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5*H*-2-Pyrindines From 2-Bromocyclopentene-1-carboxaldehyde

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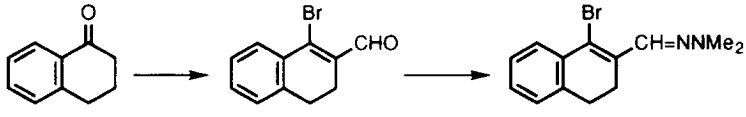
Abstract: The palladium(0) catalysed coupling of 2-bromocyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone 1 with vinylzinc halides and with 2-furyl- and 2-thienylzinc halides provides a route to the corresponding 2-vinyl- and 2-heteroaryl-cyclopentene-1-carboxaldehyde dimethylhydrazones. These cyclise thermally to 6,7-dihydro-5*H*-2-pyrindines (*e.g.*, **3**).

The thermal electrocyclic ring closure of 1-azatrienes has been used as a method of preparation of a variety of fused pyridines.[1] We have previously made use of the Vilsmeier-Haack formylation of cyclic ketones such as α-tetralone to produce intermediates suitable for conversion into 1-azatrienes (Scheme 1).[2,3] The bromoaldehydes so formed were converted into *NN*-dimethylhydrazones and the bromo substituent was then exchanged for a vinyl group by palladium(0) coupling. The aim of the work described in this paper was to extend this methodology to simple monocyclic ketones, of which cyclopentanone was chosen as an example. The electrocylic reaction was expected to provide a route to the 5*H*-2-pyrindine ring system.



Scheme 1

Cyclopentanone was converted into 2-bromocyclopentene-1-carboxaldehyde in 58% yield by reaction of cyclopentanone with phosphorus tribromide and DMF. This reaction was first carried out by Arnold and Holy, who reported that the product was unstable.[4] We found that the aldehyde could not be stored for more than 48 h at –20 °C without decomposition, so it was converted into its *N,N*-dimethylhydrazone **1**, which was much more stable, as soon as possible after purification.

We have previously shown that *N,N*-dimethylhydrazones of this type can participate in palladium(0) coupling reactions either as the electrophilic components (with vinylzinc halides) or as the nucleophilic components (by bromine–lithium exchange and transmetallation with zinc chloride). Both methods were investigated with the dimethylhydrazone **1**. We first investigated its use as the electrophilic component by coupling it to the vinylzinc chloride **2**, which is readily generated from (1-bromoethenyl)trimethylsilane. The

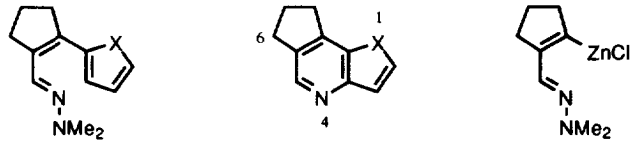
coupling was carried out at –20 °C with tetrakis(triphenylphosphine)palladium(0) as the catalyst. The reaction mixture in THF was then briefly heated to give 6,7-dihydro-4-trimethylsilyl-5*H*-2-pyrindine **3** as the only product (Scheme 2); the intermediate azatriene was not detected. Evidently this cyclises at or below 60 °C with the loss of dimethylamine. This easy cyclisation of a 1-azatriene in which neither of the carbon–carbon double bonds is part of an aromatic ring has been observed before.[3] The pyridine was identified from its ^{1}H NMR spectrum which showed signals at δ 8.54 and 8.60 for the hydrogen atoms attached to aromatic ring. It was characterised by conversion to a picrate.

1 **3**

Reagents: i, $H_2C{=}C(ZnBr)SiMe_3$ (**2**), $Pd(PPh_3)_4$ cat.; ii. <60 °C

Scheme 2

Analogous coupling reactions were carried out with 2-furylzinc bromide and with 2-thienylzinc bromide. The products of coupling, the hydrazones **4** and **5**, were isolated in moderate yield and were fully characterised. Compound **4** was heated under reflux in 1-octanol (b.p. 196 °C) in an attempt to induce it to cyclise, but it was recovered unchanged. The cyclisation could, however, be achieved by flash vacuum pyrolysis of the dimethylhydrazone at 600 °C and 10^{-3} mmHg. The dimethylhydrazone cyclised under the same conditions. The structures **6** and **7** for the cyclisation products were supported by their ^{1}H NMR spectra. The spectrum of compound **6** showed signals for H-2 and H-3 on the furan ring as doublets (*J* 2.2 Hz) at δ 7.76 and 6.96 and for H-5 on the pyridine ring as a singlet at δ 8.45. The corresponding signals in the spectrum of compound **7** appeared at δ 7.65, 7.56 and 8.59, these values being close to those reported for a known compound containing this ring system, 6-ethylthieno[3,2-*b*]pyridine.[5]



