Studies towards the synthesis of diazonamide A. Unexpected formation of a 3,4-bridged indole

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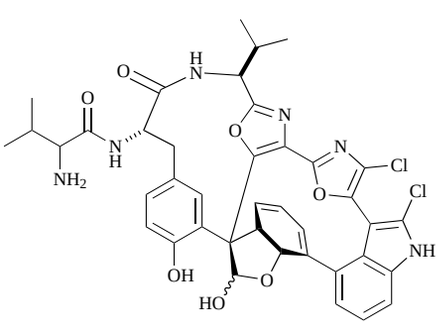
Model studies towards the synthesis of the cytotoxic marine natural product diazonamide A are described. Three model 3-phenylbenzo[*b*]furan derivatives 5, 8 and 10 were prepared using rhodium(II) catalysed decomposition of the diazophenylacetate 3, Claisen rearrangement of the ether 7, and a classical intramolecular Friedel–Crafts reaction as key steps. Only the aromatic benzofuran system proved satisfactory in palladium coupling reactions; diazoacetyl(benzofuranyl)indole 18 was prepared by Suzuki coupling of (benzofuran-7-yl)boronic acid 11 with 4-bromoindole 14 to give 17, followed by diazo-transfer. Rhodium(II) catalysed decomposition of 18 in acetonitrile resulted in the formation of the 3,4-bridged indole 19 rather than the desired oxazole 20.

Recently the isolation of a number of oxazole containing natural products, particularly from marine sources, has caused a renewed interest in the chemistry of oxazoles.[1,2] Naturally occurring oxazoles range in structure from relatively simple 2,5-substituted derivatives to more complex bis-oxazoles such as the diazonamides. The diazonamides, exemplified by diazonamide A **1**, isolated from the ascidan *Diazona chinensis*[3] show potent anticancer activity, and their fascinating structure incorporating a unique array of heterocyclic rings has made them attractive targets for synthesis. Konopelski *et al.*[4] have recently disclosed one approach to diazonamide A fragments based on cross-coupling methodology for the functionalisation of the indole 4-position and the catalysed decomposition of diazocarbonyl compounds developed by us[5–7] and others[8] for the formation of the oxazole fragment.



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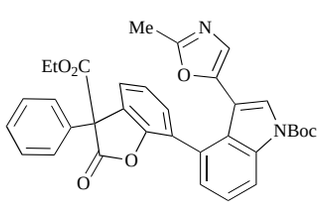

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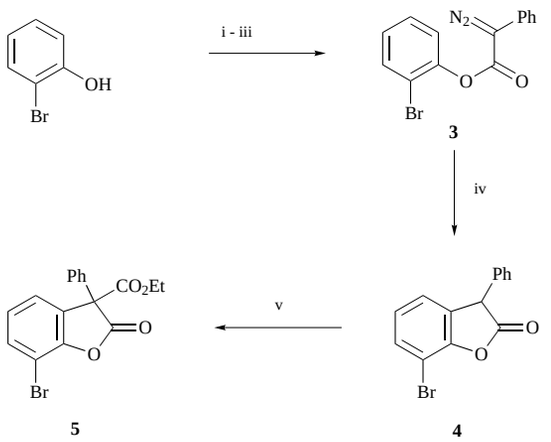
Following our recent synthesis of simple bis-oxazoles,[5] and of the 3-(oxazol-5-yl)indole alkaloids using rhodium(II) catalysed reactions of diazocarbonyl compounds with nitriles,[6,7] we turned our attention to the synthesis of model compounds for the 4-benzofuranyl-3-oxazolylindole fragment of diazonamide A, in which a simple phenyl group replaces the tyrosine residue of the natural product. In particular we targeted compound **2** in which a cyclisation of an anion derived from the 2-methyloxazole onto the 3-ester of the benzofuranone will complete the formation of the lower diazonamide fragment and allow elaboration of the valine-derived oxazole.[9] We now report the results of our initial studies in this area.[10]

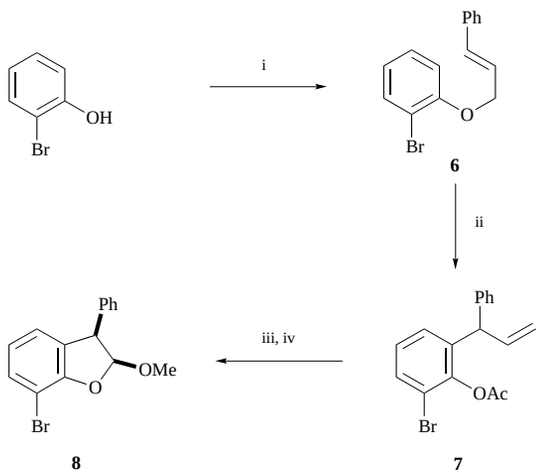
Results and discussion

We have previously reported the formation of oxoindolines by intramolecular rhodium(II) catalysed aromatic C–H insertion reactions,[11] and in particular have established that catalysts bearing perfluorinated amide ligands are particularly effective for such transformations. We wished to extend this methodology to the synthesis of benzofuranones as precursors to the 2-hydroxybenzofuran ring of diazonamide A. From the outset we had intended to join the indole and benzofuran rings using palladium catalysed cross-coupling, so that the 7-bromobenzofuran derivatives **4** and **5** were chosen as initial targets. The diazophenylacetate substrate **3** was prepared in a straightforward manner from 2-bromophenol (Scheme 1). However, rhodium(II) perfluorobutyramide-catalysed decomposition of **3** provided the desired benzofuranone **4** in only 20% yield (Scheme 1). This poor yield in the intramolecular aromatic C–H insertion reaction is in direct contrast to the preparation of 3-acetylbenzofuran-2-ones by the rhodium(II) catalysed decomposition of the corresponding α-diazo-β-keto esters which are reported to proceed in high yield.[12] Presumably the additional carbonyl substituent renders the intermediate carbenoid more electrophilic. Nevertheless sufficient benzofuranone **4** was obtained, and following the method of Black *et al.*[13] it was *C*-acylated in high yield to give the 3-ester **5**.

In view of the poor yield in the rhodium(II) catalysed cyclisation reaction, we investigated an alternative route to 3-arylbenzofuran derivatives based on the Claisen rearrangement.[14] Thus Claisen rearrangement of the cinnamyl ether **6** in the presence of acetic anhydride gave the desired rearranged



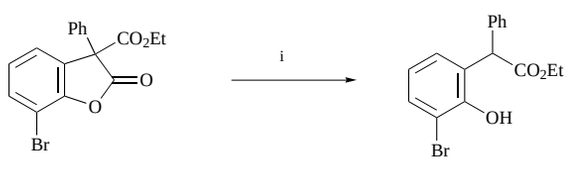
Scheme 1 *Reagents and conditions:* i, $PhCOCO_2H$, DCC; ii, $TsNHNH_2$; iii, Et_3N (47% overall); iv, $Rh_2(NHCOC_3F_7)_4$, CH_2Cl_2, reflux (20%); v, EtOCOCl, Et_3N, DMAP (96%)



