CH, *C*1), 64.9 (CH, *C*HN), 84.1 (CH, *C*3), 84.3 (CH, *C*2), 117.4 (CH_2, CH=*C*H_2), 136.0 (CH, *C*H=CH_2); *m/z* (ES) 332.1 [$(M + H)^+$, 91%], 248.1 (100, M – 3CO + H) [Found $[M + H]^+$ 332.0965. $C_{16}H_{22}FeNO_3$ requires *M* + H, 332.0949].

[(2*Z*, 2''*E*, 1*S, 4*S**, 2'*R**)-1-[*N*-(3''-Bromo-2''-methylprop-2''-enyl)piperidin-2'-yl]-(1,2,3,4-η)-penta-2-en-1,4-diyl]tricarbonyliron and [(2*Z*, 2''*Z*, 1*S**, 4*S**, 2'*R**)-1-[*N*-(3''-bromo-2''-methylprop-2''-enyl)piperidin-2'-yl]-(1,2,3,4-η)-penta-2-en-1,4-diyl]tricarbonyliron 7af.** A solution of 1-bromo-3-[*N*-(*tert*-butoxycarbonyl)amino]-2-methylprop-1-ene (163 mg, 0.65 mmol, 5:1 mixture of (*E*)/(*Z*) isomers) in CH_2Cl_2 (7 mL) was cooled to 0 °C and treated with an excess of CF_3CO_2H (2 mL). After 30 min, the volatiles were removed under reduced pressure, and the residue dissolved in THF (10 mL) and treated with Et_3N (273 μL, 1.96 mmol). After stirring for 5 min, $NaBH(OAc)_3$ (280 mg, 1.31 mmol) was added to the reaction mixture, shortly followed by a solution of keto-aldehyde **8a** (100 mg, 0.33 mmol) in THF (5 mL). After 12 h, work up as detailed for **7aa** and

purification by SiO_2 column chromatography (hexane/Et_2O, 4:1 plus 1% Et_3N) afforded piperidine **7af** as a yellow crystalline solid (0.119 g, 86%, mixture of (*E*)/(*Z*) isomers, 5:1). SiO_2 column chromatography (hexane/Et_2O, 16:1 plus 1% Et_3N) allowed separation of the two isomers. Data for (*E*)-isomer: R_f (hexane/Et_2O, 4:1) 0.67; (Found: C, 48.38; H, 5.06; N, 3.29. $C_{17}H_{22}BrFeNO_3$ requires C, 48.14; H, 5.23; N, 3.30%); υ_{max}(CH_2Cl_2 film)/cm^{-1} 2937m, 2857w, 2791w, 2040s (CO), 1968s br (CO), 1632w (C=C), 1442w, 1265m, 1031w; δ_H(300 MHz; $CDCl_3$) 0.96 (1H, apparent t, *J* 8.8, C(1)*H*), 1.15-1.94 (15H, stack, including [1.40 (3H, d, *J* 6.3, C(5)H_3)], [1.73 (3H, s, =CCH_3)], C(4)*H*, C*H*NCH_2CH_2CH_2C$H_a$$H_b$, C(5)$H_3$, =CC$H_3$), 2.57-2.68 (2H, stack, CH_aH_bN, C$H_a$$H_b$C=), 3.58 (1H, d, *J* 13.2, CH_aH_bC=), 4.93-5.03 (2H, stack, C(3)*H*, C(2)*H*), 6.06 (1H, s, =C*H*Br); δ_C(75 MHz; $CDCl_3$) 17.9 (CH_3, =C*C*H_3), 19.0 (CH_3, *C*5), 23.5 (CH_2, *C*H_2CH_2CHN), 25.6 (CH_2, *C*H_2CH_2N), 35.8 (CH_2, *C*H_2CHN), 50.4 (CH_2, *C*H_2N), 58.0 (CH, *C*4), 60.9 (CH_2, *C*H_2C=), 64.6 (CH, *C*1), 65.0 (CH, *C*HN), 84.1 (CH, *C*3), 84.2 (CH, *C*2), 103.2 (CH, =*C*HBr), 140.4 (C_{quat}, =*C*Me); *m/z* (ES) 426 {[M (Br 81) + H]$^+$, 88%}, 424 [92, M (Br 79) + H], 342 [86, M (Br 81) – 3CO + H], 340 [100, M (Br 79) – 3CO + H] [Found [M (Br 79) + H]$^+$ 424.0199. $C_{17}H_{23}BrFeNO_3$ requires *M* (Br 79) + H, 424.0211]. Data for (*Z*)-isomer: R_f (hexane/Et_2O, 4:1) 0.51; (Found: C, 48.29; H, 5.21; N, 3.44. $C_{17}H_{22}BrFeNO_3$ requires C, 48.14; H, 5.23; N, 3.30%); υ_{max}(CH_2Cl_2 film)/cm^{-1} 2937m, 2856m, 2790m, 2040s (CO), 1962s br (CO), 1631w (C=C), 1442m, 1380m, 1264m, 1034m; δ_H(300 MHz; $CDCl_3$) 0.97 (1H, apparent t, *J* 9.0, C(1)*H*), 1.15-2.00 (15H, stack, including [1.40 (3H, d, *J* 5.9, C(5)H_3)], [1.73 (3H, s, =CCH_3)], C(4)*H*, C*H*NCH_2CH_2CH_2C$H_a$$H_b$, C(5)$H_3$, =CC$H_3$), 2.59-2.71 (1H, m, CH_aH_b), 3.07 (1H, d, *J* 12.9, C$H_a$$H_b$C=), 3.53 (1H, d, *J* 12.9, CH_aH_bC=), 4.99 (1H, dd, *J* 8.8, 5.0, C(3)*H*), 5.07 (1H, dd, *J* 9.0, 5.0, C(2)*H*), 5.98 (1H, s, =C*H*Br); δ_C(75 MHz; $CDCl_3$) 19.1 (CH_3, *C*5), 21.3 (CH_3, =C*C*H_3), 23.8 (CH_2, *C*H_2CH_2CHN), 25.7 (CH_2, *C*H_2CH_2N), 35.8 (CH_2, *C*H_2CHN), 50.6 (CH_2, *C*H_2N), 56.8 (CH_2, *C*H_2C=), 58.0 (CH, *C*4), 65.2 (CH, *C*1), 65.4 (CH, *C*HN), 84.2 (CH, *C*3), 84.6 (CH, *C*2), 102.6 (CH, *C*HBr), 140.1 (C_{quat}, =*C*Me); *m/z* (ES) 426.2 {[M (Br 81) + H]$^+$, 87%}, 424.2 [100, M (Br 79) + H], 342.2 [37, M (Br 81) – 3CO + H], 340.2 [48, M (Br 79) – 3CO + H] [Found