4 (X = O)
5 (X = S)

6 (X = O)
7 (X = S)

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An attempt to prepare the dimethylhydrazone **5** by an inverse coupling procedure met with only moderate success. 2-Bromocyclopentenecarboxaldehyde dimethylhydrazone **1** was treated with butyllithium at –78 °C and then with zinc chloride at –20 °C; the chlorozinc intermediate **8** so generated was then reacted with 2-iodothiophene in the presence of tetrakis(triphenylphosphine)palladium(0). The dimethylhydrazone **5** was isolated from the reaction mixture in 39% yield. The methodology thus appeared to offer no advantages over the normal palladium coupling procedure. However, the success of the bromine–lithium exchange allowed other electrophiles to be introduced into the 2-position. The intermediate was intercepted by reaction

with cyclohexanecarboxaldehyde and with the ketones acetophenone, cyclohexanone and ethyl pyruvate. The alcohols **9–12** were isolated in moderate to good yield. The alcohols **10** and **11** were then dehydrated by heating in toluene with a few crystals of *p*-toluenesulfonic acid. The products isolated were the fused pyridines **13** and **14**; the intermediate azatrienes were not detected. Compound **14** has been reported previously as a component of an inseparable mixture.[6] The NMR spectrum reported for the compound was consistent with that obtained from our sample. A different synthesis of compound **13** has also been described recently.[7] Both compounds **13** and **14** were characterised by forming crystalline picrates from them. The alcohols **9** and **12** both gave complex mixtures when they were heated with *p*-toluenesulfonic acid.

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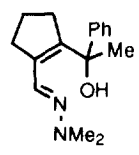

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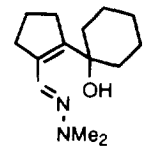

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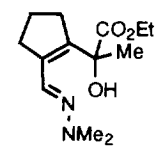

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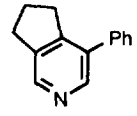

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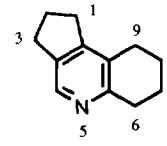

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These results and related studies[1–3] allow some general conclusions to be drawn about the formation of the pyridine ring system from such 1-azatrienes. As expected the reactions go easily (at temperatures below 100 °C) when neither of the carbon–carbon double bonds is part of an aromatic ring system. Those in which the central double bond is aromatic require higher temperatures, usually in the range 100 °C to 200 °C. The temperature of cyclisation is at the lower end of this range when there is a degree of bond fixation, as in the 2,3-double bond of indoles. When the terminal double bond is part of an aromatic ring system the cyclisation is much more difficult, but it can be brought about by flash vacuum pyrolysis.

EXPERIMENTAL

^{1}H nmr spectra were recorded either on a Bruker AC 200 (200 MHz) or on a Bruker AMX 400 (400 MHz) spectrometer. Multiplicities are recorded as broad peaks (br), singlets(s), doublets(d), triplets(t), quartets(q) and multiplets(m). Infrared spectra were recorded either on a Perkin-Elmer 298 or on a Perkin-Elmer 1720-X FTIR spectrometer. Solid samples were run as KBr discs or nujol mulls as indicated, and liquids as thin films. Mass spectra were recorded on a VG micromass 7070E as electron impact or chemical ionisation spectra. Microanalyses were performed in the University of Liverpool Microanalysis Laboratory. Melting points (m.p.) were determined on a Kofler block. Flash column chromatography was carried out

using Mackerey Nagel MN-Kieselgel 60 and hand bellows or an air line to supply the pressure to the column. Thin layer chromatography (tlc) was carried out on Merck 10 x 2 cm aluminium-backed plates with a 0.2 mm layer of Kieselgel 60 F_{254}.