Scheme 2 *Reagents and conditions:* i, $PhCH{=}CHCH_2Cl$, K_2CO_3, acetone (85%); ii, $PhNMe_2$, Ac_2O, heat (81%); iii, O_3, CH_2Cl_2, −78 °C, then Me_2S; iv, MeOH, aq. ammonia (36% overall)

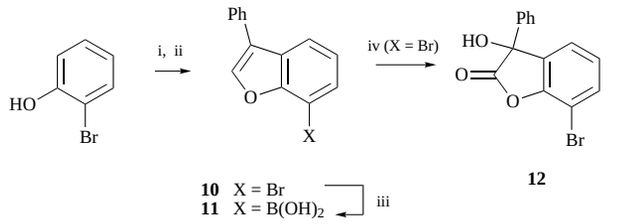
acetoxybenzene **7** (Scheme 2). Ozonolysis gave an intermediate aldehyde, which was intercepted by the phenol liberated by treatment of the crude product with methanolic aqueous ammonia to give the 2-methoxydihydrobenzofuran **8** (Scheme 2). Dihydrobenzofuran **8** is formed as a mixture of diastereoisomers (*ca.* 16 : 1 by ^{1}H NMR spectroscopy) and a combination of NOE studies and comparison of coupling constants with literature values[15] suggested that the major product was the *cis*-isomer.

Initial experiments showed that the required cross-coupling reactions were not as straightforward as anticipated. Thus, Stille couplings of benzofuranones **4** or **5** with phenyltrimethyltin were not successful, despite extensive modification of the reaction parameters. Suzuki couplings are often more facile, but in this case we were only able to isolate products such as **9**, derived from hydrolysis and decarboxylation upon attempted palladium catalysed coupling of **5** with phenylboronic acid under standard conditions (Scheme 3).



Scheme 3 *Reagents and conditions:* i, $PhB(OH)_2$, $(Ph_3P)_4Pd$, Na_2CO_3, aq. DME (57%)

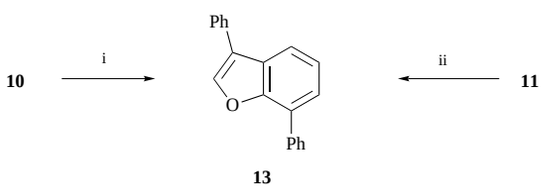
Because of the problems encountered in coupling benzofuranones, we turned our attention to more robust 3-arylbenzofurans as coupling partners, with the intention of carrying out a subsequent oxidation of the benzofuran to a benzofuranone. Adam has shown that benzofurans are readily oxidised to benzofuran-2-ones by the action of dimethyldioxirane[16] and in our case the 7-bromobenzo[*b*]furan **10**, prepared conventionally as shown in Scheme 4, was quantitatively con-



Scheme 4 *Reagents and conditions:* i, $PhCOCH_2Br$, K_2CO_3, acetone (92%); ii, PPA, heat (80%); iii, BuLi, $B(OMe)_3$, aq. work-up (80%); iv, dimethyldioxirane, acetone (100%)

verted to the 3-hydroxybenzo[*b*]furan-2-one **12**. Removal of the doubly benzylic hydroxy group in **12** would not be expected to be particularly difficult, so we proceeded to investigate cross-coupling reactions of **10** as a route to benzofuranylindoles related to diazonamide A.

In principle **10** can be coupled directly with a 4-substituted (*e.g.* boron, tin) indole derivative, or with a 4-haloindole through initial conversion of **10** to a suitable 'metal' derivative. Preliminary studies showed that **10** could be phenylated to give the 7-phenyl derivative **13** either directly with phenylboronic acid, or indirectly by conversion into the boronic acid **11** followed by reaction with bromobenzene (Scheme 5). Both



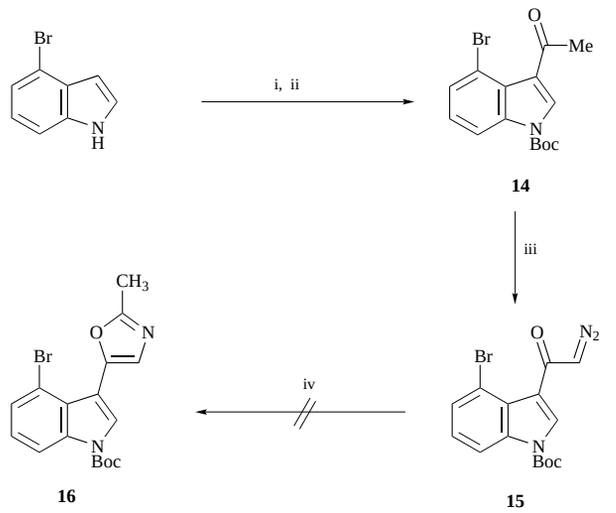
Scheme 5 *Reagents and conditions:* i, $PhB(OH)_2$, $(Ph_3P)_4Pd$, Na_2CO_3, aq. DME (81%); ii, PhBr, $(Ph_3P)_4Pd$, Na_2CO_3, aq. DME (67%)

these processes occurred with comparable efficiency but the ease of preparation of **11** led us to choose it as a coupling partner and we therefore addressed the coupling of this compound with a suitable 4-haloindole derivative.

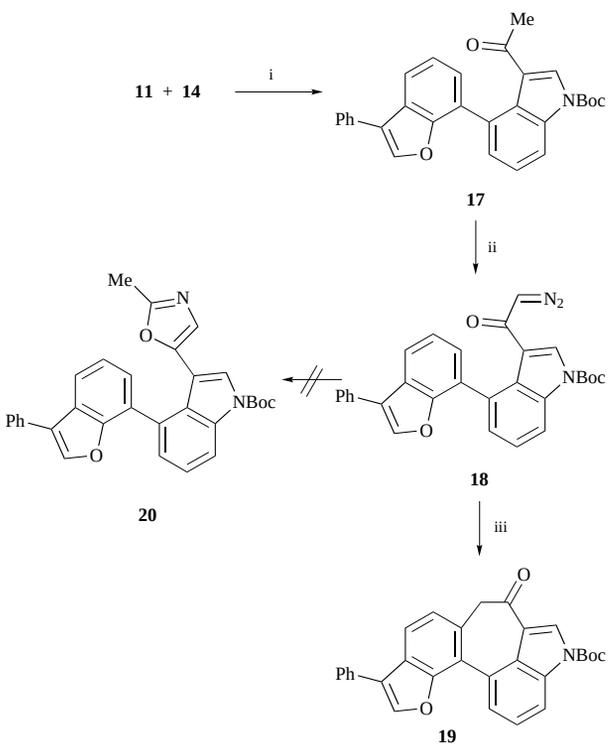
4-Bromoindole[17] was acetylated under Vilsmeier conditions and subsequent reaction with $(Boc)_2O$ gave the *N*-protected indole **14**. The original intention was to elaborate the acetyl group into the oxazole ring using our previously developed synthesis of 3-oxazolylindoles,[6] and to this end, the diazo ketone **15** was prepared using Danheiser's modified diazo-transfer procedure.[18]