[M (Br 79) + H]$^+$ 424.0215. $C_{17}H_{23}BrFeNO_3$ requires *M* (Br 79) + H, 424.0211].

[(2*Z*, 2''*Z*, 1*S, 4*S**, 2'*R**)-1-[*N*-(2''-Bromo-3''-trimethylsilyl-prop-2''-enyl)piperidin-2'-yl]-(1,2,3,4-η)-penta-2-en-1,4-diyl]tricarbonyliron 7ag.** A solution of (2*Z*)-2-bromo-1-[*N*-(*tert*-butoxycarbonyl)]-3-trimethylsilanyl-prop-2-enylamine (480 mg, 1.56 mmol) in CH_2Cl_2 (10 mL) was cooled to 0 °C and treated with an excess of CF_3CO_2H (3 mL). After 30 min, the volatiles were removed under reduced pressure and the residue was dissolved in THF (25 mL) and treated with Et_3N (840 μL, 6.00 mmol). After stirring for 5 min, $NaBH(OAc)_3$ (1.02 g, 4.80 mmol) was added to the reaction mixture, followed by a solution of keto-aldehyde **8a** (370 mg, 1.20 mmol) in THF (10 mL). After 15 h, work up as detailed for **7aa** and purification by SiO_2 column chromatography (hexane/Et_2O, 10:1 plus 1% Et_3N) afforded piperidine **7ag** as a yellow oil (420 mg, 73%); R_f (hexane/Et_2O, 4:1) 0.66; υ_{max}(film)/cm^{-1} 3018w, 2935s, 2857s, 2790s, 2041s (CO), 1962s br (CO), 1609s (C=C), 1442s, 1380m, 1364m, 1334w, 1280w, 1248s, 1214w, 1180m, 1128m, 1098m, 1070w, 1045m, 1051m; δ_H(300 MHz; $CDCl_3$) 0.18 (9H, s, Si(C*H*$_3$)$_3$), 1.00 (1H, apparent t, *J* 8.8, C(1)*H*), 1.17-1.23 (1H, m, C(4)*H*), 1.40 (3H, d, *J* 6.3, C(5)*H*$_3$), 1.49-1.75 (5H, stack, C*H*$_2$C*H*$_2$C*H*$_a$H$_b$CHN), 1.78-1.88 (1H, m, CH$_a$*H*$_b$CHN), 1.94-2.13 (2H, stack, C*H*N, C*H*$_a$H$_b$N), 2.72-2.83 (1H, m, CH$_a$*H*$_b$N), 3.02 (1H, d, *J* 15.3, C*H*$_a$H$_b$C=), 3.78 (1H, d, *J* 15.3, CH$_a$*H*$_b$C=), 4.94-5.06 (2H, stack, C(3)*H*, C(2)*H*), 6.31 (1H, s, =C*H*(TMS)); δ_C(75 MHz; $CDCl_3$) -0.8 (CH_3, Si(*C*H$_3$)$_3$), 19.1 (CH_3, *C*5), 23.5 (CH_2, *C*H$_2$CH$_2$CHN), 25.6 (CH_2, *C*H$_2$CH$_2$N), 35.5 (CH_2, *C*H$_2$CHN), 51.1 (CH_2, *C*H$_2$N), 58.1 (CH, *C*4), [64.3, 64.4 (2 x CH, *C*1, *C*HN)], 66.0 (CH_2, *C*H$_2$C=), 84.1 (CH, *C*3), 84.4 (CH, *C*2), 129.0 (CH, =*C*H(TMS)), 140.9 (C_{quat}, =*C*); *m/z* (ES) 484.0 {[M (Br 81) + H]$^+$, 87%}, 482.0 [100, M (Br 79) + H] [Found [M (Br 79) + H]$^+$ 482.0461. $C_{19}H_{29}BrFeNO_3Si$ requires *M* (Br 79) + H, 482.0449].

