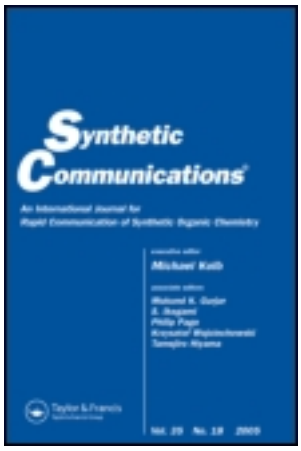

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Application of Baylis–Hillman Methodology in the Synthesis of Coumarin Derivatives

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ABSTRACT

A general, chemoselective approach to 3-substituted coumarins via Baylis–Hillman reactions of *O*-benzylated salicylaldehyde precursors has been demonstrated. Competitive cyclization to chromene derivatives is inhibited by conjugate addition of benzylamine or piperidine to the α,β-unsaturated ester intermediates.

Key Words: Coumarins; Baylis–Hillman reaction; Synthesis.

Coumarins (2*H*-1-benzopyran-2-ones) are widely distributed in nature,[1] and many are known to exhibit pharmacological activity. These include the anti-coagulant, dicoumarol,[2] the antibiotics, novobiocin and chlorobiocin,[3] and the calanolides A and B, which have been shown to inhibit HIV-1 replication in vitro.[4] We have previously demon-

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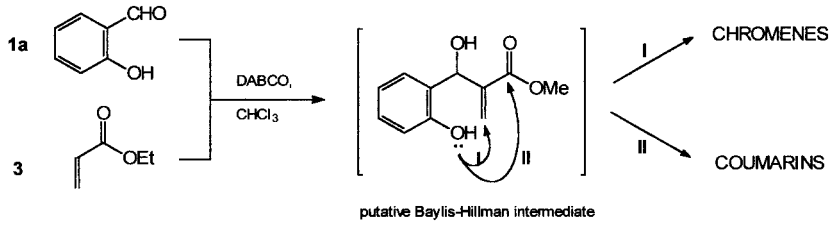
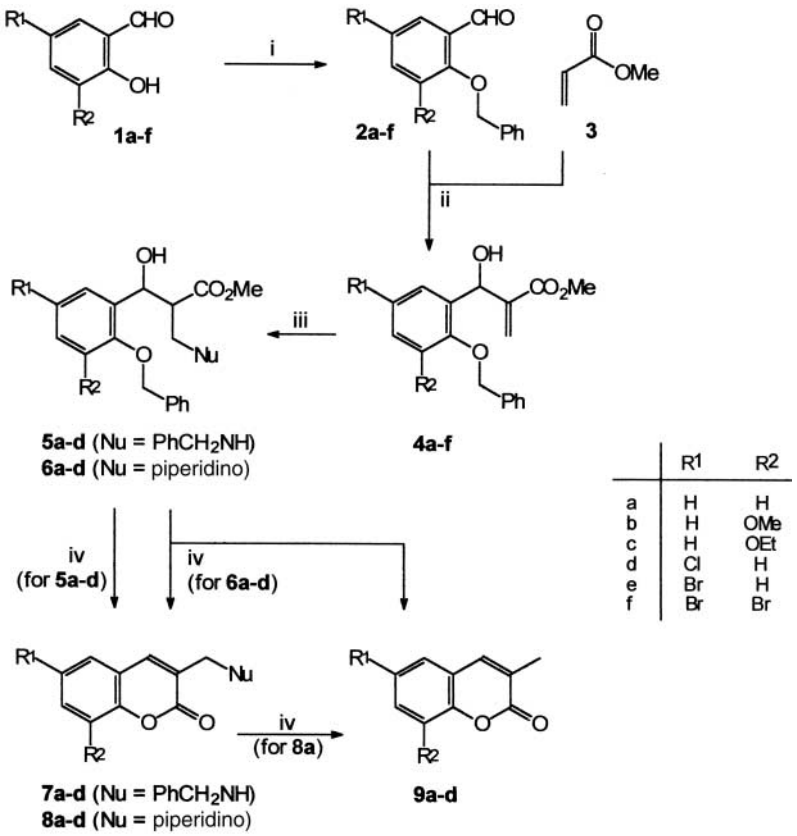


Scheme 1.

strated the utility of the Baylis–Hillman reaction in the construction of benzannulated heterocycles, such as indolizines[5] and quinolines.[6] However, earlier attempts to use this approach to access 2*H*-1-chromenes from salicylaldehyde precursors afforded complex mixtures of chromene and coumarin derivatives[7,8] via putative Baylis–Hillman intermediates (Sch. 1). Attention was subsequently focussed on the chemoselective synthesis of 2*H*-1-chromenes[9] and 2*H*-1-thiochromenes[10] and, in this communication, we now report the application of Baylis–Hillman methodology in the preparation of 3-substituted coumarins.

The strategy adopted to inhibit the formation of chromene derivatives (Path I; Sch. 1) involved three phases, viz., (i) protection of the salicylaldehyde phenolic hydroxyl group; (ii) nucleophilic interception of the electrophilic vinylic centre in the Baylis–Hillman product; and (iii) deprotection of the phenolic oxygen to permit cyclization to coumarins via acyl substitution. Attempts to protect the phenolic hydroxyl group as the *O*-silylated or *O*-acetylated derivatives had proved unsatisfactory,[11] and it was decided to make use of *O*-benzylated analogues, as reported by Drewes et al.[12] Consequently, the salicylaldehyde derivatives **1a–f** (Sch. 2) were treated with benzyl bromide in the presence of K_2CO_3 and NaI to afford the corresponding benzyl ethers **2a–f** in yields ranging from 66 to 89%. The next phase involved treatment of the benzyl ethers **2a–f** with methyl acrylate **3** under Baylis–Hillman conditions. In order to optimize yields, the reaction of 2-benzyloxybenzaldehyde **2a** with methyl acrylate in the presence of DABCO was investigated in some detail. The reagent and catalyst concentrations and the solvent system were varied until, finally, the required Baylis–Hillman product **4a** was obtained in ca. 95% yield (as determined by ^{1}H NMR analysis of the crude reaction mixture). This protocol was then applied to the synthesis of the Baylis–Hillman products **4a–f**, which were obtained in isolated yields of 66–84%.