2-Bromocyclopentene-1-carboxaldehyde.[4] Dry DMF (5.53 ml, 71.0 mmol) in dry dichloromethane (20 ml) was cooled to 0 °C, and phosphorus tribromide (5.65 ml, 59.5 mmol) was then added dropwise. The mixture was stirred at 0 °C for 1 h and a white suspension was formed. A solution of cyclopentanone (2.1 ml, 23.8 mmol) in dry dichloromethane (20 ml) was added and the solution stirred at room temperature for 17 h. The solvent was removed *in vacuo*, the oily residue poured onto ice (*ca* 100g) and solid sodium hydrogen carbonate was added slowly until effervescence had subsided. Extraction into ether, washing with aqueous potassium carbonate followed by drying ($MgSO_4$) and removal of the solvent *in vacuo* gave a red-brown oil. Flash column chromatography eluting with dichloromethane gave 2-bromocyclopentene-1-carboxaldehyde (2.37g, 58%) as a pale yellow oil (Found: C, 41.3; H, 4.1. Calc. for C_6H_7BrO: C, 41.3; H, 4.1%); δ (200 MHz; $CDCl_3$) 2.04–2.11 (2 H, m), 2.52 (2 H, t, *J* 6.9 Hz), 2.91 (2 H, t, *J* 6.9 Hz) and 8.82 (1 H, s, C<u>H</u>O); ν_{max} (film)/cm^{-1} 2710, 2660, 1670 and 1595; *m/z* 173.9679 (M^+, 83%. C_6H_7BrO requires 173.9680), 149 (65) and 65 (100).

2-Bromocyclopentene-1-carboxaldehyde N,N-dimethylhydrazone **1**. To a solution of 2-bromocyclopentene-1-carboxaldehyde (1.95 g, 11.27 mmol) in dichloromethane (20 ml) was added 1,1-dimethylhydrazine (1.03 ml, 13.52 mmol) followed by a few crystals of *p*-toluenesulfonic acid. The solution was stirred at room temperature for 17 h. Removal of the solvent *in vacuo* followed by flash column chromatography eluting with dichloromethane (100%) gave *2-bromocyclopentene-1-carboxaldehyde N,N-dimethylhydrazone* **1** (2.32 g, 95%) as a yellow oil (Found: C, 44.1; H, 6.0; N, 13.0. $C_8H_{13}BrN_2$ requires C, 44.2; H, 6.0; N, 12.9%); δ (200MHz; $CDCl_3$); 1.85–2.06 (2 H, m), 2.54 (2 H, t, *J* 7.4 Hz), 2.71 (2 H, t, *J* 7.4 Hz), 2.94 (6 H, s, N<u>Me</u>2) and 7.11 (1 H, s, C<u>H</u>=N); ν_{max} (film)/cm^{-1} 2954, 2851, 1632, 1551 and 740;*m/z* 216.0261 (M^+, 67%. $C_8H_{13}BrN_2$ requires 216.0262) and 137 (100).

4-Trimethylsilyl-6,7-dihydro-5<u>H</u>-2-pyrindine **3**. Butyllithium (2.3 <u>M</u>, 2.6 ml, 6.0 mmol) was added dropwise to a stirred solution of (1-bromoethenyl)trimethylsilane (0.69 ml, 5.6 mmol) in dry THF (20 ml) at –78 °C. The mixture was stirred at –78 °C for 1 h to form the yellow organolithium species and zinc chloride (1 <u>M</u>, 8.37 ml, 8.37 mmol) was then added. The resulting solution was stirred at –20 °C for 1 h and a solution containing 2-bromocyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone **1** (1.09 g, 5.0 mmol) and $Pd(PPh_3)_4$ in dry THF (15 ml) was then added. The solution was heated under reflux for 3 h. Aqueous ammonium chloride was added and the mixture extracted into ethyl acetate, dried ($MgSO_4$) and the solvent removed *in vacuo* to leave a yellow oil. Purification by flash column chromatography eluting with dichloromethane gave *4-trimethylsilyl-6,7-dihydro 5<u>H</u>-2-pyrindine* **3** (0.62 g, 65%); δ (400 MHz; $CDCl_3$) 0.29 (9 H, s, Si<u>Me</u>3), 2.29–2.37 (2 H, m), 3,14–3.49 (4 H, m), 8.54 (1 H, s) and 8.60 (1 H, s), *m/z* 191 (M^+, 26%) and 176 (100), which was further characterised as its *picrate*, m.p. 140 °C (decomp.) (Found: C, 48.5; H, 4.8; N, 13.3. $C_{17}H_{20}N_4SiO_7$ requires C, 48.5; H, 4.8; N, 13.3%).