(2'*Z*, 1''*E*, 3''*E*)-*N*-(2'-Bromo-3'-trimethylsilanyl-prop-2'-ene)-2-(penta-1'',3''-dienyl) piperidine 20. A solution of $CuCl_2$ (590 mg, 4.36 mmol) in EtOH (42 mL) was added quickly to a stirred solution of iron complex **7ag** (420 mg, 0.87 mmol) in EtOH (30 mL). The reaction mixture was stirred at rt for 10 min, and the solvent removed under reduced pressure. The residue was partitioned between H_2O (75 mL) and Et_2O (75 mL). The aqueous phase was extracted with Et_2O (2 x 75 mL) and the combined organic phases were dried ($MgSO_4$). Removal of the solvent under reduced pressure yielded diene **20** as a pale brown oil (290 mg, 99%) which was characterised without any further purification; R_f (hexane/Et_2O, 4:1) 0.63; υ_{max}(film)/cm^{-1} 3018m, 2934s, 2855s, 2787s, 2743w, 1609s (C=C), 1442m, 1379m, 1362m, 1332w, 1292w, 1248s, 1214w, 1179m, 1132m, 1101m, 1063w, 1048m; δ_H(300 MHz; $CDCl_3$) 0.19 (9H, s, Si(C*H*$_3$)$_3$), 1.21-1.69 (6H, stack, CHNC*H*$_2$C*H*$_2$C*H*$_2$), 1.74 (3H, d, *J* 6.8, C*H*$_3$), 1.96 (1H, apparent dt, *J* 10.0, 3.0, C*H*$_a$H$_b$N), 2.68 (1H, apparent dt, *J* 10.0, 3.0, CH$_a$*H*$_b$), 2.81 (1H, d, *J* 15.4, C*H*$_a$H$_b$C=), 2.87-2.97 (1H, m, C*H*N), 3.66 (1H, d, *J* 15.4, CH$_a$*H*$_b$C=), 5.49 (1H, dd, *J* 14.2, 8.7, =C*H*), 5.57-5.70 (1H, m, =C*H*), 5.97-6.13 (2H, stack, 2 x =C*H*), 6.30 (1H, s, =C*H*(TMS)); δ_C(100 MHz; $CDCl_3$) -1.3 (CH_3, Si(*C*H$_3$)$_3$), 17.6 (CH_3), 23.5 (CH_2, *C*H$_2$CH$_2$CHN), 25.5 (CH_2, *C*H$_2$CH$_2$N), 33.3 (CH_2, *C*H$_2$CHN), 52.2 (CH_2, *C*H$_2$N), 65.1 (CH, *C*HN), 67.1 (CH_2, *C*H$_2$C=), [128.8, 129.1, 131.6, 131.9, 134.3 (5 x CH, 4 x =*C*H, =*C*H(TMS))], 141.2 (C_{quat}, =*C*); *m/z* (ES) 344.2 {[M (Br 81) + H]$^+$, 93%}, 342.2 [100, M (Br 79) + H] [Found [M (Br 79) + H]$^+$ 342.1264. $C_{16}H_{29}BrNSi$ requires *M* (Br 79) + H, 342.1253].