Drewes et al.[12] have reported conjugate addition of dimethylamine to compound **4a**, but we decided to use the less volatile amines, benzylamine and piperidine, to effect protection of the olefinic moiety in com-

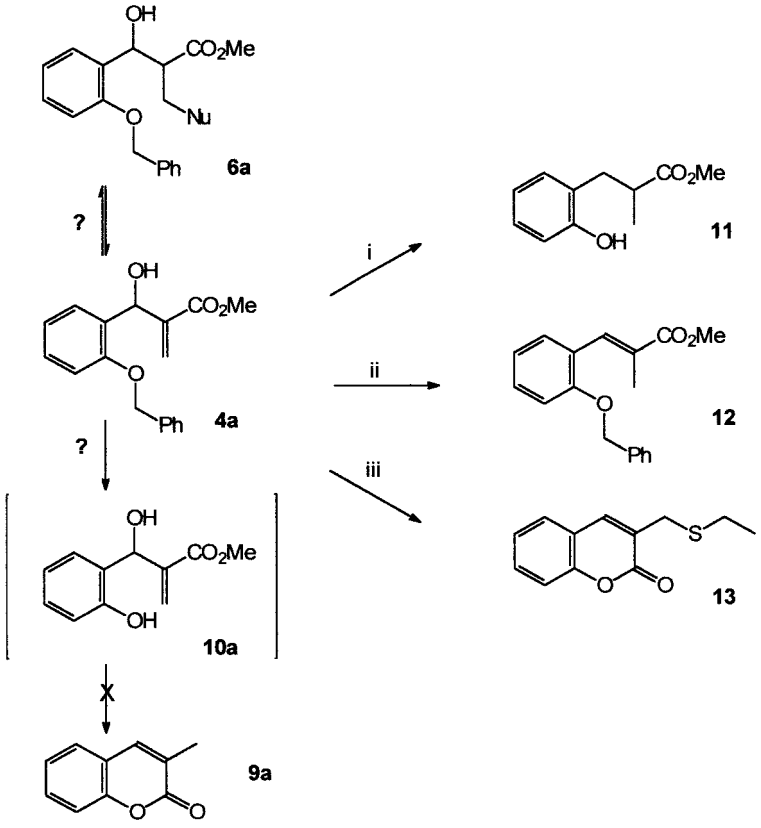


Reagents. i, $PhCH_2Br$, K_2CO_3, NaI; ii, DABCO, $CDCl_3$; iii, $PhCH_2NH_2$, MeOH or piperidine, THF; iv, H_2, Pd-C, EtOH.

Scheme 2.

pounds **4a–f**. The novel, conjugate addition products **5a–f** and **6a–f** were isolated in moderate to good yield (55–87%) and fully characterized. Selected systems (**5a–d** and **6a–d**) were then subjected to hydrogenolysis in the presence of 10% palladium-on-carbon catalyst. Fission of the benzyl ether and spontaneous cyclization via acyl substitution afforded, in each case, the expected 3-substituted coumarins **7a–d** and **8a–d**. Somewhat surprisingly, the piperidinyl derivatives **8a–d** were accompanied by the corresponding de-aminated derivatives **9a–d** in yields ranging from 9–21%.

A possible explanation for the concomitant formation of the 3-methylcoumarins **9a–d** lay in the cyclization and dehydration of hydroxy intermediates of type **10** [arising from in situ elimination of piperidine (**6** → **4**) or incomplete conjugate addition (**4** → **6**)] (Sch. 3). However, various attempts to effect reductive cyclization of compound **4a** failed to yield the corresponding 3-methylcoumarin **9a**. Thus, (i) hydrogenolysis using 10% palladium-on-carbon catalyst in ethanol yielded the phenolic product **11**; (ii) use of the same reagents in the presence of 1,4-cyclohexadiene yielded the benzyl ether **12**; and (iii) use of ethanethiol and BF_3–Et_2O yielded the 3-substituted coumarin **13**. An alternative explanation for the formation of the 3-methylcoumarins



Reagents. i, H_2, Pd-C, EtOH; ii, H_2, Pd-C, 1,4-cyclohexadiene, EtOH; iii, EtSH, BF_3-Et_2O

Scheme 3.

9a–d, finds a possible precedent in a report by Weir et al.,[13] which describes the reductive elimination of piperidine from allylic amine precursors, using triethylammonium formate as a reducing agent and 10% palladium-on-carbon as the catalyst. The formation of non-terminal alkenes as the dominant products, in their study, parallels the formation of the 3-methylcoumarins **9a–d** from the corresponding ''allylic amines'' **8a–d**. In fact, hydrogenolysis of the piperidino derivative **8a**, (Sch. 2), in the presence of 10% palladium-on-carbon catalyst, afforded 3-methylcoumarin **9a** as the sole product.

EXPERIMENTAL

Infrared spectra were recorded on a Perkin Elmer Spectrum 2000 FT-IR spectrometer. The ^{1}H and ^{13}C NMR spectra were recorded using CDC_3 solutions on a Bruker Avance 400 MHz NMR spectrometer and are referenced using the solvent signals. Low-resolution mass spectra were recorded on a Finnigan-Mat GCQ mass spectrometer; FAB mass spectra were obtained on a MASPEC II system and high-resolution mass spectra on a VG70-SEQ double-focusing magnetic sector instrument by Dr. P. Boshoff at the Mass Spectrometry Unit, Cape Technikon, Cape Town.

The following compounds have been reported previously:- **2a** (79%)[14]; **2b** (89%)[15]; **2c** (85%)[16]; **2e** (71%)[17]; **2f** (66%)[17]; **4a** (75%)[12]; **9a** (20%)[18]; and **9d** (9%).[18] Illustrative general synthetic procedures and analytical data for new compounds prepared in this study are as follows.

2-Benzyloxy-5-chlorobenzaldehyde 2d

A solution of 5-chlorosalicylaldehyde (4.9 g, 31 mmol), benzyl bromide (3.72 mL, 31.3 mmol), anhydrous K_2CO_3 (26 g, 0.19 mol) and NaI (28.2 g, 0.19 mol) in distilled acetone (100 mL) was boiled under reflux for 12 h. Water (50 mL) was then added and the aqueous layer extracted with $CHCl_3$ (2×100 mL). The combined extracts were washed with satd. brine and dried (anhyd. Na_2SO_4), filtered and concentrated in vacuo to give a dark brown oil. Crystallization from hexane afforded, as yellow crystals, 2-benzyloxy-5-chlorobenzaldehyde **2d**, (5.15 g, 67%), m.p. 70–72°C (from hexane) (Found: M^+, 246.04567. $C_{14}H_{11}O_2{}^{35}Cl$ requires *M*, 246.04476.); ν_{max} (KBr)/cm^{-1} 1680 (C=O); δ_H 5.18 (2H, s, OCH_2Ph), 7.00 (1H, d, Ar-H), 7.34–7.47 (6H, series of multiplets, Ar-H), 7.79 (1H, d, ArH) and

10.47 (1H, s, CHO); δ_C 71.0 (OCH_2Ph), 114.8, 126.2, 126.8, 127.3, 128.0, 128.5, 128.8, 135.3, 135.6 and 159.4 (Ar-C) and 188.3 (C=O); *m*/*z* 246 [M^+ (^{35}Cl), 9.6%] and 91 (100).