Unfortunately rhodium(II) catalysed decomposition of **15** in acetonitrile resulted in none of the desired oxazole **16** (Scheme 6) and therefore we decided to form the oxazole ring *after* the biaryl coupling. It is interesting to note that in the attempted formation of compounds **4** and **16**, both substrates possess a bromine atom close to the site of generation of the carbenoid. It therefore seems possible that the formation of a cyclic bromonium ylide is competing with the desired reaction.[19]

The Suzuki reaction between the benzofuranylboronic acid **11** and the 4-bromoindole **14** proceeded smoothly and gave the desired 4-(benzofuran-7-yl)indole **17** in 80% yield (Scheme 7).[20] Diazo-transfer under the Danheiser conditions gave the diazo ketone **18**, rhodium(II) acetate catalysed decomposition of which in acetonitrile gave a complex mixture. When rhodium(II) perfluorobutyramide was used as catalyst a product



Scheme 6 *Reagents and conditions:* i, Me_2NCOCH_3, $POCl_3$ (70%); ii, $(Boc)_2O$, DMAP, MeCN (94%); iii, LHMDS, $CF_3CO_2CH_2CF_3$; MsN_3, Et_3N (74%); iv, cat. Rh^{2+}, MeCN



Scheme 7 *Reagents and conditions:* i, $(Ph_3P)_4Pd$, Na_2CO_3, aq. DME (80%); ii, LHMDS, $CF_3CO_2CH_2CF_3$, MsN_3, Et_3N (82%); iii, $Rh_2(NHCOC_3F_7)_4$, MeCN (24%)

was found in low yield (24%). However, this turned out not to be the desired oxazole **20** but the unusual 3,4-bridged indole **19**, the result of a formal intramolecular aromatic C–H insertion reaction at the 6-position of the benzofuran. The formation of the 3,4-bridged indole **19** was surprising in that the external carbenoid trap (acetonitrile) was used in large excess, but is in line with our previous observations that fluorinated carboxamide ligands on rhodium favour aromatic C–H insertion reactions.[11]

Conclusions

Although the desired target **2** has yet to be obtained, the model study has provided useful information; the efficiency of the Suzuki coupling for the construction of the 4-benzofuranyl-3-acetylindole fragment **17** is impressive and the use of the benzo[*b*]furan as an extremely robust precursor to the 2-hydroxybenzofuran ring of diazonamide A is attractive. Recent work within our group has secured an efficient route to valine-derived oxazoles,[9] and we are currently investigating other methods for the formation of suitably functionalised indolyl-oxazoles. The results of these investigations will be reported in due course.

Experimental

For general points, see ref. 11(*c*).

2-Bromophenyl 2-diazo-2-phenylacetate 3

Benzoylformic acid (2.33 g, 15.5 mmol) and 2-bromophenol (2.6 g, 15 mmol) were dissolved in dichloromethane (50 ml). The solution was cooled to 0 °C and dicyclohexylcarbodiimide (3.09 g, 15 mmol) was added, and the solution stirred at room temperature for 1 h. The solution was filtered, concentrated *in vacuo* and purified by flash column chromatography (4:1 light petroleum–ether) to give the intermediate α-keto ester (3.447 g, 75%) as a colourless oil. A solution of this α-keto ester (4 g, 13.1 mmol) and toluene-4-sulfonohydrazide (2.44 g, 13.1 mmol) in toluene (100 ml) was heated under reflux with removal of water (Dean–Stark) for 3 h. The toluene was then removed *in vacuo* and dichloromethane (100 ml) added. Triethylamine (1.5 ml, 15 mmol) was added and the solution stirred for 5 min at room temperature. The organic solution was then washed with water (50 ml) and brine (50 ml), then dried over magnesium sulfate, filtered, concentrated *in vacuo* and purified by flash column chromatography (99:1 light petroleum–ether) to give the *title compound* **3** (2.62 g, 47% from 2-bromophenol) as a yellow oil which solidified to a waxy yellow solid, mp 54–55 °C (Found: M^+, 315.9849. $C_{14}H_9{}^{79}BrN_2O_2$ requires *M*, 315.9848); ν_{max}(film)/cm^{-1} 2095, 1725, 1472, 1212 and 1129; δ_H(250 MHz; $CDCl_3$) 7.63 (1 H, dd, *J* 8.0 and 1.5, ArH), 7.57–7.52 (2 H, m, ArH), 7.45–7.36 (2 H, m, ArH), 7.34 (1 H, dd, *J* 7.1 and 1.5, ArH), 7.31–7.19 (2 H, m, ArH) and 7.14 (1 H, ddd, *J* 8.0, 7.1 and 1.9, ArH); δ_C(62.9 MHz; $CDCl_3$) 162.4 (C=O), 147.8 (C), 133.4 (CH), 129.1 (CH), 128.5 (CH), 127.5 (CH), 126.3 (CH), 124.8 (C), 124.2 (CH), 124.1 (CH) and 116.4 (C) (diazo carbon not observed); *m/z* (EI) 318 (^{81}Br-M^+, 2%), 316 (^{79}Br-M^+, 2), 261 (12), 259 (12), 209 (42), 105 (100), 89 (79), 77 (55) and 63 (43).

7-Bromo-3-phenyl-2,3-dihydrobenzo[*b*]furan-2-one 4

A solution of 2-bromophenyl 2-diazo-2-phenylacetate **3** (1 g, 3.15 mmol) in dichloromethane (25 ml) was added over 20 min to a refluxing suspension of rhodium(II) perfluorobutyramide (5 mg) in dichloromethane (15 ml). The solution was heated under reflux for a further 20 min, then allowed to cool to room temperature and concentrated *in vacuo*. Purification by flash column chromatography (9:1 light petroleum–ether) gave 7-*bromo*-3-*phenyl*-2,3-*dihydrobenzo*[b]*furan*-2-*one* **4** (180 mg, 20%) as a colourless solid, mp 82–83 °C (from light petroleum–diethyl ether) (Found: C, 58.4; H, 2.9. $C_{14}H_9BrO_2$ requires C, 58.2; H, 3.1%); ν_{max}(CH_2Cl_2)/cm^{-1} 1818, 1446, 1065 and 1048; δ_H(250 MHz; $CDCl_3$) 7.52 (1 H, dt, *J* 7.9 and 1.2, ArH), 7.4–7.3 (3 H, m, ArH), 7.25–7.2 (2 H, m, ArH), 7.14 (1 H, dt, *J* 7.5 and 1.2, ArH), 7.06 (1 H, t, *J* 7.9, ArH) and 4.98 (1 H, s, C*H*Ph); δ_C(62.9 MHz; $CDCl_3$) 173.3 (C=O), 151.7 (C), 134.4 (C), 132.7 (CH), 129.2 (CH), 128.4 (CH), 128.3 (C), 128.2 (CH), 125.6 (CH), 124.1 (CH), 103.6 (C) and 50.6 (*C*HPh); *m/z* (EI) 290 (^{81}Br-M^+, 18%), 288 (^{79}Br-M^+, 18), 261 (43), 259 (42), 210 (54), 181 (80), 152 (48), 84 (77), 64 (76) and 49 (100).