[(3*Z*, 2*S, 5*S**)-11-(Prop-2'-enyl)amino-6-oxo-(2,3,4,5-η)-undec-3-en-2,5-diyl]tricarbonyliron 21.** Keto-aldehyde **8b** (16 mg, 0.50 mmol), allylamine (50 μL, 0.60 mmol) and $NaBH(OAc)_3$ (420 mg, 2.00 mmol) were reacted as detailed for **7aa**. After 12 h, work up afforded keto-amine **21** as a yellow oil (0.18 g, quant). Selected data: R_f (Et_2O plus 1% Et_3N) 0.13; δ_C(75 MHz; $CDCl_3$) 18.9 (CH_3, *C*1), [24.2, 26.7, 29.3 (3 x CH_2, *C*8, *C*9, *C*10)], 42.2 (CH_2, *C*7), [48.6, 52.0 (2 x CH_2, *C*11, *C*H$_2$CH=CH$_2$), [53.3, 59.1 (2 x CH, *C*2, *C*5)], [81.1, 88.4 (2 x CH, *C*3, *C*4)], 115.9 (CH_2, CH$_2$CH=*C*H$_2$), 136.1 (CH, CH$_2$*C*H=CH$_2$), 205.1 (C_{quat}, *C*=O); *m/z* (ES) 362.0 [(M + H)$^+$, 100%], 278.0

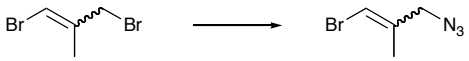
(22, M - 3CO + H) [Found $[M + H]^+$ 362.1051. $C_{17}H_{24}FeNO_4$ requires *M* + H, 362.1055].