2-(2-Furyl)cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone **4**. Furan (0.5 ml, 6.88 mmol) was converted into 2-furyllithium by reaction with butyllithium (2.1 <u>M</u>, 3.60 ml, 7.6 mmol) and TMEDA (1.04 ml,

6.88 mmol) in THF (10 ml) at 0 °C for 0.5 h. A solution of zinc chloride (1 M, 10.3ml, 10.3 mmol) was added and the mixture stirred at –20 °C for 40 min. A solution of $Pd(PPh_3)_4$ (0.318 g, 4 mol%) and 2-bromocyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone **1** (0.57 g, 2.6 mmol) in THF (10 ml) was added and the reaction mixture allowed to warm to room temperature and heated to reflux for 17 h. Ammonium chloride was added and the mixture extracted into ether, dried ($MgSO_4$) and the solvent removed *in vacuo* to leave a yellow oil. Purification by flash column chromatography eluting with dichloromethane gave *2-(2-furyl)cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone* **4** (0.28 g, 52%) as a yellow solid, m.p. 48 °C (Found: C, 70.5; H, 7.8; N, 13.5. $C_{12}H_{16}N_2O$ requires C, 70.5; H, 7.8; N, 13.7%); δ (400 MHz; $CDCl_3$) 1.91–1.96 (2 H, m), 2.72 (2 H, t, *J* 7.4 Hz), 2.78 (2 H, t, *J* 7.4 Hz), 2.94 (6 H, s, NMe$_2$), 6.22 (1 H, d, *J* 1.3 Hz, furan H-3), 6.40 (1 H, dd, *J* 1.9 and 3.3 Hz, furan H-4), 7.44 (1 H, d, *J* 1.6 Hz, furan H-5) and 8.00 (1 H, s, CH=N); ν_{max} (CH_2Cl_2)/cm^{-1} 3000 and 2800; *m/z* 204.1265 (M^+,100%. $C_{12}H_{16}N_2O$ requires 204.1263), 158(46) and 132 (13).

2-(2-Thienyl)cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone **5**. *Method 1*. Thiophene (0.5 ml, 6.2 mmol) was converted into 2-thienyllithium by reaction with butyllithium (2.1 M, 3.26 ml, 6.85 mmol) and TMEDA (0.47 ml, 6.2 mmol) in THF (10 ml) at 0 °C for 0.5 h. A solution of zinc chloride (1 M, 9.3 ml, 9.3 mmol) was added and the mixture stirred at –20 °C for 40 min. A solution of $Pd(PPh_3)_4$ (0.287 g, 4 mol%) and 2-bromocyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone **1** (1.35 g, 6.25 mmol) in THF (10 ml) was added and the reaction mixture allowed to warm to room temperature and heated to reflux for 1 h. Ammonium chloride was added and the mixture extracted into ether, dried ($MgSO_4$) and the solvent removed *in vacuo* to leave a yellow oil. Purification by flash column chromatography eluting with dichloromethane (100%) gave *2-(2-thienyl)cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone* **5** (0.70 g, 51%) (Found: C, 65.4; H, 7.3; N, 12.6. $C_{12}H_{16}N_2S$ requires C, 65.4; H, 7.3; N, 12.6%); δ (400 MHz; $CDCl_3$) 1.98–2.00 (2 H, m), 2.82 (2 H, t, *J* 7.4 Hz), 2.88 (2 H, t, *J* 7.4 Hz), 2.96 (6 H, s, NMe$_2$), 7.02- 7.05 (2 H, m, thiophene H-3 and H-4), 7.25 (1 H, d, *J* 4,9 Hz, thiophene H-5), 7.78 (1 H, s CH=N); ν_{max} (CH_2Cl_2)/cm^{-1} 3000 and 2800; *m/z* 220.1029 (M^+, 100%. $C_{12}H_{16}N_2S$ requires 220.1034) and 174 (75).