Ethyl 7-bromo-2-oxo-3-phenyl-2,3-dihydrobenzo[*b*]furan-3-carboxylate 5

7-Bromo-3-phenyl-2,3-dihydrobenzo[*b*]furan-2-one **4** (500 mg, 1.73 mmol) was dissolved in dichloromethane (30 ml). Ethyl chloroformate (250 mg, 2.3 mmol) and triethylamine (200 mg, 2 mmol) were added, and the solution stirred for 5 min. 4-Dimethylaminopyridine (5 mg) was added to give an intense

purple solution which faded to colourless over 15 h. The solution was diluted with dichloromethane (20 ml) and washed with water (50 ml) and brine (50 ml), then dried over magnesium sulfate, filtered, concentrated *in vacuo* and purified by flash column chromatography (4:1 light petroleum–ether) to give the *title compound* **5** (597 mg, 96%) as a sticky solid (Found: M^+, 361.9987. $C_{17}H_{13}{}^{81}BrO_4$ requires *M*, 361.9978); $\nu_{max}(CH_2Cl_2)$/cm^{-1} 2977, 1822, 1740, 1444, 1239, 969 and 739; δ_H(250 MHz; $CDCl_3$) 7.61 (1 H, dd, *J* 8.1 and 1.2, 4-H or 6-H), 7.46 (1 H, dd, *J* 7.6 and 1.2, 4-H or 6-H), 7.40–7.30 (5 H, m, ArH), 7.18 (1 H, t, *J* 7.4, 5-H), 4.35–4.19 (2 H, m, OCH_2) and 1.25 (3 H, t, *J* 7.1, Me); δ_C(62.9 MHz; $CDCl_3$) 169.9 (C=O), 167.1 (C=O), 151.6 (C), 134.1 (C), 133.8 (CH), 129.01 (CH), 128.98 (CH), 127.4 (CH), 126.9 (C), 125.7 (CH), 125.1 (CH), 104.0 (C), 63.3 (OCH_2) and 13.9 (CH_3); one quaternary C unobserved; *m/z* (EI) 362 (^{81}Br-M^+, 10%), 360 (^{79}Br-M^+, 10), 318 (14), 316 (14), 290 (96), 288 (100), 261 (44), 259 (42), 209 (32), 180 (45), 152 (90) and 29 (66).

1-Bromo-2-[(3-phenylprop-2-enyl)oxy]benzene 6

A mixture of 2-bromophenol (10.0 g, 57.8 mmol), cinnamyl chloride (8.82 g, 1 equiv.) and anhydrous potassium carbonate (7.99 g, 1 equiv.) in acetone (30 ml) was heated under reflux for 12 h. After cooling, the reaction mixture was poured into water (100 ml) and extracted with ether (3 × 20 ml). The combined organics were washed with aqueous NaOH (40%; 2 × 30 ml), brine (40 ml) and dried ($MgSO_4$). Filtration, followed by concentration *in vacuo* gave a pale yellow viscous oil which crystallised on standing at 5 °C to give the *title compound* **6** (14.14 g, 85%) used without further purification, mp 48–50 °C; ν_{max}(film)/cm^{-1} 1479, 1244 and 1031; δ_H(250 MHz; $CDCl_3$) 7.60 (1 H, d, *J* 7.9, ArH), 7.25–7.58 (6 H, m, ArH), 6.91 (1 H, m, CH), 6.72 (2 H, m, ArH), 6.46 (1 H, m, CH) and 4.79 (2 H, d, *J* 5.4, OCH_2); δ_C(62.9 MHz; $CDCl_3$) 155.0 (C), 136.4 (C), 133.4 (CH), 133.0 (CH), 128.4 (CH), 128.2 (CH), 127.9 (CH), 126.6 (CH), 123.7 (CH), 122.1 (CH), 113.8 (CH), 112.4 (C) and 69.7 (OCH_2).

2-Bromo-6-(1-phenylprop-2-enyl)phenyl acetate 7

A mixture of the allyl ether **6** (2.0 g, 6.9 mmol), acetic anhydride (6 ml) and *N*,*N*-dimethylaniline (6 ml) was heated to reflux under a nitrogen atmosphere for 19 h. After cooling, the reaction mixture was poured into ice–water (50 ml) and stirred for 10 min. After extraction with ether (100 ml), the organic layer was washed with aqueous HCl (5%; 4 × 20 ml), saturated aqueous $NaHCO_3$ (3 × 20 ml), dried ($MgSO_4$) and then concentrated *in vacuo*. Purification by flash chromatography (1:9 ether–light petroleum) gave the *title compound* **7** as a pale yellow oil (1.87 g, 81%) (Found: M + NH_4^+, 348.0599. $C_{17}H_{15}{}^{79}BrO_2 + NH_4$ requires *M*, 348.0600); ν_{max}(film)/cm^{-1} 1772, 1441, 1190 and 1167; δ_H(250 MHz; $CDCl_3$) 7.52 (1 H, dd, *J* 1.7 and 7.7, ArH), 7.25–7.37 (3 H, m, ArH), 7.16–7.23 (3 H, m, ArH), 7.10 (1 H, m, ArH), 6.26 (1 H, m, C*H*=CH_2), 5.30 (1 H, dt, *J* 1.4 and 10.3, *Z* CH=CH_2), 4.98 (1 H, dt, *J* 1.1 and 17.9, *E* CH=CH_2) and 2.20 (3 H, s, Me); δ_C(62.9 MHz; $CDCl_3$) 167.6 (C=O), 146.5 (C), 141.4 (C), 138.8 (CH), 137.9 (C), 131.5 (CH), 128.9 (CH), 128.5 (CH), 128.4 (CH), 127.1 (CH), 126.7 (CH), 117.3 (CH), 49.3 (CH) and 20.5 (CH_3); *m/z* (CI) 350 (^{81}Br-M + NH_4^+, 90%), 348 (^{79}Br-M + NH_4^+, 100) and 224 (20).