[(3*Z*, 2*S, 5*S**)-11-[*N*-Acetyl-*N*-(prop-2'-enyl)amino]-6-oxo-(2,3,4,5-η)-undec-3-en-2,5-diyl]tricarbonyliron 22 and [(3*Z*, 2*S**, 5*S**)-11-[*N*-ethyl-*N*-(prop-2'-enyl)amino]-6-oxo-(2,3,4,5-η)-undec-3-en-2,5-diyl]tricarbonyliron 23.** A solution of keto-amine **21** (180 mg, 0.50 mmol) in THF (10 mL) was treated with $NaBH(OAc)_3$ (210 mg, 1.00 mmol) and glacial AcOH (30 μL, 0.50 mmol) at rt. The reaction mixture was warmed to 70 °C, stirred at this temperature for 16 h, and then allowed to cool to rt. The reaction mixture was partitioned between Et_2O (10 mL) and $NaHCO_3$ solution (10 mL), and the aqueous phase extracted with Et_2O (2 x 10 mL). The combined organic phases were dried ($MgSO_4$) and the solvent removed under reduced pressure. Purification of the residue by SiO_2 column chromatography yielded, in order of elution, keto-amide **22** (100 mg, 51%), and then keto-amine **23** (80 mg, 43%), both as yellow oils; **22**: R_f (EtOAc plus 1% Et_3N) 0.41; υ_{max}(film)/cm^{-1} 2936m, 2054s (CO), 1983s br (CO), 1672s (C=O), 1637s (C=O), 1460m, 1440m, 1266s; δ_H(300 MHz; $CDCl_3$) 1.17-1.31 (3H, stack, C(2)*H*, C(5)*H*, C(9)H_a), 1.42-1.62 (8H, stack, C(1)H_3, C(8)H_2, C(9)H_b, C(10)H_2), [2.04 (3/2H, s, C(O)CH_3), 2.09 (3/2H, s, C(O)CH_3) rotamers], 2.27-2.43 (2H, m, C(7)H_2), [3.19 (1H, t, *J* 7.7, C(11)H_a), 3.29 (1H, t, *J* 7.7, C(11)H_b)], 3.84-3.96 (2H, m, CH_2CH=CH_2), 5.05-5.27 (3H, stack, CH_2CH=C$H_a$$H_b$, C(3)*H*), 5.67-5.82 (2H, stack, CH_2C*H*=CH_2, C(4)*H*); δ_C(75 MHz; $CDCl_3$) 19.1 (CH_3, *C*1), [21.3, 21.5 (CH_3, *C*H_3CO), rotamers], [24.0, 24.2, 26.3, 26.5, 27.5, 28.5 (3 x CH_2, *C*8, *C*9, *C*10), rotamers], [42.2, 42.4, 45.7, 47.7, 47.9, 51.0 (3 x CH_2, *C*7, *C*11, *C*H_2C=), rotamers], [53.38, 53.44, 59.3, 59.4 (2 x CH, *C*2, *C*5), rotamers], [81.18, 81.25, 88.6, 88.7 (2 x CH, *C*3, *C*4), rotamers], [116.3, 116.7 (CH_2, CH_2CH=*C*H_2), rotamers], [132.9, 133.5 (CH, CH_2C*H*=CH_2), rotamers], [170.0, 170.5 (C_{quat}, amide *C*=O), rotamers], [204.9, 205.3 (C_{quat}, ketone *C*=O), rotamers]; *m/z* (ES) 426.2 [$(M + Na)^+$, 46%], 390.2 (100) [Found $[M + Na]^+$ 426.0972. $C_{19}H_{25}FeNNaO_5$ requires *M* + Na, 426.0980]; **23**: R_f (EtOAc plus 1% Et_3N) 0.30; υ_{max}(film)/cm^{-1} 2936s, 2861m, 2800m, 2052s (CO), 1978s br (CO), 1675s (C=O), 1493m, 1461s,

1441m, 1381m, 1296m, 1174m, 1032m; δ_H(300 MHz; $CDCl_3$) 0.99 (3H, t, *J* 7.0, CH_2CH_3), 1.17-1.30 (3H, stack, C(2)*H*, C(5)*H*, C(9)H_a), 1.38-1.60 (8H, stack, including [1.45 (3H, d, *J* 5.5, C(1)H_3], C(8)H_2, C(9)H_b, C(10)H_2, C(1)H_3), 2.30-2.42 (4H, stack, C(7)H_2, C(11)H_2), 2.49 (2H, q, *J* 7.0, CH_2CH_3), 3.06 (2H, d, *J* 6.6, $CH_2CH{=}CH_2$), 5.04-5.18 (2H, stack, $CH_2CH{=}CH_aH_b$), 5.22 (1H, dd, *J* 8.1, 5.2, C(3)*H*), 5.71-5.92 (2H, stack, including [5.76 (1H, dd, *J* 8.1, 5.2, C(4)*H*)], $CH_2CH{=}CH_2$, C(4)*H*); δ_C(75 MHz; $CDCl_3$) 11.6 (CH_3, CH_2CH_3), 19.1 (CH_3, *C*1), [24.6, 26.7, 27.2 (3 x CH_2, *C*8, *C*9, *C*10)], 42.6 (CH_2, *C*7), 47.2 (CH_2, NCH_2), 52.9 (CH_2, NCH_2), 53.5 (CH, *C*2 or *C*5), 56.7 (CH_2, NCH_2), 59.2 (CH, *C*5 or *C*2), [81.3, 88.6 (2 x CH, *C*3, *C*4)], 117.0 (CH_2, $CH_2CH{=}CH_2$), 135.9 (CH, $CH_2CH{=}CH_2$), 205.5 (C_{quat}, *C*=O); *m/z* (ES) 390.2 [$(M + H)^+$, 100%], 362.2 (12, M - CO + H), 306.2 (54, M - 3CO + H), 250.3 (8, M - $Fe(CO)_3$ + H) [Found $[M + H]^+$ 390.1373. $C_{19}H_{28}FeNO_4$ requires *M* + H, 390.1368].