Method 2. A solution of 2-bromocyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone **1** (0.25 g, 1.15 mmol) in dry THF (15 ml) was allowed to react with butyllithium (2.37 M, 0.53 ml, 1.25 mmol) at –78 °C. After 1 h zinc chloride (1 M, 1.73 ml, 1.73 mmol) was added and the reaction mixture was warmed to –20 °C. After 1 h a solution of $Pd(PPh_3)_4$ (0.05 g, 4 mol%) and 2-iodothiophene (0.11 ml, 1.15 mmol) in THF (10 ml) was added and the reaction mixture allowed to warm to room temperature and then heated to reflux for 17 h. Aqueous ammonium chloride was added the reaction mixture extracted into ethyl acetate, dried ($MgSO_4$) and the solvent removed *in vacuo*. Purification of the residue by flash column chromatography eluting with cyclohexane–ethyl acetate (4:1) gave an oil which was identified by NMR as cyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone (0.07 g, 44%), δ (200MHz; $CDCl_3$) 1.86–2.03 (2 H, m), 2.41 (2 H, m), 2.54–2.63 (2 H, m), 2.84 (6 H, s, NMe$_2$), 5.78–5.83 (1 H, br m) and 7.24 (1 H, s, CH=N); and *2-(2-thienyl)cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone* **5** (0.10 g, 39%) as a yellow oil.

2-[Cyclohexyl(hydroxy)methyl]cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone **9**. A solution of 2-bromocyclopentene-1-carboxaldehyde*N,N*-dimethylhydrazone **1** (0.50 g, 2.3 mmol) in dry THF (15 ml) at –78 °C was allowed to react with butyllithium (2.3 M, 1.1 ml, 2.5 mmol). After 1 h a solution of

cyclohexanecarboxaldehyde (0.26 g, 2.3 mmol) in dry THF (10 ml) was added dropwise and the solution was stirred at –78 °C for a further 0.5 h and the reaction to warm to room temperature. Ammonium chloride was added and the mixture extracted into ether, dried ($MgSO_4$) and the solvent removed *in vacuo* to give a yellow oil. Purification by flash column chromatography eluting with dichloromethane gave *2-[cyclohexyl(hydroxy)methyl]cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone* **9** (0.38 g, 66%) as a yellow oil (Found: C, 71.5; H, 10.5; N, 11.0. $C_{15}H_{26}N_2O$ requires C, 71.9; H, 10.5; N, 11.2%); δ (400 MHz; $CDCl_3$) 0.81–1.91 (12 H, m), 2.06 (1H, m), 2.55–2.64 (4 H, m), 2.85 (6 H, s, NMe_2), 4.25 (1 H, d, *J* 8.6 Hz) and 7.26 (1 H, s, CH=N) (OH signal not observed); ν_{max} (film)/cm^{-1} 3520–3220, 2940, 2860, 1740 and 1720; *m/z* 250.2045 (M^+, 24%. $C_{15}H_{26}N_2O$ requires 250.2045), 232 (11), 206 (15) and 167 (100).

2-(1-Hydroxy-1-phenylethyl)cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone **10**. A solution of 2-bromocyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone **1** (0.50 g, 2.3 mmol) in dry THF (15 ml) at –78 °C was allowed to react with butyllithium (2.3 M, 1.1 ml, 2.53 mmol). After 1 h acetophenone (0.28 g, 2.3 mmol) in THF (10 ml) was added dropwise and the solution was stirred at –78 °C for a further 0.5 h and the reaction to warm to room temperature. Ammonium chloride was added and the mixture extracted into ether, dried ($MgSO_4$) and the solvent removed *in vacuo* to give a red-brown oil. Purification by flash column chromatography eluting with dichloromethane gave *2-(1-hydroxy-1-phenylethyl)cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone* **10** as a brown oil (0.28 g, 47%) δ (400 MHz; $CDCl_3$) 1.66 (3 H, s, Me), 1.80–1.86 (2 H, m), 2.47–2.65 (4 H, m), 2.69 (6 H, s, NMe_2), 6.93 (1 H, s, CH=N), 7.17–7.20 (1 H, m), 7.26–7.29 (2 H, m) and 7.44 (2 H, d, *J* 7.4 Hz) (OH signal not observed); ν_{max} (film)/cm^{-1} 3340, 3460, 2860 and 2960; *m/z* 258.1730 (M^+, 20%. $C_{16}H_{22}N_2O$ requires 258.1732), 240 (17), 215 (57) and 59 (100).