Methyl 3-(2-benzyloxy-3-methoxyphenyl)-3-hydroxy-2-methylenepropanoate 4b (General Procedure)

A mixture of 2-benzyloxy-3-methoxybenzaldehyde **2b** (1.21g, 5 mmol), methyl acrylate **3** (2.37 mL, 26.3 mmol) and DABCO (294 mg, 2.63 mmol) in $CDCl_3$ (0.25 mL) was stirred in a stoppered reaction flask for three weeks. The mixture was concentrated in vacuo to give a brown oil, which was purified by flash chromatography [elution with hexane–EtOAc (3:1)] to afford, as pale yellow oil, methyl 3-(2-benzyloxy-3-methoxyphenyl)-3-hydroxy-2-methylenepropanoate **4b** (1.34 g, 84%) (Found: M^+, 328.13079. $C_{19}H_{20}O_5$ requires M, 328.13107.); ν_{max} (thin film)/cm^{-1} 3501 (OH) and 1714 (C=O); δ_H 2.88 (1H, d, OH), 3.69 and 3.89 (6H, 2 × s, 2 × OCH_3), 5.07 (2H, s, OCH_2), 5.71 and 6.27 (2H, 2 ×s, $C=CH_2$), 5.86 (1H, d, C*H*OH) and 6.89–7.45 (8H, series of multiplets, Ar-H); δ_C 51.8 and 55.8 (2 × OCH_3), 67.7 (CHOH), 74.7 (OCH_2), 112.1, 119.4, 124.1, 125.8, 128.0, 128.2, 128.4, 135.1, 137.6, 141.7, 145.3 and 152.5 ($C=CH_2$ and Ar-C) and 166.8 (C=O); *m*/*z* 328 (M^+, 9.7%) and 205 (100).

Methyl 3-(2-benzyloxy-3-ethoxyphenyl)-3-hydroxy-2-methylenepropanoate 4c as a pale yellow oil, (1.37 g, 80%). (Found: M^+, 342.14677. $C_{20}H_{22}O_5$ requires M, 342.14672.); ν_{max} (thin film)/cm^{-1} 3484 (OH) and 1720 (C=O); δ_H 1.47 (3H, t, CH_2CH_3), 2.93 (1H, d, OH), 3.69 (3H, s, OCH_3), 4.10 (2H, q, OCH_2CH_3), 5.10 (2H, s, OCH_2Ph), 5.72 and 6.28 (2H, 2 × s, $C=CH_2$) 5.87 (1H, d, *CH*OH) and 6.89–7.46 (8H, series of multiplets, Ar-H); δ_C 15.0 (OCH_2CH_3), 51.8 (OCH_3), 64.3 (OCH_2CH_3), 68.0 (CHOH), 74.7 (OCH_2Ph), 125.8 ($C=CH_2$), 113.2, 119.4, 124.1, 128.0, 128.35, 128.42, 135.2, 137.7, 141.7, 145.5 and 151.9 ($C=CH_2$ and Ar-C) and 166.9 (C=O); *m*/*z* 342 (M^+, 15.6%) and 219 (100).

Methyl 3-(2-benzyloxy-3-chlorophenyl)-3-hydroxy-2-methylenepropanoate 4d as pale yellow oil (1.29 g, 78%). (Found: M^+, 332.08243. $C_{18}H_{17}O_4{}^{35}Cl$ requires M, 332.08154.); ν_{max} (thin film)/cm^{-1} 3479 (OH) and 1715 (C=O); δ_H 3.32 (1H, br s, OH), 3.73 (3H, s, OCH_3), 5.05 (2H, s, OCH_2Ph), 5.66 and 6.29 (2H, 2 × s, $C=CH_2$), 5.88 (1H, s, *CH*OH), 6.84 (1H, d, Ar-H) and 7.17–7.40 (7H, series of multiplets, Ar-H); δ_C 52.0 (OCH_3), 67.8 (CHOH), 70.5 (OCH_2Ph), 126.4 ($C=CH_2$), 113.1, 126.2, 127.3, 127.8, 128.2, 128.5, 128.6, 131.5, 136.3, 140.7 and 154.2 ($C=CH_2$ and Ar-C) and 166.9 (C=O); *m*/*z* 332 [M^+(^{35}Cl), 5.7%] and 209 (100).

Methyl 3-(2-benzyloxy-5-bromophenyl)-3-hydroxy-2-methylenepropanoate 4e as pale yellow crystals (1.58 g, 84%), m.p. 114–116°C. (Found: M^+, 376.02870. $C_{18}H_{17}O_4{}^{79}Br$ requires M, 376.03102.); ν_{max} (KBr)/cm^{-1} 3217 (OH) and 1716 (C=O); δ_H 3.32 (1H, br s, OH), 3.72 (3H, s, OCH_3), 5.04 (2H, s, OCH_2Ph), 5.65 and 6.28 (2H, 2 × s, $C=CH_2$), 5.88 (1H, s, CHOH), 6.78 (1H, d, Ar-H), 7.30–7.39 (6H, series of multiplets, Ar-H) and 7.54 (1H, d, Ar-H); δ_C 52.0 (OCH_3), 67.7 (CHOH), 70.5 (OCH_2Ph), 113.5, 113.7, 126.4, 127.3, 128.2, 128.6, 130.6, 131.5, 131.9, 136.2, 140.8 and 154.7 ($C=CH_2$ and Ar-C) and 166.9 (C=O); m/z 376 [M^+ (^{79}Br), 11.5%] and 255 (100).

Methyl 3-(2-benzyloxy-3,5-dibromophenyl)-3-hydroxy-2-methylenepropanoate 4f as a pale yellow oil (1.50 g, 66%). (Found: M^+, 453.94193. $C_{18}H_{16}O_4{}^{79}Br_2$ requires M, 453.94153.); ν_{max} (thin film)/cm^{-1} 3479 (OH) and 1715 (C=O); δ_H 2.84 (1H, br s, OH) 3.69 (3H, s, OCH_3), 5.07 (2H, d, OCH_2Ph), 5.76 and 6.35 (2H, 2 × s, $C=CH_2$), 5.81 (1H, d, *CH*OH), 7.35–7.48 (6H, series of multiplets, Ar-H) and 7.68 (1H, d, Ar-H); δ_C 52.1 (OCH_3), 67.2 (CHOH), 75.5 (OCH_2Ph), 126.9 ($C=CH_2$), 117.7, 118.3, 128.3, 128.5, 128.6, 130.2, 135.6, 136.3, 138.5, 140.5 and 152.5 ($C=CH_2$ and Ar-C) and 166.4 (C=O); m/z 454 [M^+ ($^{79}Br_2$), 1.9%] and 333 (100).

Methyl 2-(benzylaminomethyl)-3-(2-benzyloxyphenyl)-3-hydroxypropanoate 5a (General Procedure)

A mixture of methyl 3-(2-benzyloxyphenyl)-3-hydroxy-2-methylenepropanoate **4a** (0.6 g, 2 mmol) and benzylamine (0.22 mL, 2 mmol) in methanol (4 mL) was stirred in a stoppered reaction flask for 3 days. Excess benzylamine was evaporated in vacuo to give a yellow oil (0.80 g), which was purified by preparative layer chromatography [elution with hexane–MeOH–EtOAc (2:0.1:1)] to afford, as pale yellow crystals, methyl 2-(benzylaminomethyl)-3-(2-benzyloxyphenyl)-3-hydroxypropanoate **5a** (0.50 g, 62%), m.p. 94–96°C (Found: MH^+, 406.201633. $C_{25}H_{27}NO_4$ requires M+1, 406.201834.); ν_{max} (KBr)/cm^{-1} 3308 (OH) and 1720 (C=O); δ_H 2.54 (1H, dd, CH_ANHCH_2Ph), 3.06–3.13 (2H, complex of overlapping signals, $CHCH_BNHCH_2Ph$), 3.64 and 3.69 (2H, 2 × d, NCH_2Ph), 3.75 (3H, s, OCH_3), 5.13 (2H, 2 × d, OCH_2Ph), 5.77 (1H, m, *CH*OH), 6.90–6.96 (2H, m, Ar-H) and 7.20–7.47 (12H, series of multiplets, Ar-H); δ_C 46.2 (CH_2NHCH_2Ph), 47.4 ($CHCO_2CH_3$), 51.9 (OCH_3), 54.2 (CH_2NHCH_2Ph), 69.6 (OCH_2Ph), 71.8 (CHOH), 111.3, 120.9, 126.8, 127.0, 127.2, 127.7, 128.1, 128.37, 128.42, 128.5, 131.7, 137.0, 139.1 and 154.5 (Ar-C) and 174.2 (C=O); m/z 405 (M^+, 0.1%) and 91 (100).