7-Bromo-2-methoxy-3-phenyl-2,3-dihydrobenzo[*b*]furan 8

Ozone was bubbled through a stirred solution of the alkene **7** (250 mg, 0.75 mmol) in dichloromethane (10 ml) at −78 °C. After all the starting material had been consumed (as indicated by TLC) and the reaction mixture turning deep blue, the excess ozone was removed by bubbling nitrogen gas through the mixture for 1 min, after which time dimethyl sulfide (0.5 ml, 10 equiv.) was added and the solution was allowed to warm to room temperature slowly. After concentration *in vacuo*, the crude product was dissolved in methanol (10 ml) to which was added aqueous ammonia (2 ml). After stirring for 12 h, aqueous HCl (2 M; 3 ml) was added, and the solution was extracted with ether (3 × 10 ml). The combined organics were washed with water (10 ml), brine (10 ml), dried ($MgSO_4$) and concentrated *in vacuo*. Purification by flash chromatography (1:9 ethyl acetate–light petroleum) gave the *title compound* **8** as a clear oil (82 mg, 36% overall, 16:1 ratio *cis* : *trans*) (Found: M^+, 304.0099. $C_{15}H_{13}{}^{79}BrO_2$ requires *M*, 304.0099); ν_{max}-($CDCl_3$)/cm^{-1} 1625, 1602 and 1448; δ_H(250 MHz; $CDCl_3$) *cis*-**8** 7.14–7.27 (6 H, m, ArH), 6.79 (1 H, m, ArH), 6.68 (1 H, t, *J* 7.7, ArH), 5.59 (1 H, d, *J* 6.3, C*H*OMe), 4.65 (1 H, d, *J* 6.3, C*H*Ph) and 3.34 (3 H, s, OMe); NOE experiment, irradiation at δ 5.59 caused enhancement at δ 4.65 (4.4%); *trans*-**8** 7.13 (6 H, m, ArH), 7.01 (1 H, d, *J* 7.2, ArH), 6.69 (1 H, t, *J* 7.7, ArH), 5.52 (1 H, d, *J* 2.3, C*H*OMe), 4.46 (1 H, d, *J* 2.3, C*H*Ph) and 3.60 (3 H, s, OMe); NOE experiment, irradiation at δ 5.52 caused no enhancement at δ 4.46; δ_C(62.9 MHz; $CDCl_3$) *cis*-**8** 131.4 (CH), 130.2 (CH), 128.1 (CH), 127.6 (CH), 124.0 (CH), 112.5 (CH), 108.5 (CH), 56.5 (CH) and 53.8 (OCH_3); *trans*-**8** 131.7 (CH), 129.2 (CH), 127.6 (CH), 127.4 (CH), 114.1 (CH), 103.2 (*C*HOCH_3), 56.4 (CH) and 55.6 (OCH_3); quaternary Cs unobserved; *m/z* (EI) 306 (^{81}Br-M^+, 20%), 304 (^{79}Br-M^+, 30), 165 (100) and 105 (40).

Ethyl 2-(3-bromo-2-hydroxyphenyl)-2-phenylacetate 9

A solution of ethyl 7-bromo-2-oxo-3-phenyl-2,3-dihydrobenzo[*b*]furan-3-carboxylate **5** (100 mg, 0.28 mmol) in dimethoxyethane (8 ml) was degassed. Tetrakis(triphenylphosphine)-palladium(0) (30 mg) was added and the solution further degassed. After stirring for 10 min, aqueous sodium carbonate (2 M; 0.5 ml, 1 mmol) was added followed by phenylboronic acid (65 mg, 0.5 mmol) and the solution was degassed then stirred under an atmosphere of nitrogen for 150 h. Dichloromethane (50 ml) was added and the solution washed with water (50 ml) and brine (50 ml), then dried over magnesium sulfate, filtered and concentrated *in vacuo*. Purification by flash column chromatography (9:1 light petroleum–dichloromethane) afforded the *title compound* **9** (53 mg, 57%) as a colourless oil (Found: M^+, 336.0184. $C_{16}H_{15}{}^{81}BrO_3$ requires *M*, 336.0185); ν_{max}(film)/cm^{-1} 3520 (br, OH), 1735, 1450, 1240, 1175 and 700; δ_H(250 MHz; $CDCl_3$) 7.42–7.27 (6 H, m, ArH), 7.05 (1 H, dd, *J* 7.7 and 1.2, ArH), 6.77 (1 H, t, *J* 7.7, ArH), 6.72 (1 H, s, exchangeable with D_2O, OH), 5.30 (1 H, s, C*H*CO_2Et), 4.25 (2 H, qd, *J* 7.1 and 0.8, OCH_2) and 1.28 (3 H, t, *J* 7.1, Me); δ_C(62.9 MHz; $CDCl_3$) 172.6 (C=O), 150.0 (C), 137.0 (C), 131.1 (CH), 129.2 (CH), 128.84 (C), 128.79 (CH), 128.6 (CH), 127.4 (CH), 121.4 (CH), 110.9 (C), 61.4 (OCH_2), 52.1 (CH) and 14.1 (CH_3); *m/z* (EI) 336 (^{81}Br-M^+, 16%), 334 (^{79}Br-M^+, 16), 290 (26), 288 (26), 263 (64), 261 (100), 181 (53), 152 (58), 76 (24) and 29 (38).

7-Bromo-3-phenylbenzo[*b*]furan 10

Potassium carbonate (10 g, 72 mmol) was added to a solution of phenacyl bromide (14.4 g, 72 mmol) and 2-bromophenol (12.5 g, 72 mmol) in acetone (40 ml), and the resulting suspension heated under reflux for 4 h. The suspension was then allowed to cool to room temperature and poured into water (300 ml). The precipitate was collected by filtration and recrystallised from absolute ethanol to afford 2-(2-bromophenoxy)-1-phenylethan-1-one (19.3 g, 92%) as a colourless solid, mp 114–115 °C (Found: C, 57.5; H, 3.6. $C_{14}H_{11}BrO_2$ requires C, 57.8; H, 3.8%); $\nu_{max}(CH_2Cl_2)$/cm^{-1} 1706, 1479 and 1220; δ_H(250 MHz; $CDCl_3$) 8.06–8.00 (2 H, m, ArH), 7.66–7.46 (4 H, m, ArH), 7.22 (1 H, td, *J* 7.9 and 1.6, ArH), 6.90–6.81 (2 H, m, ArH) and 5.33 (2 H, s, CH_2O); δ_C(62.9 MHz; $CDCl_3$) 194.0 (C=O), 154.5 (C), 134.3 (C), 133.9 (CH), 133.6 (CH), 128.8 (CH), 128.4 (CH), 128.2 (CH), 122.8 (CH), 113.8 (CH), 112.3 (CBr) and 71.8 (OCH_2); *m/z* (EI) 292 (^{81}Br-M^+, 0.5%), 290 (^{79}Br-M^+, 0.5), 211 (20), 105 (100), 77 (36) and 41 (74).

Polyphosphoric acid (30 g) was pre-heated to 80 °C for 20 min. 2-(2-Bromophenoxy)-1-phenylethan-1-one (5.82 g, 20 mmol) was added in one portion and the viscous mixture heated at 90 °C with stirring for 40 h. Water (50 ml) was added and

the precipitate collected by filtration. Recrystallisation from absolute ethanol gave the *title compound* **10** (4.78 g, 88%) as a colourless solid, mp 73–74 °C (Found: C, 61.5; H, 3.1. $C_{14}H_9BrO$ requires C, 61.6; H, 3.3%); $\nu_{max}(CH_2Cl_2)/cm^{-1}$ 3111, 3052, 1444, 1229, 1104 and 696; δ_H(250 MHz; $CDCl_3$) 7.84 (1 H, s, 2-H), 7.76 (1 H, dd, *J* 7.8 and 1.0, ArH), 7.63–7.58 (2 H, m, ArH), 7.53–7.35 (4 H, m, ArH) and 7.18 (1 H, t, *J* 7.85, ArH); δ_C(62.9 MHz; $CDCl_3$) 152.9 (C), 141.9 (CH), 131.5 (C), 129.1 (CH), 127.92 (C), 127.89 (CH), 127.7 (CH), 127.6 (CH), 124.4 (CH), 123.2 (C), 119.7 (CH) and 104.7 (CBr); *m/z* (EI) 274 (^{81}Br-M^+, 98%), 272 (^{79}Br-M^+, 100), 165 (80), 82 (48) and 63 (20).