2-(1-Hydroxycyclohex-1-yl)cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone **11**. A solution of 2-bromocyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone **1** (0.50 g, 2.3 mmol) in dry THF (15 ml) at –78 °C was allowed to react with butyllithium (2.3 M, 1.1 ml, 2.53 mmol). After 1 h cyclohexanone (0.23 g, 2.3 mmol) in THF (10 ml) was added dropwise and the solution was stirred at –78 °C for a further 0.5 h and the reaction to warm to room temperature. Ammonium chloride was added and the mixture extracted into ether, dried ($MgSO_4$) and the solvent removed *in vacuo* to give a yellow oil. Purification by flash column chromatography eluting with dichloromethane gave *2-(1-hydroxy-1-cyclohexyl)cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone* **11** (0.34 g, 61%) as a yellow oil; δ (400 MHz; $CDCl_3$) 1.47–1.55 (4 H, m), 1.65–1.79 (8 H, m,), 2.49 (2 H, t, *J* 5.5Hz)), 2.59 (2 H, t, *J* 5.5Hz), 2.83 (6 H, s, NMe_2) and 7.46 (1 H, s, CH=N) (OH signal not observed); ν_{max} (film)/cm^{-1} 3500, 3300, 2940 and 2820; *m/z* 236.1887 (M^+, 19%. $C_{14}H_{24}N_2O$ requires 236.1888), 218 (40), 189 (66), 179 (17), 172 (40) and 146 (100).

2-(1-Ethoxycarbonyl-1-hydroxyethyl)cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone **12**. A solution of 2-bromocyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone **1** (0.50 g, 2.3 mmol) in dry THF (15 ml) at –78 °C was allowed to react with butyllithium (2.3 M, 1.1 ml, 2.53 mmol). After 1 h a solution of ethyl pyruvate (0.27 g, 2.3 mmol) in dry THF (10 ml) was added dropwise and the solution was stirred at –78 °C for a further 0.5 h and the reaction to warm to room temperature. Ammonium chloride was added and the mixture extracted into ether, dried ($MgSO_4$) and the solvent removed *in vacuo* to give a yellow oil. Purification by flash column chromatography eluting with dichloromethane gave *2-(1-ethoxycarbonyl-1-*

hydroxyethyl)cyclopentene-1-carboxaldehyde N,N-dimethylhydrazone **12** (0.41 g, 69%) as a red oil (Found: C, 61.6; H, 8.7; N, 11.0. $C_{13}H_{22}N_2O_3$ requires C, 61.4; H, 8.7; N, 11.0%);δ (400 MHz; $CDCl_3$) 1.24 (3 H, t, *J* 7.1 Hz), 1.58 (3 H, s, Me), 1.78–1.85 (2 H, m), 2.60–2.66 (4 H, m), 2.87 (6 H, s, NMe_2), 4.18 (2 H, q, *J* 7.1 Hz), 7.25 (1 H, s, CH=N) (OH signal not observed); ν_{max} (film)/cm^{-1} 3530–3280, 2960 and 1730; *m/z* 254.1634 (M^+, 18%. $C_{13}H_{22}N_2O_3$ requires 254.1630), 211 (14), 181 (81) and 59 (100).

Flash vacuum pyrolysis of 1-heteroaryl-N,N-dimethylhydrazones. General procedure. The hydrazone was subjected to flash vacuum pyrolysis (600 °C and 1.3 x 10^{-3} mmHg) over a period of approximately 4 h. The solid was allowed to sublime under vacuum through a heated silica tube (20 cm) onto a glass cold finger cooled with liquid nitrogen. The pyrolysate was then extracted off the cold finger with dichloromethane, the solvent was removed *in vacuo*, and the product was purified by column chromatography.