Methyl 2-(benzylaminomethyl)-3-(2-benzyloxy-3-methoxyphenyl)-3-hydroxypropanoate 5b as a pale yellow oil (0.76 g, 87%). (Found: MH^+, 436.212314. $C_{26}H_{29}O_5N$ requires $M+1$, 436.212398.); ν_{max} (thin film)/cm^{-1} 3325 (OH) and 1732 (C=O); δ_H 2.48 (1H, dd, CH_ANHCH_2Ph), 3.04–3.12 (2H, complex of overlapping signals, $CHCH_BNHCH_2Ph$), 3.65 (2H, s, CH_2NHCH_2Ph), 3.73 and 3.90 (6H, $2\times$s, OCH_3), 4.89 and 5.22 (2H, $2\times$d, OCH_2), 5.65 (1H, m, *CH*OH) and 6.89–7.53 (13H, series of multiplets, Ar-H); δ_C 46.1 (CH_2NHCH_2Ph), 48.1 ($CHCO_2CH_3$), 51.8 and 55.7 ($2\times OCH_3$), 54.1 ($NHCH_2Ph$), 72.1 (CHOH), 74.5 (OCH_2Ph), 111.2, 118.8, 123.9, 127.1, 127.9, 128.19, 128.24, 128.3, 128.4, 137.1, 137.5, 139.0, 143.8 and 152.3 (Ar-C) and 173.8 (C=O); *m*/*z* 436 (M^+, 17.3%) and 120 (100).

Methyl 2-(benzylaminomethyl)-3-(2-benzyloxy-3-ethoxyphenyl)-3-hydroxypropanoate 5c as a pale yellow oil (0.64 g, 71%). (Found: MH^+, 450.228102. $C_{27}H_{31}O_5N$ requires $M+1$, 450.228048.); ν_{max} (thin film)/cm^{-1} 3323 (OH) and 1733 (C=O); δ_H 1.49 (3H, t, CH_2CH_3), 2.47 (1H, dd, CH_ANHCH_2Ph), 3.06–3.10 (2H, m, $CHCH_BNHCH_2Ph$), 3.64 (2H, s, $NHCH_2Ph$), 3.72 (3H, s, OCH_3), 4.10 (2H, q, OCH_2CH_3), 4.89 and 5.24 (2H, $2\times$d, OCH_2Ph), 5.64 (1H, s, *CH*OH) and 6.86–7.52 (13H, series of multiplets, Ar-H); δ_C (400 MHz, $CDCl_3$) 15.0 (OCH_2CH_3), 46.2 (CH_2NHCH_2Ph), 48.1 ($CHCO_2CH_3$), 51.9 (OCH_3), 54.2 ($NHCH_2Ph$), 64.1 (OCH_2CH_3), 72.2 (CHOH), 74.6 (OCH_2Ph), 112.2, 118.7, 123.9, 127.2, 128.0, 128.28, 128.31, 128.46, 128.50, 137.2, 137.7, 139.1, 143.9 and 151.7 (Ar-C) and 174.0 (C=O); *m*/*z* 450 (MH^+, 6.9%) and 91 (100%).

Methyl 2-(benzylaminomethyl)-3-(2-benzyloxy-5-chlorophenyl)-3-hydroxypropanoate 5d as a yellow solid (0.61 g, 69%), m.p. 68–70°C. (Found: MH^+, 440.162907. $C_{25}H_{26}O_4N^{35}Cl$, requires: $M+1$, 440.162861.); ν_{max} (KBr)/cm^{-1} 3298 (OH) and 1732 (C=O); δ_H 2.51 (1H, dd, CH_ANHCH_2Ph), 3.05 (1H, dd, $CHCH_2NH$), 3.14 (1H, m, CH_BNHCH_2Ph), 3.68 (2H, s, $NHCH_2Ph$), 3.74 (3H, s, OCH_3), 5.06 (2H, $2\times$d, OCH_2Ph), 5.72 (1H, d, *CH*OH) and 6.83–7.51 (13H, series of multiplets, Ar-H); δ_C 46.3 (CH_2NHCH_2Ph), 47.0 ($CHCO_2CH_3$), 52.0 (OCH_3), 54.2 ($CH_2NH_2CH_2Ph$), 70.0 (OCH_2Ph), 71.5 (CHOH), 112.7, 126.3, 126.8, 127.3, 127.4, 127.8, 127.9, 128.2, 128.5, 128.6, 133.8, 136.5, 138.7 and 153.0 (Ar-C) and 173.8 (C=O); *m*/*z* 440 [MH^+ (^{35}Cl), 1.8%] and 91 (100).

Methyl 2-(benzylaminomethyl)-3-(2-benzyloxy-5-bromophenyl)-3-hydroxypropanoate 5e as a yellow oil (0.61 g, 63%). (Found: MH^+, 484.112392. $C_{25}H_{26}O_4N^{79}Br$ requires $M+1$, 484.112345.); ν_{max} (thin film)/cm^{-1} 3324 (OH) and 1732 (C=O); δ_H 2.53 (1H, dd, CH_ANHCH_2Ph), 3.07 (1H, dd, $CHCH_2NHCH_2Ph$), 3.16 (1H, ddd,

CH_BNHCH_2Ph), 3.69 (2H, dd, $NHCH_2Ph$), 3.75 (3H, s, OCH_3), 5.08 (2H, dd, OCH_2Ph), 5.74 (1H, s, *CH*OH), 6.80 (1H, d, Ar-H), 7.27–7.44 (11H, series of multiplets, Ar-H) and 7.69 (1H, d, Ar-H); δ_C 46.3 (CH_2NHCH_2Ph), 47.0 ($CHCO_2CH_3$), 52.0 (OCH_3), 54.2 ($NHCH_2Ph$), 69.9 (OCH_2Ph), 71.3 (CHOH), 113.2, 113.6, 126.7, 127.3, 127.9, 128.1, 128.4, 128.5, 130.1, 130.8, 134.1, 136.3, 138.7 and 153.5 (Ar-C) and 173.7 (C=O); *m*/*z* 484 [MH^+ (^{79}Br), 3.0%] and 121 (100).