(3-Phenylbenzo[*b*]furan-7-yl)boronic acid 11

A solution of 7-bromo-3-phenylbenzo[*b*]furan **10** (5 g, 18.3 mmol) in dry THF (200 ml) was cooled to −78 °C under an atmosphere of nitrogen. *n*-Butyllithium (15.4 ml of a 2.5 M solution in hexanes, 38.5 mmol) was added dropwise, and the resulting solution stirred at −78 °C for 30 min. Trimethyl borate (15 ml, excess) was added rapidly in one portion and the solution stirred at −78 °C for 1 h, then allowed to warm to room temperature and poured into aqueous hydrochloric acid (0.001 M). The product was extracted into dichloromethane (3 × 100 ml) and the combined organic phases dried over sodium sulfate, filtered and concentrated *in vacuo* to give a solid which was recrystallised (dichloromethane–light petroleum with 1 drop of water) to afford the *title compound* **11** (3.491 g, 80%) as a colourless powder, mp 107–108 °C (Found: M^+, 238.0800. $C_{14}H_{11}BO_3$ requires *M*, 238.0801); $\nu_{max}(CH_2Cl_2)/cm^{-1}$ 3276 (br, OH), 2964, 2924, 1364, 1265 and 737; δ_H(250 MHz; $CDCl_3$–[$^2H_6$]DMSO) 7.91 (1 H, dd, *J* 7.8 and 1.6, ArH), 7.88 (1 H, s, 2-H), 7.85 (1 H, dd, *J* 7.3 and 1.6, ArH), 7.67–7.36 (5 H, m, ArH), 7.34 (1 H, dd, *J* 7.8 and 7.3, ArH) and 7.15 [2 H, s, exchangeable with D_2O, $B(OH)_2$]; δ_C(62.9 MHz; $CDCl_3$–[$^2H_6$]DMSO) 160.8 (C), 141.1 (CH), 131.7 (C), 131.1 (CH), 128.9 (CH), 127.4 (CH), 127.2 (CH), 125.1 (C), 122.8 (CH), 122.3 (CH), 122.3 (C–B, J_{C-B} 94) and 111.6 (C); *m/z* (EI) 238 (M^+, 52%), 194 (100), 165 (74) and 45 (97).

7-Bromo-3-hydroxy-3-phenyl-2,3-dihydrobenzo[*b*]furan-2-one 12

A cooled (−78 °C) solution of dimethyldioxirane (0.0976 M in acetone, 4 ml, 0.39 mmol) was rapidly added to a cooled (−78 °C) solution of 7-bromo-3-phenylbenzo[*b*]furan **10** (50 mg, 0.18 mmol) in acetone (1.5 ml). The solution was stirred at −78 °C for 1 h, then allowed to warm to room temperature overnight. The solvent was removed *in vacuo* to afford the pure *title compound* **12** (56 mg, 100%) as a colourless oil (Found: M^+, 305.9713. $C_{14}H_9{}^{81}BrO_3$ requires *M*, 305.9716); ν_{max}(film)/cm^{-1} 3420 (br, OH), 1817, 1440 and 1044; δ_H(250 MHz; $CDCl_3$) 7.55 (1 H, dd, *J* 7.1 and 1.3, ArH), 7.39–7.34 (5 H, m, ArH), 7.25 (1 H, dd, *J* 7.5 and 1.3, ArH), 7.09 (1 H, t, *J* 7.6, ArH) and 3.7–3.2 (1 H, br s, exchangeable with D_2O, OH); δ_C(62.9 MHz; $CDCl_3$) 174.8 (C=O), 151.1 (C), 138.3 (C), 134.2 (CH), 131.0 (C), 129.3 (CH), 129.0 (CH), 126.3 (CH), 125.4 (CH), 124.2 (CH), 104.1 (CBr) and 78.0 (3-C); *m/z* (EI) 306 (^{81}Br-M^+, 4%), 304 (^{79}Br-M^+, 3), 279 (10), 278 (19), 277 (20), 276 (18), 275 (13), 105 (22), 58 (38) and 43 (100).

3,7-Diphenylbenzo[*b*]furan 13

Tetrakis(triphenylphosphine)palladium(0) (60 mg) was added to a degassed solution of 7-bromo-3-phenylbenzo[*b*]furan **10** (273 mg, 1 mmol) in dimethoxyethane (18 ml). The solution was further degassed and aqueous sodium carbonate (2 M; 1 ml, 2 mmol) and phenylboronic acid (183 mg, 1.5 mmol) were added and the solution heated under reflux for 8 h. The solution was then allowed to cool to room temperature, diluted with dichloromethane (30 ml) and washed with water (30 ml), then with brine (30 ml). The solution was dried over magnesium sulfate, filtered and concentrated *in vacuo*. Recrystallisation from ethanol afforded the *title compound* **13** (220 mg, 81%) as a colourless solid, mp 96–97 °C (Found: M^+, 270.1052. $C_{20}H_{14}O$ requires *M*, 270.1045); ν_{max}(KBr)/cm^{-1} 3064, 3061, 1409, 1123, 760 and 698; δ_H(250 MHz; $CDCl_3$) 7.89–7.85 (2 H, m, ArH), 7.81 (1 H, s, 2-H), 7.80 (1 H, dd, *J* 7.7 and 1.3, ArH), 7.67–7.63 (2 H, m, ArH) and 7.53–7.32 (8 H, m, ArH); δ_C(62.9 MHz; $CDCl_3$) 141.4 (CH), 136.4 (C), 132.0 (C), 128.9 (CH), 128.7 (CH), 128.6 (CH), 128.5 (C), 127.7 (CH), 127.6 (CH), 127.5 (CH), 127.2 (C), 126.0 (C), 124.2 (CH), 123.5 (CH), 122.4 (C) and 119.5 (CH); *m/z* (EI) 270 (M^+, 100%), 241 (15), 239 (16) and 165 (12).

The same compound was produced (67% yield) by an identical coupling reaction between (3-phenylbenzo[*b*]furan-7-yl)boronic acid **11** and bromobenzene.

3-Acetyl-4-bromoindole

To a stirred solution of phosphorus oxychloride (4.71 ml, 3.3 equiv.) in chloroform (50 ml) was added dimethylacetamide (4.69 ml, 3.3 equiv.) dropwise, keeping the temperature below 10 °C. After the addition was complete, the reaction mixture was stirred for 10 min to allow complete formation of the greenish yellow Vilsmeier complex. 4-Bromoindole[17] (3.0 g, 15.3 mmol) in chloroform (50 ml) was added to the reaction mixture dropwise over 30 min, keeping the reaction mixture around 10 °C. The reaction mixture was then refluxed for 4 h. After cooling, it was extracted with water (3 × 100 ml). The combined aqueous phases were taken to pH 5 using sodium acetate and allowed to stand at room temperature overnight. The suspension was then filtered, collected and recrystallised from chloroform. This yielded the *title compound* as a colourless solid (2.55 g, 70%), mp 184–186 °C (Found: C, 50.2; H, 3.23; N, 6.3. $C_{10}H_8BrNO$ requires C, 50.45; H, 3.39; N, 5.9%) (Found: M^+, 236.979. $C_{10}H_8{}^{79}BrNO$ requires *M*, 236.9790); ν_{max}(KBr)/cm^{-1} 3270, 1644 and 1435; δ_H(250 MHz; $CDCl_3$) 7.80 (1 H, s, ArH), 7.06–7.15 (2 H, m, ArH), 6.71–6.80 (1 H, m, ArH), 2.84 (1 H, br s, exchangeable with D_2O, NH) and 2.24 (3 H, s, Me); δ_C(62.9 MHz; $CDCl_3$) 192.2 (C=O), 138.8 (C), 133.5 (C), 126.9 (CH), 124.5 (C), 123.8 (CH), 118.5 (C), 114.2 (C), 111.4 (CH) and 29.6 (CH_3); *m/z* (EI) 239 (^{81}Br-M^+, 30%), 237 (^{79}Br-M^+, 35), 224 (100) and 222 (100).