Synthesis of Boc-Protected Amines used to prepare 7af and 7ag

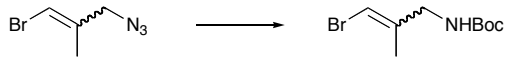
(*E*)-3-Azido-1-bromo-2-methylprop-1-ene and (*Z*)-3-azido-1-bromo-2-methylprop-1-ene.



A solution of 1,3-dibromo-2-methylprop-1-ene[5] (500 mg, 2.34 mmol) in acetone (4 mL) was added to a stirred suspension of NaN_3 (760 g, 11.70 mmol) in acetone (11 mL). The reaction mixture was stirred at rt for 15 min and then warmed to 60 °C. After 2 h, the reaction mixture was cooled to rt, and the solvent removed under reduced pressure. The residue was partitioned between H_2O (20 mL) and Et_2O (20 mL) and the aqueous phase was extracted with Et_2O (3 x 20 mL). The combined organic phases were dried (Na_2SO_4) and concentrated under reduced pressure to yield 3-azido-1-bromo-2-methylprop-1-ene as a pale oil (0.35 g, 85%, mixture of (*E*)/(*Z*) isomers, 1.7:1), which was used directly in the next step (see immediately

below) without further purification; R_f (hexane) 0.23; υ_{max}(film)/cm^{-1} 3072w, 2977w, 2918m, 2852w, 2104s br (N_3), 1734w, 1634m, 1439s, 1380m, 1335s, 1295s, 1266s, 1221m, 1166m; δ_H(300 MHz; $CDCl_3$; major isomer) 1.84 (3H, s, C*H*$_3$), 3.78 (2H, s, C*H*$_2$), 6.25-6.29 (1H, m, =C*H*); δ_H(300 MHz; $CDCl_3$; minor isomer) 1.90 (3H, s, C*H*$_3$), 3.99 (2H, s, C*H*$_2$), 6.15 (1H, s, =C*H*); δ_C(75 MHz; $CDCl_3$; major isomer) 17.5 (CH_3), 56.7 (CH_2, C*H*$_2$N$_3$), 106.5 (CH, =*C*H), 136.3 (C_{quat}, =*C*); δ_C(75 MHz; $CDCl_3$; minor isomer) 20.7 (CH_3), 52.9 (CH_2, *C*H$_2$N$_3$), 104.9 (CH, =CH), 135.9 (C_{quat}, =*C*); *m/z* (EI) 135 {[M (Br 81) - Br]$^+$, 77%}, 133 (79, M (Br 79) - Br), 53 (100, $C_4H_5^+$).

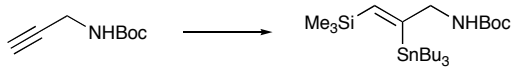
(*E*)-1-Bromo-3-[*N*-(*tert*-butoxycarbonyl)amino]-2-methylprop-1-ene and (*Z*)-1-bromo-3-[*N*-(*tert*-butoxycarbonyl)amino]-2-methylprop-1-ene.



PPh_3 (3.04 g, 11.60 mmol) and Boc_2O (1.26 g, 5.79 mmol) were added sequentially to a stirred solution of 3-azido-1-bromo-2-methylprop-1-ene (0.68 g, 3.86 mmol) in ^{t}BuOH (20 mL). The reaction mixture was stirred at rt for 2 d, and then the solvent removed under reduced pressure. The residue was purified by SiO_2 column chromatography (hexane/Et_2O, 3:1) to yield 1-bromo-3-[*N*-(*tert*-butoxycarbonyl)amino]-2-methylprop-1-ene as a colourless oil, which solidified upon standing to yield a white solid (0.43 g, 45%, mixture of (*E*)/(*Z*) isomers, 4.5:1); R_f (Et_2O) 0.41; (Found: C, 43.47; H, 6.47; N, 5.38. $C_9H_{16}BrNO_2$ requires C, 43.22; H, 6.45; N, 5.60%); m.p. 70-72 °C (from hexane/Et_2O); υ_{max}(film)/cm^{-1} 3336s (N-H), 2981m, 2932m, 1810m, 1759m, 1676s (C=O), 1526m, 1455m, 1367s, 1250m, 1171s, 1119s, 1068s; δ_H(300 MHz; $CDCl_3$; major isomer) 1.42 (9H, s, C(C*H*$_3$)$_3$), 1.75 (3H, s, C*H*$_3$), 3.67-3.77 (2H, m, C*H*$_2$), 4.67 (1H, s (br), N*H*), 6.05-6.11 (1H, m, =C*H*); δ_H(300 MHz; $CDCl_3$; minor isomer) selected data: 1.80 (3H, s, C*H*$_3$), 3.86-3.93 (2H, m, C*H*$_2$), 5.92-5.97 (1H, m, =C*H*); δ_C(100 MHz; $CDCl_3$; major isomer) 17.0 (CH_3), 28.0 (CH_3, C(*C*H$_3$)$_3$), 46.2 (CH_2), 85.1 (C_{quat}, *C*(CH$_3$)$_3$), 104.0 (CH, =*C*H), 139.4 (C_{quat}, =*C*), 156.1 (C_{quat}, *C*=O); δ_C(100 MHz; $CDCl_3$; minor isomer) selected data: 20.2 (CH_3), 27.0 (CH_3, C(*C*H$_3$)$_3$), 42.9 (CH_2), 79.6