Methyl 2-(benzylaminomethyl)-3-(2-benzyloxy-3,5-dibromophenyl)-3-hydroxypropanoate 5f as a yellow oil (0.80 g, 71%). (Found: MH^+, 562.022773. $C_{25}H_{25}O_4N^{79}Br_2$, requires: M + 1, 562.022856.); ν_{max} (thin film)/cm^{-1} 3419 (OH) and 1747 (C=O); δ_H 2.43 (1H, dd, CH_ANHCH_2Ph), 3.02 (1H, m, $CHCH_2NH$), 3.14 (1H, dd, CH_BNHCH_2Ph), 3.60 (2H, s, $NHCH_2Ph$), 3.70 (3H, s, OCH_3), 4.81 and 5.15 (2H, 2 × d, OCH_2Ph), 5.59 (1H, d, C*H*OH) and 7.27–7.57 (12H, series of multiplets, Ar-H); δ_C 46.3 (CH_2NHCH_2Ph), 47.7 ($CHCO_2CH_3$), 52.1 (OCH_3), 54.2 ($NHCH_2Ph$), 72.1 (CHOH), 75.2 (OCH_2Ph), 117.9, 118.3, 127.6, 128.3, 128.48, 128.54, 128.6, 128.7, 130.0, 134.8, 136.1, 138.2, 140.6 and 151.3 (Ar-C) and 173.1 (C=O); *m*/*z* 562 [MH^+ ($^{79}Br_2$), 1.2%] and 92 (100).

Methyl 3-(2-benzyloxyphenyl)-3-hydroxy-2-(piperidinomethyl)propanoate 6a (General Procedure)

A mixture of methyl 3-(2-benzyloxyphenyl)-3-hydroxy-2-methylenepropanoate **4a** (0.56 g, 2 mmol) and piperidine (0.50 mL) in THF (5 mL) was stirred in a stoppered reaction flask for 3 days. Excess piperidine was evaporated in vacuo to give a yellow oil (0.77 g), which was purified by preparative layer chromatography [elution with $CHCl_3$-EtOAc (3:1)] to afford, as pale yellow crystals, methyl 3-(2-benzyloxyphenyl)-3-hydroxy-2-(piperidinomethyl)propanoate **6a** (0.61 g, 80%), m.p 102–104°C. (Found: M^+, 383.21036. $C_{23}H_{29}NO_4$ requires M, 383.20966.); ν_{max} (KBr)/cm^{-1} 3145 (OH) and 1722 (C=O); δ_H 1.43 (2H, m, $CH_2CH_2CH_2N$), 1.58 (4H, m, CH_2CH_2N), 2.41 and 2.51 (4H, 2 × br s, CH_2CH_2N), 2.69 (1H, d, CH_ANHCH_2Ph), 3.00 (1H, t, $CHCH_2NH$), 3.26 (1H, m, CH_BNHCH_2Ph), 3.40 (3H, s, OCH_3), 5.05 and 5.10 (2H, 2 × d, OCH_2Ph), 5.38 (1H, d, *CH*OH), 6.90 (1H, d, Ar-H), 6.94 (1H, t, Ar-H) and 7.18–7.37 (7H, series of multiplets, Ar-H); δ_C 23.9, 25.8 and 54.8 ($CH_2CH_2CH_2N$), 47.3 ($CHCO_2CH_3$), 51.5 (OCH_3), 60.0 (CH_2CH_2N), 70.2 (OCH_2Ph), 72.9 (CHOH), 112.0, 120.9, 127.3, 127.7, 128.41, 128.43, 128.7, 130.5, 137.2 and 155.9 (Ar-C) and 172.6 (C=O); *m*/*z* 383 (M^+, 1.0%) and 91 (100).

Methyl 3-(2-benzyloxy-3-methoxyphenyl)-3-hydroxy-2-(piperidinomethyl)propanoate 6b as a pale yellow oil (0.46 g, 55%). (Found: M^+, 413.22071. $C_{24}H_{31}NO_5$ requires M, 413.22022; δ_H 1.42 (2H, m, $CH_2CH_2CH_2N$), 1.57 (4H, m, CH_2CH_2N), 2.37 and 2.52 (4H, 2 × br s, CH_2CH_2N), 2.64 and 2.96 (2H, 2 × dd, CH_2NHCH_2Ph), 3.21 (1H, m, $CHCO_2CH_3$), 3.41 and 3.88 (6H, 2 × s, OCH_3), 4.97 and 5.13 (2H, 2 × d, OCH_2Ph), 5.31 (1H, d, *CH*OH), 6.85 (1H, dd, Ar-H), 7.02–7.38 (5H, series of multiplets, Ar-H) and 7.52 (2H, d, Ar-H); δ_C 23.9, 25.9 and 54.7 ($CH_2CH_2CH_2N$), 47.5 ($CHCO_2CH_3$), 51.5 and 55.8 (2 × OCH_3), 60.4 (CH_2N), 73.3 (CHOH), 74.8 (OCH_2Ph), 111.8, 120.2, 124.0, 127.6, 127.9, 128.2, 136.0, 138.2, 145.7 and 152.7 (Ar-C) and 172.4 (C=O); *m*/*z* 413 (M^+, 1.3%) and 99 (100).

Methyl 3-(2-benzyloxy-3-ethoxyphenyl)-3-hydroxy-2-(piperidinomethyl)propanoate 6c as a pale yellow oil (0.50 g, 58%). (Found: M^+, 427.23545. $C_{25}H_{33}NO_5$ requires M, 427.23587.); δ_H 1.47 (5H, overlapping signals, OCH_2CH_3 and $CH_2CH_2CH_2N$), 1.54 (4H, m, CH_2CH_2N), 2.37 (2H, br s, CH_2CH_2N), 2.53 (2H, m, CH_2CH_2N), 2.64 and 2.99 (2H, dd, $CHCH_2N$), 3.21 (1H, m, $CHCO_2CH_3$), 3.40 (3H, s, OCH_3), 4.06 (2H, q, OCH_2CH_3), 4.98 and 5.13 (2H, 2 × d, OCH_2Ph), 5.30 (1H, d, *CH*OH) and 6.84–7.53 (8H, series of multiplets, Ar-H); δ_C 15.0 (OCH_2CH_3), 23.9, 25.9 and 54.7 ($CH_2CH_2CH_2N$), 47.4 ($CHCO_2CH_3$), 51.5 (OCH_3), 60.3 (CH_2N), 64.2 (OCH_2CH_3), 73.4 (CHOH), 74.8 (OCH_2Ph), 113.0, 120.1, 123.9, 127.6, 128.1, 128.2, 136.1, 138.3, 146.0 and 152.0 (Ar-C) and 172.5 (C=O); *m*/*z* 427 (M^+, 1.2%) and 99 (100).