***tert*-Butyl 3-acetyl-4-bromoindole-1-carboxylate 14**

To a stirred suspension of 3-acetyl-4-bromoindole (2.0 g, 18.8 mmol) and di-*tert*-butyl dicarbonate (2.02 g, 1.2 equiv.) in acetonitrile (50 ml) was added 4-dimethylaminopyridine (102.6 mg, 10% mol equiv.). After 30 min the reaction mixture was diluted with ether (50 ml). The organic layer was washed in succession by $KHSO_4$ (1 M; 3 × 50 ml), water (50 ml), saturated aqueous $NaHCO_3$ (50 ml), brine (50 ml), then dried ($MgSO_4$) and concentrated *in vacuo*. Recrystallisation from ethyl acetate gave the *title compound* **14** as a colourless solid (2.68 g, 94%), mp 70–72 °C (Found: M^+, 337.0314. $C_{15}H_{16}{}^{79}BrNO_3$ requires *M*, 337.0314); ν_{max}(KBr)/cm^{-1} 1750, 1685, 1541 and 1420; δ_H(250 MHz; $CDCl_3$) 8.18–8.22 (1 H, m, ArH), 8.03 (1 H, s, ArH), 7.51–7.54 (1 H, m, ArH), 7.19–7.25 (1 H, m, ArH), 2.64 (3 H, s, Me) and 1.69 (9 H, s, CMe_3); δ_C(62.9 MHz; $CDCl_3$) 194.7 (C=O), 137.0 (C=O), 130.4 (CH), 129.0 (CH), 127.2 (C), 126.4 (CH), 123.3 (C), 114.7 (C), 114.4 (CH), 85.6 (*C*Me_3), 31.2 (CH_3) and 28.0 (CH_3); one quaternary C unobserved; *m/z* (EI) 340 (^{81}Br-MH^+, 30%), 338 (^{79}Br-MH^+, 30), 240 (100) and 238 (100).

***tert*-Butyl 4-bromo-3-diazoacetylindole-1-carboxylate 15**

A solution of LiHMDS was prepared *in situ* by the dropwise addition of butyllithium (1.6 M; 6.65 ml, 1.2 equiv.) to a stirred solution of hexamethyldisilazane (2.25 ml, 1.3 equiv.) in THF (30 ml) at 0 °C under a nitrogen atmosphere. After stirring for 15 min at this temperature, the solution was cooled to −78 °C. At this temperature, *tert*-butyl 3-acetyl-4-bromoindole-1-carboxylate **14** (3.0 g, 8.87 mmol) was added dropwise as a solution in THF (70 ml), over a 20 min period. The reaction mixture was stirred at −78 °C for 30 min and then 2,2,2-trifluoroethyl trifluoroacetate (1.43 ml, 1.2 equiv.) was added rapidly in one

portion. After stirring for 10 min the mixture was diluted with ether (40 ml) and washed with aqueous HCl (5%; 40 ml). The aqueous layer was extracted with ether (2 × 40 ml). The combined organics were washed with brine (20 ml) and concentrated *in vacuo*. The resulting solid was then suspended in acetonitrile (40 ml) to which was added water (0.160 ml, 1 equiv.) and triethylamine (1.85 ml, 1.5 equiv.). To this stirred solution was added methanesulfonyl azide (1.90 g, 1.5 equiv.) dropwise as a solution in acetonitrile (20 ml) over a 20 min period. After the addition was complete, the resulting mixture was stirred for 12 h. The reaction mixture was then diluted with ether (100 ml) and washed with aqueous NaOH (15%; 4 × 30 ml), brine (30 ml), dried ($MgSO_4$) and concentrated under reduced pressure. Purification by flash chromatography (1:9 ethyl acetate–light petroleum) gave the *title compound* **15** as a pale yellow solid (2.40 g, 74%), mp 131–133 °C (Found: C, 49.7; H, 3.8; N, 11.6. $C_{15}H_{14}BrN_3O_3$ requires C, 49.5; H, 3.9; N, 11.5%); ν_{max}(KBr)/cm^{-1} 2099, 1740, 1622 and 1421; δ_H(250 MHz; $CDCl_3$) 8.18 (1 H, m, ArH), 7.90 (1 H, s, ArH), 7.48 (1 H, m, ArH), 7.23 (1 H, m, ArH), 5.67 (1 H, s, CH) and 1.67 (9 H, s, CMe_3); δ_C(100 MHz; $CDCl_3$) 183.2 (C=O), 148.5 (C), 136.6 (C), 128.4 (CH), 128.2 (CH), 126.5 (C), 126.1 (CH), 121.1 (C), 114.4 (CH), 114.1 (C), 85.5 (*C*Me$_3$), 58.3 (CH) and 28.0 (CH_3); *m*/*z* (EI) 366 (^{81}Br-MH$^+$, 100%), 364 (^{79}Br-MH$^+$, 100), 210 (60) and 208 (60).

tert-Butyl 3-acetyl-4-(3-phenylbenzo[*b*]furan-7-yl)indole-1-carboxylate 17

A solution of *tert*-butyl 3-acetyl-4-bromoindole-1-carboxylate **14** (338 mg, 1 mmol) in 1,2-dimethoxyethane (15 ml) was degassed. Tetrakis(triphenylphosphine)palladium(0) (30 mg) was added and the solution further degassed. Aqueous sodium carbonate (2 M; 1.5 ml, 3 mmol) was added followed by (3-phenylbenzo[*b*]furan-7-yl)boronic acid **11** (357 mg, 1.5 mmol) and the solution further degassed, then heated under reflux for 15 h. Dichloromethane (50 ml) was added and the solution washed with water (2 × 30 ml), then dried over magnesium sulfate, filtered and concentrated *in vacuo*. Purification by chromatography (dichloromethane) gave the *title compound* **17** (359 mg, 80%) as a colourless foam; δ_H(250 MHz; $CDCl_3$) 8.37 (1 H, dd, *J* 6.8 and 2.6, ArH), 8.18 (1 H, s, ArH), 7.89 (1 H, dd, *J* 7.1 and 2.1, ArH), 7.73–7.69 (3 H, m, ArH), 7.56–7.32 (7 H, m, ArH), 2.10 (3 H, s, Me) and 1.75 (9 H, s, CMe_3).