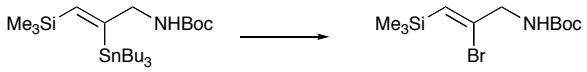
(C_{quat}, $C(CH_3)_3$), 102.6 (CH, =*C*H), 147.1 (C_{quat}, =*C*); *m/z* (ES) 274.0 {[M (Br 81) + Na]$^+$, 90%}, 272.0 [100, M (Br 79) + Na] [Found [M (Br 79) + Na]$^+$ 272.0252. $C_9H_{16}BrNNaO_2$ requires *M* (Br 79) + Na, 272.0262].

(2*Z*)-1-[*N*-(*tert*-Butoxycarbonyl)]-2-tributylstannyl-3-trimethylsilanyl-prop-2-enylamine.



Trimethylsilanyltributylstannane[6] (683 mg, 1.88 mmol) was added over 1 min to a degassed solution of PCy_3 (19 mg, 0.07 mmol), 1-[*N*-(*tert*-butoxycarbonyl)amino]prop-2-yne[7] (270 mg, 1.71 mmol), and $Pd_2(dba)_3$ (31 mg, 0.03 mmol) in benzene (18 mL) at rt. The reaction mixture was heated at 80 °C. After stirring for 1 h, the reaction mixture was cooled to rt, and the solvent removed under reduced pressure. The residue was purified by SiO_2 column chromatography (hexane/Et_2O, 10:1) to yield (2*Z*)-1-[*N*-(*tert*-butoxycarbonyl)]-2-tributylstannyl-3-trimethylsilanyl-prop-2-enylamine as a pale oil (504 g, 57%); R_f (hexane/Et_2O, 10:1) 0.34; (Found C, 53.19; H, 9.67; N, 2.71. $C_{23}H_{49}NO_2SiSn$ requires C, 53.28; H, 9.53; N, 2.70%); υ_{max}(film)/cm^{-1} 3453m (N-H), 3364m br (N-H), 2956s, 2922s, 1705s (C=O), 1496m, 1456m, 1366m, 1247s, 1170s, 1048m; δ_H(300 MHz; $CDCl_3$) 0.09 (9H, s, Si(C*H*$_3$)$_3$), 0.83-0.99 (15H, stack, including [0.88 (9H, t, *J* 7.2, 3 x CH_2CH_3)], 3 x CH_2CH_3), 1.24-1.50 (21H, stack, including [1.44 (9H, s, C(C*H*$_3$)$_3$)], Sn(C*H*$_2$C*H*$_2$CH$_2$CH$_3$)$_3$, C(C*H*$_3$)$_3$), 3.75-3.94 (2H, m, C*H*$_2$N), 4.43 (1H, s (br), N*H*), 6.47 (1H, s, =C*H*); δ_C(75 MHz; $CDCl_3$) 0.1 (CH_3, Si(*C*H$_3$)$_3$), 10.9 (CH_2, s, (and 2 x d satellites, $^1J_{C-^{119}Sn}$ 329.3, $^1J_{C-^{117}Sn}$ 314.7), Sn*C*H$_2$), 13.6 (CH_3, Sn(CH$_2$)$_3$*C*H$_3$), 27.4 (CH_2, s, (and 2 x d satellites, $^2J_{C-^{119}Sn}$ 61.8, $^2J_{C-^{117}Sn}$ 59.2), SnCH$_2$*C*H$_2$), 28.4 (CH_3, C(*C*H$_3$)$_3$), 29.1 (CH_2, s, (and d satellite, $^3J_{C-^{119}Sn}$ 19.3), Sn(CH$_2$)$_2$*C*H$_2$CH$_3$), 54.0 (CH_2, *C*H$_2$N), 79.0 (C_{quat}, *C*(CH$_3$)$_3$), 142.9 (CH, =*C*H), 155.3 (C_{quat}, *C*=O), 160.1 (C_{quat}, *C*=CH); *m/z* (ES) 542.5 [(M + Na)$^+$, 100%], 442.4 (32, M – Boc + Na) [Found [M + Na]$^+$ 542.2432. $C_{23}H_{49}NNaO_2SiSn$ requires *M* + Na, 542.2452].