Methyl 3-(2-benzyloxy-5-chlorophenyl)-3-hydroxy-2-(piperidinomethyl)propanoate 6d as a pale yellow oil (0.67 g, 63%). (Found: M^+, 417.17090. $C_{23}H_{28}NO_4{}^{35}Cl$ requires M, 417.17069.); δ_H 1.43 (2H, m, $CH_2CH_2CH_2N$), 1.58 (4 H, m, CH_2CH_2N), 2.40 and 2.52 (4H, 2 × br s, CH_2CH_2N), 2.64 and 2.99 (2H, 2 × dd, $CHCH_2N$), 3.11 (1H, m, $CHCO_2CH_3$), 3.42 (3H, s, OCH_3), 5.04 (2H, 2 × d, OCH_2Ph), 5.41 (1H, d, *CH*OH), 6.80 (1H, d, Ar-H) and 7.13–7.46 (7H, series of multiplets, Ar-H); δ_C 23.9, 25.9 and 54.8 ($CH_2CH_2CH_2N$), 47.3 ($CHCO_2CH_3$), 51.5 (OCH_3), 59.9 (CH_2CH_2N), 70.5 (OCH_2Ph), 71.9 (CHOH), 113.2, 126.1, 127.2, 127.9, 128.2, 128.4, 128.5, 132.8, 136.7 and 154.3 (Ar-C) and 172.2 (C=O); *m*/*z* 417 [M^+ (^{35}Cl), 1.2%] and 98 (100).

Methyl 3-(2-benzyloxy-5-bromophenyl)-3-hydroxy-2-(piperidinomethyl)propanoate 6e as a pale yellow oil (0.60 g, 62%). (Found: M^+, 461.12015. $C_{23}H_{28}NO_4{}^{79}Br$ requires M, 461.12017.); ν_{max} (thin film)/cm^{-1} 3419 (OH) and 1732 (C=O); δ_H 1.43 (2H, m, $CH_2CH_2CH_2N$), 1.57 (4H, m, CH_2CH_2N), 2.39 and 2.51 (4H, 2 × br s,

CH_2CH_2N), 2.64 (1H, m, $CHCH_AN$), 2.99 (1H, t, $CHCH_BN$), 3.10 (1H, m, $CHCO_2CH_3$), 3.42 (3H, s, OCH_3), 5.03 (2H, q, 2 × d, OCH_2Ph), 5.41 (1H, d, CHOH), 6.75 (1H, d, Ar-H), 7.27–7.42 (6H, series of multiplets, Ar-H) and 7.53 (1H, d, Ar-H); δ_C 23.9, 25.8 and 54.7 ($CH_2CH_2CH_2N$), 47.3 ($CHCO_2CH_3$), 51.5 (OCH_3), 59.8 ($CHCH_2N$), 70.4 (OCH_2Ph), 71.8 (CHOH), 113.4, 113.6, 127.1, 127.9, 128.5, 131.15, 131.17, 133.2, 136.6, 154.7 (Ar-C) and 172.1 (C=O); m/z 462 [M^+ (^{79}Br), 3.4%] and 99 (100).

Methyl 3-(2-benzyloxy-3,5-dibromophenyl)-3-hydroxy-2-(piperidinomethyl)propanoate 6f as a pale yellow oil (0.73 g, 65%). (Found: M^+, 539.02614. $C_{23}H_{27}NO_4{}^{79}Br_2$ requires M, 539.03068.); δ_H 1.44 (2H, m, $CH_2CH_2CH_2N$), 1.56 (4H, m, CH_2CH_2N), 2.38 and 2.56 (4H, 2 × br s, CH_2CH_2N), 2.63 (1H, d, $CHCH_AN$), 3.02 (2H, overlapping multiplets, $CHCH_BN$), 3.42 (3H, s, OCH_3), 4.91 and 5.12 (2H, 2 × d, OCH_2Ph), 5.24 (1H, d, CHOH), 7.33–7.53 (5H, series of multiplets, Ar-H),7.59 (1H, d, Ar-H) and 7.64 (1H, d, Ar-H); δ_C 23.8, 25.8 and 54.8 ($CH_2CH_2CH_2N$), 47.3 ($CHCO_2CH_3$), 51.8 (OCH_3), 60.4 ($CHCH_2N$), 73.1 (CHOH), 75.5 (OCH_2Ph), 117.6, 118.4, 127.9, 128.1, 128.4, 130.9, 135.1, 136.8, 139.6 and 152.8 (Ar-C) and 171.5 (C=O); m/z 539 [M^+ ($^{79}Br_2$), 0.9%] and 91 (100).

3-(Benzylaminomethyl)coumarin 7a (General Procedure)

A mixture of methyl 2-(benzylaminomethyl)-3-(2-benzyloxyphenyl)-3-hydroxypropanoate **5a** (490 mg, 1.21 mmol) and pre-equilibrated 10% Pd–C catalyst (84 mg) in 95% EtOH (6.7 mL) was hydrogenated at room temperature and atmospheric pressure. (Hydrogen absorption ceased after the uptake of one equivalent of hydrogen.) The mixture was filtered and the solvent removed in vacuo to give the crude mixture (360 mg) as a pale yellow oil, which was purified using preparative layer chromatography [on silica; elution with $CHCl_3$–EtOAc (3 : 1)] to afford, as a pale yellow solid, 3-(benzylaminomethyl)coumarin **7a** (170 mg, 53%), m.p. 70–74°C. (Found: M^+, 265.10796. $C_{17}H_{15}O_2N$ requires M, 265.11028.); ν_{max} (KBr)/cm^{-1} 3323 (N-H) and 1713 (C=O); δ_H 1.95 (1H, br, s, NH), 3.76 (2H, d, 1′-CH_2), 3.86 (2H, s, CH_2Ph), 7.23–7.51 (9H, series of overlapping signals, Ar-H) and 7.72 (1H, s, 4-H); δ_C 48.3 and 53.2 (2 × CH_2), 116.4, 119.2, 124.3, 127.0, 127.4, 127.5, 128.1, 128.4, 130.9, 139.1, 139.7 and 153.1 (Ar-C) and 161.4 (C=O); m/z 265 (M^+, 0.9%) and 174 (100).

3-(Benzylaminomethyl)-8-methoxycoumarin 7b as a pale yellow oil (190 mg, 50%). (Found: M^+, 295.11855. $C_{18}H_{17}O_3N$ requires M, 295.12084.); ν_{max} (KBr)/cm^{-1} 3394 (NH) and 1714 (C=O); δ_H 1.88 (1H, br s, NH), 3.76 (2H, d, 1′-CH_2), 3.84 (2H, s, CH_2Ph), 3.95 (3H, s,

OCH_3), 7.04 (2H, d, Ar-H), 7.17–7.36 (6H, series of multiplets, Ar-H) and 7.69 (1H, d, 4-H); δ_C 48.4 and 53.2 ($2 \times CH_2$), 56.3 (OCH_3), 113.0, 119.1, 120.0, 124.2, 127.1, 127.7, 128.2, 128.5, 139.3, 139.7, 142.9 and 147.1 (Ar-C) and 160.9 (C=O); *m*/*z* (FAB) 296 (MH^+, 100%).