The compound was characterised, after removal of the nitrogen protecting group, as 3-*acetyl*-4-(3-*phenylbenzo*[b]*furan*-7-*yl*)*indole*, mp 257–257 °C (decomp.) (Found: C, 81.9; H, 5.0; N, 3.9. $C_{24}H_{17}NO_2$ requires C, 82.0; H, 4.9; N, 4.0%); ν_{max}(CH_2Cl_2)/cm^{-1} 3456, 1722, 1602 and 1121; δ_H(250 MHz; $CDCl_3$) 10.6 (1 H, br s, N*H*), 8.22 (1 H, m, ArH), 8.06 (1 H, s, ArH), 7.85 (1 H, dd, *J* 6.8 and 2.2, ArH), 7.74 (2 H, d, *J* 7.5, ArH), 7.61–7.48 (3 H, m, ArH), 7.41–7.23 (5 H, m, ArH) and 2.2 (3 H, s, Me); δ_C(62.9 MHz; $CDCl_3$) 196.1 (C=O), 158.6 (C), 146.6 (CH), 142.8 (C), 138.7 (CH), 137.0 (C), 135.1 (C), 134.1 (CH), 133.4 (C), 133.0 (C), 132.3 (CH), 132.0 (CH), 130.0 (C), 129.3 (CH), 129.2 (CH), 127.8 (CH), 127.7 (CH), 126.4 (C), 124.5 (C), 123.4 (CH), 117.0 (CH) and 32.9 (CH_3); *m*/*z* (EI) 351 (M$^+$, 100%), 336 (41), 139 (15) and 43 (30).

tert-Butyl 3-diazoacetyl-4-(3-phenylbenzo[*b*]furan-7-yl)indole-1-carboxylate 18

Hexamethyldisilazane (194 mg, 0.25 ml, 1.2 mmol) in THF (2 ml) was cooled to 0 °C under a nitrogen atmosphere. A solution of *n*-butyllithium in hexanes (2.5 M; 0.48 ml, 1.2 mmol) was added and the solution stirred for 10 min. The solution was cooled to −78 °C and **17** (451 mg, 1 mmol) in THF (3 ml) added dropwise. After stirring at −78 °C for 45 min, 2,2,2-trifluoroethyl trifluoroacetate (235 mg, 0.16 ml, 1.2 mmol) was added rapidly in one portion. The solution was stirred at −78 °C for 30 min, then poured into aqueous hydrochloric acid (5%; 30 ml) and dichloromethane (30 ml). The phases were separated and the aqueous phase extracted twice with dichloromethane (30 ml). The combined organic phases were washed with brine (2 × 30 ml) and concentrated *in vacuo* to give 680 mg of an oil which was immediately dissolved in acetonitrile (10 ml). Triethylamine (120 mg, 1.2 mmol), water (1 drop) and methanesulfonyl azide (150 mg, 1.2 mmol) were added and the solution stirred overnight at room temperature in the dark. The solution was concentrated *in vacuo* to a volume of *ca.* 10 ml and dichloromethane (50 ml) added. The solution was then washed with aqueous NaOH (10%; 3 x 30 ml), then with brine (30 ml), then dried over magnesium sulfate, filtered, concentrated *in vacuo* and purified by flash column chromatography (3:2 dichloromethane–light petroleum) to give the *title compound* **18** (393 mg, 82%) as a yellow oil, used without further purification; ν_{max}(film)/cm^{-1} 2101, 1744, 1626, 1296 and 1152; δ_H(250 MHz; $CDCl_3$) 8.35 (1 H, m, ArH), 8.04 (1 H, s, ArH), 7.85 (1 H, dd, *J* 7.2 and 1.9, ArH), 7.70 (1 H, s, ArH), 7.67–7.63 (2 H, m, ArH), 7.52–7.37 (7 H, m, ArH), 4.68 (1 H, s, C*H*N$_2$) and 1.69 (9 H, s, CMe_3); δ_C(250 MHz; $CDCl_3$) 182.9 (C=O), 153.5 (C=O), 149.0 (C), 141.4 (CH), 136.2 (C), 131.9 (C), 129.8 (C), 129.0 (CH), 128.8 (CH), 127.66 (CH), 127.57 (CH), 126.4 (C), 126.2 (C), 126.0 (CH), 125.8 (C), 125.4 (CH), 125.0 (CH), 123.5 (CH), 122.8 (C), 120.0 (CH), 115.2 (CH), 114.5 (C), 85.0 (*C*Me$_3$) and 28.1 (CH_3) (diazo carbon not observed); *m*/*z* (EI) 309 (100%), 280 (16) and 252 (13).

Rhodium(II) perfluorobutyramide catalysed decomposition of *tert*-butyl 3-diazoacetyl-4-(3-phenylbenzo[*b*]furan-7-yl)indole-1-carboxylate 18

A solution of **18** (98 mg, 0.205 mmol) in chloroform (5 ml) was added over 8 h to a suspension of rhodium(II) perfluorobutyramide (1 mg) in chloroform (3 ml) containing acetonitrile (82 mg, 2 mmol). The solvent was then removed *in vacuo* and the residue purified twice by flash column chromatography (3:2 dichloromethane–light petroleum) to give tert-*butyl* 7-*oxo*-3-*phenyl*-7,9-*dihydro*-6H-*furo*[3″,2″:5′,6′]*benzo*[4,5]*cyclohepta*-[cd]*indole*-9-*carboxylate* **19** (22 mg, 24%) as a colourless oil (Found: M$^+$, 449.1638. $C_{29}H_{23}NO_4$ requires *M*, 449.1627); ν_{max}(film)/cm^{-1} 1746, 1686, 1546, 1258 and 1149; δ_H(250 MHz; $CDCl_3$) 8.41 (1 H, dd, *J* 7.8 and 0.8, indole 5-H or 7-H), 8.33 (1 H, dd, *J* 8.3 and 0.8, indole 5-H or 7-H), 8.27 (1 H, s, indole 2-H or benzofuran 2-H), 7.83 (1 H, s, indole 2-H or benzofuran 2-H), 7.81 (1 H, d, *J* 7.9, benzofuran 4-H or 5-H), 7.68–7.61 (3 H, m, ArH), 7.52–7.46 (2 H, m, ArH), 7.42–7.39 (1 H, m, ArH), 7.37 (1 H, d, *J* 7.9, benzofuran 4-H or 5-H), 4.09 (2 H, s, $COCH_2$) and 1.70 (9 H, s, CMe_3); δ_C(62.9 MHz; $CDCl_3$) 190.1 (C=O), 153.8 (C=O), 149.0 (C), 141.4 (CH), 136.1 (C), 131.7 (C), 129.1 (CH), 129.2 (CH), 127.7 (2 × CH), 127.6 (C), 126.8 (C), 126.6 (CH), 126.5 (CH), 125.3 (CH), 122.4 (C), 122.1 (C), 121.9 (C), 120.6 (CH), 115.2 (CH), 85.5 (*C*Me$_3$), 52.5 (*C*H$_2$CO) and 28.1 (CH_3) (2 quaternary carbons not seen); *m*/*z* (EI) 449 (M$^+$, 20%), 394 (12), 349 (41), 320 (26), 57 (47), 56 (59), 43 (61) and 41 (100).

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