7,8-Dihydro-6H-cyclopenta[d]furo[3,2-b]pyridine **6**. Pyrolysis of 2-(furyl)cyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone **4** (0.145 g, 0.71 mmol) gave *7,8-dihydro-6H-cyclopenta[d]furo [3,2-b]pyridine* **6** (0.06 g, 53%) as an orange gum after flash column chromatography (dichloromethane); δ (400 MHz; $CDCl_3$) 2.20–2.27 (2 H, m), 3.06 (2 H, t, *J* 7.4 Hz), 3.15 (2 H, t. *J* 7.4 Hz), 6.96 (1 H, d, *J* 2.2 Hz), 7.76 (1 H, d, *J*, 2.2 Hz) and 8.45 (1 H, s); *m/z* 159.0687 (M^+, 100%. $C_{10}H_9NO$ requires 159.0684).

7,8-Dihydro-6H-cyclopenta[d]thieno[3,2-b]pyridine **7**. Pyrolysis of 2-(2-thienyl)cyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone **5** (0.102 g, 0.46 mmol) gave *7,8-dihydro-6H-cyclopenta[d]thieno[3,2-b]pyridine* **7** (0.043 g, 53%) as an orange gum after flash column chromatography (dichloromethane); δ (400 MHz; $CDCl_3$) 2.22–2.30 (2 H, m), 3.04–3.14 (4 H, m), 7.56 (1 H, d, *J* 5.4Hz), 7.65 (1 H, d, *J* 5.4 Hz) and 8.59 (1 H, s); *m/z* 175.0450 (M^+, 71%). $C_{10}H_9NS$ requires 175.0455) and 174 (100).

4-Phenyl-6,7-dihydro-5H-2-pyrindine **13**. A solution of 2-(1-hydroxy-1-phenylethyl)cyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone **10** (0.20 g, 0.78 mmol) in toluene (50 ml) containing a catalytic amount of *p*-toluenesulfonic acid was heated under reflux for 21 h. The reaction mixture was washed with aqueous sodium hydrogen carbonate, extracted into ether, dried ($MgSO_4$) and the solvent removed *in vacuo* to give a brown oil. Purification by flash column chromatography eluting with dichloromethane then methanol gave *4-phenyl-5,6-dihydro-5H-2-pyrindine* **13** (0.13 g, 86%); δ (200 MHz; $CDCl_3$) 2.00–2.40 (2 H, m), 2.90–3.10 (4 H, m), 7.30–7.50 (5 H, m), 8.40 (1 H, s) and 8.50 (1 H, s), *m/z* 195 (M^+, 100%) and 193 (92).which was further characterised by preparing its *picrate*, m.p. 186–188 °C (Found: C, 56.6; H, 3.8; N, 13.0. $C_{20}H_{16}N_4O_7$ requires C, 56.6; H, 3.8; N, 13.2%).

2,3,6,7,8,9-Hexahydro-1H-cyclopenta[c]quinoline **14**. A solution of 2-(1-hydroxycyclohex-1-yl)cyclopentene-1-carboxaldehyde *N,N*-dimethylhydrazone **11** (0.17 g, 0.72 mol) in toluene (50 ml) containing a catalytic amount of *p*-toluenesulfonic acid was heated to reflux for 15 h. The reaction mixture was washed with aqueous sodium hydrogen carbonate, extracted into ether, dried ($MgSO_4$) and the solvent removed *in vacuo* to give a brown oil. Purification by flash column chromatography eluting with dichloromethane and washing with methanol gave *2,3,6,7,8,9-hexahydro-1H-cyclopenta[c]quinoline* **14** (0.10 g, 80%); δ (200 MHz; $CDCl_3$) 1.77–1.85 (4 H, m), 1.97–2.14 (2 H, m), 2.60–2.80 (4 H, m), 2.82–2.94 (4 H, m) and 8.23 (1 H, m),

m/z 173 (M^+, 100%) which was further characterised by preparing its *picrate*, m.p. 188 °C (decomp.) (Found: C, 53.7; H, 4.5; N, 13.8. $C_{18}H_{18}N_4O_7$ requires C, 53.7; H, 4.5; N, 13.9%).

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