3-(Benzylaminomethyl)-8-ethoxycoumarin 7c as a pale yellow solid (250 mg, 66%), m.p. 98–102°C. (Found: M^+, 309.13418. $C_{19}H_{19}O_3N$ requires M, 309.13649.); ν_{max}(KBr)/cm^{-1} 3300 (NH) and 1712 (C=O); δ_H 1.49 (3H, t, OCH_2CH_3), 2.00 (1H, br s, 3.75 (2H, d, 1′-CH_2), 3.84 (2H, s, CH_2Ph), 4.20 (2H, q, OCH_2CH_3), 7.01–7.36 (8H, series of multiplets, Ar-H) and 7.68 (1H, s, 4-H); δ_C 14.7 (OCH_2CH_3), 48.4 and 53.1 ($2 \times CH_2$), 64.9 (OCH_2CH_3), 114.3, 119.0, 120.0, 124.2, 127.0, 127.5, 128.1, 128.4, 139.3, 139.8, 143.1 and 146.4 (Ar-C) and 161.0 (C=O); *m*/*z* (FAB) 310 (MH^+, 100%).

3-(Benzylaminomethyl)-6-chlorocoumarin 7d as a yellow solid (190mg, 50%), m.p. 106–110°C. (Found: M^+, 298.06240. $C_{17}H_{14}O_3N^{35}Cl$ requires M − 1, 298.06348.); ν_{max} (KBr)/cm^{-1} 3322 (NH) and 1719 (C=O); δ_H 1.82 (1H, br s, NH), 3.74 (2H, d, 1′-CH_2), 3.85 (2H, s, CH_2Ph), 7.23–7.45 (8H, series of multiplets, Ar-H) and 7.69 (1H, s, 4-H); δ_C 48.1 and 53.2 ($2 \times CH_2$), 117.8, 120.3, 126.7, 127.1, 128.0, 128.4, 128.8, 129.5, 130.8, 137.7, 139.6 and 151.4 (Ar-C) and 160.7 (C=O); *m*/*z* (FAB) 300 [MH^+ (^{35}Cl), 96.1%] and 91 (100).

3-(Piperidinomethyl)coumarin 8a and 3-methylcoumarin 9a (General Procedure)

A mixture of methyl 3-(2-benzyloxyphenyl)-3-hydroxy-2-(piperidinomethyl)propanoate **5a**, (466 mg, 1.22 mmol) and pre-equilibrated 10% Pd-C catalyst (84 mg) in absolute EtOH (6.7 mL) was hydrogenated at room temperature and atmospheric pressure for 6 h. The resulting mixture was filtered and the solvent removed from the filtrate in vacuo to give a pale yellow oil (380 mg), which was purified by preparative layer chromatography [on silica; elution with $CHCl_3$–EtOAc (3:1)] to afford two products:

(i) 3-(Piperidinomethly)coumarin 8a as a brown solid (150 mg, 51%), m.p. 66–68°C. (Found: M^+, 243.12588. $C_{15}H_{17}O_2N$ requires M, 243.12593.); ν_{max} (KBr)/cm^{-1} 1723 (C=O); δ_H 1.46 (2H, m, $CH_2CH_2CH_2N$), 1.59 (4H, m, CH_2CH_2N), 2.48 (4H, br s, CH_2CH_2N), 3.42 (2H, d, *J* 0.4 Hz, 1′-CH_2), 7.23–7.49 (4H, series of multiplets, Ar-H) and 7.78 (1H, s, Ar-H); δ_C 24.1, 25.9 and 54.7 ($CH_2CH_2CH_2N$), 56.9 (1′-CH_2), 116.3, 119.3, 124.2, 126.0, 127.5, 130.7, 139.4 and 152.9 (Ar-C) and 161.5 (C=O); *m*/*z* 243 (M^+, 62.9%) and 200 (100); and

(ii) 3-Methylcoumarin 9a as a pale yellow solid (40 mg, 20%).[18]

The general procedure was followed. Work-up and chromatography afforded:

(i) 8-Methoxy-3-(piperidinomethyl)coumarin 8b as a pale yellow oil (150 mg, 45%). (Found: M^+, 273.13684. $C_{16}H_{19}O_3N$ requires M, 273.13649.); ν_{max} (thin film)/cm^{-1} 1714 (C=O); δ_H 1.45 (2H, m, $CH_2CH_2CH_2N$), 1.60 (4H, m, CH_2CH_2N), 2.47 (4H, t, CH_2CH_2N), 3.42 (2H, d, 1′-CH_2), 3.93 (3H, s, OCH_3), 7.02 (1H, d, Ar-H), 7.06 (1H, d, Ar-H), 7.18 (1H, t, Ar-H) and 7.77 (1H, s, Ar-H); δ_C 24.1, 26.0 and 54.7 ($CH_2CH_2CH_2N$), 56.2 (OCH_3), 56.9 (1′-CH_2), 112.7, 119.1, 120.1, 124.1, 126.3, 139.7, 142.7 and 147.0 (Ar-C) and 161.1 (C=O); *m*/*z* 273 (M^+, 91.2%) and 230 (100); and

(ii) 8-Methoxy-3-methylcoumarin 9b as a grey solid, (22 mg, 9.5%), m.p. 68–72°C. (Found: M^+, 190.06299. $C_{11}H_{10}O_3$ requires M, 190.06299.); ν_{max} (KBr)/cm^{-1} 1716 (C=O); δ_H 2.20 (3H, s, CH_3), 3.94 (3H, s, OCH_3), 6.99 (2H, t, Ar-H), 7.16 (1H, t, Ar-H) and 7.48 (1H, s, 4-H); δ_C 17.2 (CH_3), 56.2 (OCH_3), 112.4, 118.4, 120.2, 124.1, 126.1, 139.3, 142.9 and 147.0 (Ar-C) and 161.6 (C=O); *m*/*z* 190 (M^+, 100%).

The general procedure was followed. Work-up and chromatography afforded:

(i) 8-Ethoxy-3-(piperidinomethyl)coumarin 8c as a pale yellow oil (170 mg, 49%). (Found: M^+, 287.15293. $C_{17}H_{21}O_3N$ requires M, 287.15214.); ν_{max} (thin film)/cm^{-1} 1714 (C=O); δ_H 1.47 (5H, m, OCH_2CH_3 and $CH_2CH_2CH_2N$), 1.62 (4H, m, CH_2CH_2N), 2.49 (4H, t, CH_2CH_2N), 3.45 (2H, s, 1′-CH_2), 4.17 (2H, q, OCH_2CH_3), 7.02 and 7.05 (2H, 2 × d, Ar-H), 7.15 (1H, t, Ar-H) and 7.77 (1H, s, 4-H); δ_C 14.8 (OCH_2CH_3), 24.2, 26.0 and 54.7 ($CH_2CH_2CH_2N$), 56.9 (1′-CH_2), 65.0 (OCH_2CH_3), 114.3, 119.1, 120.3, 124.1, 126.3, 139.8, 143.1 and 146.4 (Ar-C) and 161.3 (C=O); *m*/*z* 287 (M^+, 74.4%) and 176 (100); and

(ii) 8-Ethoxy-3-methylcoumarin 9c as a pale yellow oil (35mg, 14%). (Found: M^+, 204.07884. $C_{12}H_{12}O_3$ requires M, 204.07864.); ν_{max} (thin film)/cm^{-1} 1714 (C=O); δ_H 1.47 (3H, t, CH_2CH_3), 2.19 (3H, d, 3-CH_3), 4.16 (2H, q, OCH_2CH_3), 6.95 and 6.98 (2H, 2 × dd, Ar-H), 7.13 (1H, t, Ar-H) and 7.47 (1H, dd, Ar-H); δ_C 14.7 (OCH_2CH_3), 17.1 (3-CH_3), 64.8 (OCH_2CH_3), 113.7, 118.4, 120.3, 124.0, 125.9, 139.4, 143.1 and 146.3 (Ar-C) and 161.8 (C=O); *m*/*z* 204 (M^+, 59.1%) and 176 (100).