(2*Z*)-2-bromo-1-[*N*-(*tert*-butoxycarbonyl)]-3-trimethylsilanyl-prop-2-enylamine.



$CuBr_2$ (142 mg, 0.64 mmol) was added to a stirred solution of (2*Z*)-1-[*N*-(*tert*-butoxycarbonyl)]-2-tributylstannyl-3-trimethylsilanyl-prop-2-enylamine (150 mg, 0.29 mmol) in THF (1 mL). The mixture was stirred for 14 h, and then passed through a short SiO_2 pad, and washed with Et_2O (30 mL). Concentration under reduced pressure, and purification of the residue by SiO_2 column chromatography (hexane/Et_2O, 5:1) yielded (2*Z*)-2-bromo-1-[*N*-(*tert*-butoxycarbonyl)]-3-trimethylsilanyl-prop-2-enylamine as a pale brown oil (75 mg, 84%); R_f (hexane/Et_2O, 5:1) 0.32; υ_{max}(film)/cm^{-1} 3339s (N-H), 2957s, 1698s (C=O), 1614s, 1520s, 1455m, 1417m, 1392m, 1367s, 1336w, 1249s, 1171s, 1053m; δ_H(300 MHz; $CDCl_3$) 0.18 (9H, s, Si(C*H*$_3$)$_3$), 1.45 (9H, s, C(C*H*$_3$)$_3$), 3.90-4.02 (2H, m, C*H*$_2$N), 4.89 (1H, s (br), N*H*), 6.20 (1H, s, =C*H*); δ_C(75 MHz; $CDCl_3$) -1.1 (CH_3, Si(*C*H$_3$)$_3$), 28.2 (CH_3, C(*C*H$_3$)$_3$), [51.5, 52.8 (CH_2, *C*H$_2$N), rotamers], 79.7 (C_{quat}, *C*(CH$_3$)$_3$), [127.4, 127.9 (CH, =*C*H), rotamers], 138.3 (C_{quat}, =*C*), 155.3 (C_{quat}, *C*=O); *m/z* (ES) 332.0 {[M (Br 81) + Na]$^+$, 96%}, 330.0 [100, M (Br 79) + Na], 275.9 [37, M (Br 81) - ^{t}Bu + H + Na], 274.0 [42, [M (Br 79) - ^{t}Bu + H + Na] [Found [M (Br 79) + Na]$^+$ 330.0502. $C_{11}H_{22}BrNNaO_2Si$ requires *M* (Br 79) + Na 330.0501].

References:

1. I. Williams, B. M. Kariuki, K. Reeves and L. R. Cox, *Org. Lett.*, 2006, **8**, 4389-4392.
2. R. L. Hanson, M. D. Schwinden, A. Banerjee, D. B. Brzozowski, B.-C. Chen, B. P. Patel, C. G. McNamee, G. A. Kodersha, D. R. Kronenthal, R. N. Patel and L. J. Szarka, *Bioorg. Med. Chem.*, 1999, **7**, 2247-2252.
3. J. Guan, D. E. Kyle, L. Gerena, Q. Zhang, W. K. Milhous and A. J. Lin, *J. Med. Chem.*, 2002, **45**, 2741-2748.

4. Sheldrick, G.M. SHELXL. Program package for crystal structure determination. University of Gottingen, Germany.
5. R. A. Walsh and A. T. Bottini, *J. Org. Chem.*, 1970, **35**, 1086-1092.
6. S. Warren, A. Chow, G. Fraenkel and T. V. RajanBabu, 2003, **125**, 15402-15410.
7. T. T. Denton, X. Zhang and J. R. Cashman, *J. Am. Chem. Soc*., 2005, **48**, 224-239.