The general procedure was followed. Work-up and chromatography afforded:

(i) 6-chloro-3-(1-piperidinylmethyl)coumarin 8d, as a pale yellow solid (205 mg, 61%), m.p. 116–118°C. (Found: M^+, 277.08708. $C_{15}H_{16}O_2N^{35}Cl$ requires M, 277.08696.); ν_{max}(KBr)/cm^{-1} 1724 (C=O); δ_H 1.47 (2H, m, $CH_2CH_2CH_2N$), 1.63 (4H, m, CH_2CH_2N), 2.48 (4H, t, CH_2CH_2N), 3.42 (2H, d, 1′-CH_2), 7.25 (1H, t, Ar-H),

7.40 and 7.42 (2H, 2 × dd, Ar-H), 7.48 (1H, d, Ar-H) and 7.72 (1H, s, 4-H); δ_C 24.2, 26.1 and 54.8 ($CH_2CH_2CH_2N$), 57.0 (1′-CH_2), 117.8, 120.6, 126.8, 127.8, 129.5, 130.7, 138.0 and 151.4 (Ar-C) and 161.0 (C=O); m/z 277 [M^+ (^{35}Cl), 52.3%] and 234 (100); and

(ii) 6-chloro-3-methylcoumarin 9d, as a pale yellow solid (22 mg, 9%).[18]

Methyl 3-(2-hydroxyphenyl)-2-methylpropanoate 11

A mixture of methyl 3-(2-benzyloxyphenyl)-3-hydroxy-2-methylenepropanoate **4a** (0.36 g, 1.2 mmol) and pre-equilibrated 10% Pd-C catalyst (84 mg) in absolute EtOH (6.7 mL) was hydrogenated at room temperature and atmospheric pressure for 6 h. The mixture was filtered and the solvent removed from the filtrate in vacuo to give a yellow oil (204 mg), which was purified using flash chromatography [elution with hexane–EtOAc (3:1.5)] followed by extraction with acetone to afford, as a pale yellow oil, methyl 3-(2-hydroxyphenyl)-2-methylpropanoate **11** (186 mg, 80%). (Found: M^+, 194.09567. $C_{11}H_{14}O_3$ requires M, 194.09429.); ν_{max} (thin film)/cm^{-1} 3396 (OH) and 1709 (C=O); δ_H 1.26 (3H, d, 2-CH_3), 2.70 (1H, dd, CH_AH), 2.86 (1H, m, $CHCH_3$), 3.01 (1H, dd, CH_BH), 3.65 (3H, s, OCH_3), 6.84 (2H, m, Ar-H), 6.92 (1H, br s, ArOH), and 7.05–7.11 (2H, m, Ar-H); δ_C 17.9 ($CHCH_3$), 33.5 (CH_2), 40.7 ($CHCH_3$), 52.1 (OCH_3), 116.8, 120.5, 125.8, 127.9, 131.2 and 154.2 (Ar-C) and 178.7 (C=O); m/z 194 (M^+, 11.5%) and 162 (100).

Methyl 3-(2-benzyloxyphenyl)-2-methylpropenoate 12

A solution of methyl 3-(2-benzyloxyphenyl)-3-hydroxy-2-methylenepropanoate **4a** (0.30 g, 1 mmol) in ethanol (4 mL) was stirred, under N_2, in a two-necked, round-bottomed flask, immersed in a water bath at 25°C. Pre-equilibrated 10% Pd-C catalyst (84 mg) was then added, followed by 1,4-cyclohexadiene (0.94 mL, 10 mmol). The resulting mixture was boiled under reflux for 2 h and filtered through celite. The solid residue was washed with ethanol (ca. 5 mL), and the filtrate and washings were combined and evaporated in vacuo to afford a crude product (0.25 g), which was purified using preparative layer chromatography [elution with hexane–EtOAc (3:1)] to afford, as a yellow oil, methyl 3-(2-benzyloxyphenyl)-2-methylpropenoate **12** (50 mg, 18%). (Found: M^+, 282.12610. $C_{18}H_{18}O_3$ requires M, 282.12559.); ν_{max} (thin film)/cm^{-1} 1711 (C=O); δ_H 2.08/2.12[19] (3H, 2 × d, J 1.6 and 1.6 Hz, CH_3C=C), 3.59/3.82 (3H, 2 × s, OCH_3), 5.10/5.14 (2H, 2 × s, OCH_2OPh), 6.90–7.44 (9H, series of multiplets, Ar-H) and 7.95 (1H, br s, ArCH=C)[20]; m/z 282 (M^+, 15.4%) and 92 (100).

3-(Ethylsulfanylmethyl)coumarin 13

To a solution of methyl 3-(2-benzyloxyphenyl)-3-hydroxy-2-methylenepropanoate **4a** (0.22 g, 0.72 mmol) in EtSH (2 mL) was added boron trifluoride etherate (1 mL, 8 mmol), and the resulting mixture was stirred at room temperature for 40 min. The mixture was poured into water and extracted with Et_2O. The combined organic extracts were washed with satd. brine, dried (anhyd. Na_2SO_4), filtered and concentrated in vacuo to afford an oil (0.54 g), which was purified using preparative layer chromatography [elution with hexane–EtOAc (3:1)] to afford, as a yellow solid, 3-(ethylsulfanylmethyl)coumarin **13** (15 mg, 10%), m.p. 68–72°C (Found: $\mathbf{M}^+$, 220.05715. $C_{12}H_{12}O_2S$ requires M, 220.05580.); ν_{max} (KBr)/cm^{-1} 1720 (C=O); δ_H 1.29 (3H, t, SCH_2CH_3), 2.58 (2H, q, SCH_2CH_3), 3.66 (2H, s, CH_2S), 7.27 (1H, d, Ar-H), 7.33 (1H, d, Ar-H), 7.48 (2H, d, Ar-H) and 7.71 (1H, s, Ar-H); δ_C 14.4 (SCH_2CH_3), 26.3 and 30.8 ($CH_2SCH_2CH_3$) 116.6, 119.2, 124.4, 126.4, 127.5, 131.2, 139.4 and 153.3 (Ar-C) and 161.1 (C=O); *m*/*z* (FAB) 220 (M^+, 37%) and 160 (100).

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19. The chemical shift data reported in this format reflect a mixture (1:1.7) of the geometric isomers.
20. The COSY spectrum indicates weak coupling to the allylic methyl protons and to an aromatic proton.

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