Diversity-Oriented Synthesis of Functionalized Diaryl Sulfones by Regioselective [3+3] Cyclizations of 1,3-Bis(siloxy)buta-1,3-dienes with 2-(Arylsulfonyl)-3-ethoxy-2-en-1-ones: Scope and Limitations

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Abstract: The formal [3+3] cyclization of 1,3-bis(siloxy)buta-1,3-dienes with 2-(arylsulfonyl)-3-ethoxy-2-en-1-ones, readily available by reaction of β-keto sulfones with triethyl orthoformate, allows the synthesis of a variety of functionalized diaryl sulfones with very good regioselectivity.

Key words: arenes, sulfones, cyclizations, regioselectivity, silyl enol ethers

A number of pharmacologically active compounds contain a 4-(arylsulfonyl)phenol substructure. The wide range of pharmacological activities reported include, for example, antibacterial activity,[1] inhibition of phospholipidase A_2,[2] inhibition of catechol O-methyltransferase,[3] inhibition of dihydropteroate synthase of *Escherichia coli*,[4] hypolipidemic activity,[5] cytotoxicity against HeLa cells and the antipicornavirus,[6] neuropeptide Y_1 receptor binding activity,[7] anti-HIV activity,[8] anticholesteremic activity,[9] binding to human muscarinic M_1 and M_2 receptors,[8c,10] histamine H_3-receptor antagonistic activity,[11] antiprotozoal activity,[12] binding to neuroblastoma cells,[13] binding to the human cannabinoid CB_1 receptor,[14] and inhibition of the main protease of the recombinant SARS coronavirus.[15]

A number of synthetic approaches to diaryl sulfones have been reported. Classic approaches include, for example, the oxidation of diaryl sulfides.[16] In addition, the Friedel–Crafts-type acylation of anisole with benzenesulfonyl chloride has been reported.[17] However, this reaction proceeds with low regioselectivity. The reaction of phenol with benzenesulfonic acid requires harsh conditions (240 °C).[18] In recent years, transition-metal-mediated syntheses of diaryl sulfones have been developed. Examples include the copper(I) iodide/proline mediated reaction of aryl iodides with sodium benzenesulfinate,[19] the Suzuki reaction of 4-methoxybenzeneboronic acid with benzenesulfonyl chloride,[20] and the copper(II) acetate catalyzed reaction of 4-methoxybenzeneboronic acid with sodium benzenesulfinate (in the presence of 1,10-phenanthroline and oxygen).[21]

Despite their great synthetic utility, the sulfonations outlined above, which all rely on the coupling of two arene moieties, can suffer from several drawbacks, such as harsh reaction conditions, low regioselectivity, and narrow synthetic scope. In addition, it is important to note that the synthesis of the required starting materials, functionalized or highly substituted aryl halides or triflates, can be a difficult and tedious task, due to the low *o*/*p*-regioselectivity of electrophilic substitutions, competing isomerization reactions, and other problems.

An interesting alternative approach to diaryl sulfones is based on the application of a ‘building block strategy’. Examples include the reaction of diethyl 2,4-diaryl-3-(arylsulfonyl)buta-1,3-diene-1,1-dicarboxylates with malononitrile,[22] 6π-electrocyclizations of 1-chloro-3-(phenylsulfonyl)hexa-1,3,5-trienes,[23] [4+2] cycloadditions of 3*H*-isobenzofuran-1-one with [1-(phenylsulfonyl)vinyl]trimethylsilanes,[24] reactions of enamines with 1,2,4-tris(phenylsulfonyl)but-2-ene,[25] the [4+2] cycloaddition of Danishefsky’s diene with a sulfonyl-substituted allene,[26] the [4+2] cycloaddition of a 1,2-bis(arylsulfonyl)ethene with thiophene-1,1-dioxide,[27] the cyclization of a 1-(trimethylsiloxy)buta-1,3-diene with an aryl vinyl sulfone,[28] 6π-electrocyclizations of phenylsulfonyl-substituted alkenes,[29] and the [4+2] cycloaddition of furan with 1,3-bis(phenylsulfonyl)allene.[30]

Chan and co-workers were the first to report[31] the [3+3] cyclization mediated by titanium(IV) chloride[32] of 1,3-bis(trimethylsiloxy)buta-1,3-dienes[33] with 3-siloxy-2-en-1-ones, which allows a convenient synthesis of salicylates. In recent years, this methodology has been applied to the synthesis of various functionalized arenes.[32] Most of the [3+3] cyclizations of 1,3-bis(trimethylsiloxy)buta-1,3-dienes mediated by titanium(IV) chloride reported to date involve the use of 3-siloxy-2-en-1-ones as starting materials. Although a few regioselective cyclizations have been reported, these reactions are generally *not* regioselective, because titanium(IV) chloride mediates the isomerization (silyl shift) of the 3-siloxy-2-en-1-ones. In their early work in 1980,[31] Chan and Brownbridge reported an isolated example of a successful and regioselective cyclization of a 3-alkoxy-2-en-1-one, i.e. 1-ethoxybut-1-en-3-one. On the basis of this observation, we have recently started a synthetic program directed at regioselective [3+3] cyclizations of acceptor-substituted 3-alkoxy-

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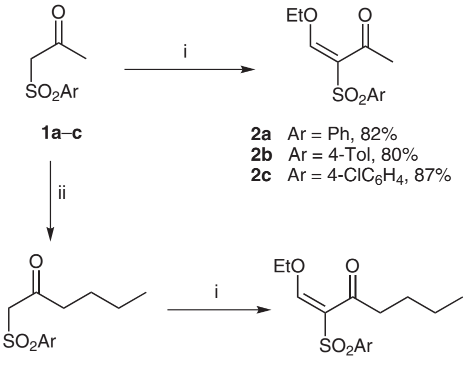
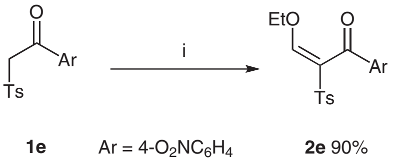
2-en-1-ones. Our strategy takes advantage of the ready availability of the required enones by reaction of acceptor-substituted ketones (such as β-keto esters or β-keto sulfones) with triethyl orthoformate.

We recently reported[34] our preliminary results related to the [3+3] cyclization of 1,3-bis(siloxy)buta-1,3-dienes with 2-(arylsulfonyl)-3-ethoxy-2-en-1-ones. These reactions provide a convenient and regioselective access to functionalized 4-(arylsulfonyl)phenols which are not readily available by other methods. In contrast to the C–S coupling reactions outlined above, this method constitutes a new building block methodology and involves the formation of one of the two arene moieties by formation of two C–C bonds. This full paper provides a comprehensive report on the scope of this methodology and a discussion of the regioselectivity.

The 1,3-bis(siloxy)buta-1,3-dienes **3a**–**m** required for the cyclization were prepared by literature procedures from the corresponding β-keto esters in two steps.[31,35,36] 2-(Arylsulfonyl)-3-ethoxy-2-en-1-ones **2a**–**d** were prepared, by a known procedure,[37] by reaction of β-keto sulfones **1a**–**d** with triethyl orthoformate and acetic anhydride (Scheme 1). β-Keto sulfone **1d** was prepared by alkylation of **1a** mediated by lithium diisopropylamide (Scheme 1). Enone **2e** was prepared in 90% yield from β-keto sulfone **1e** (Scheme 2).

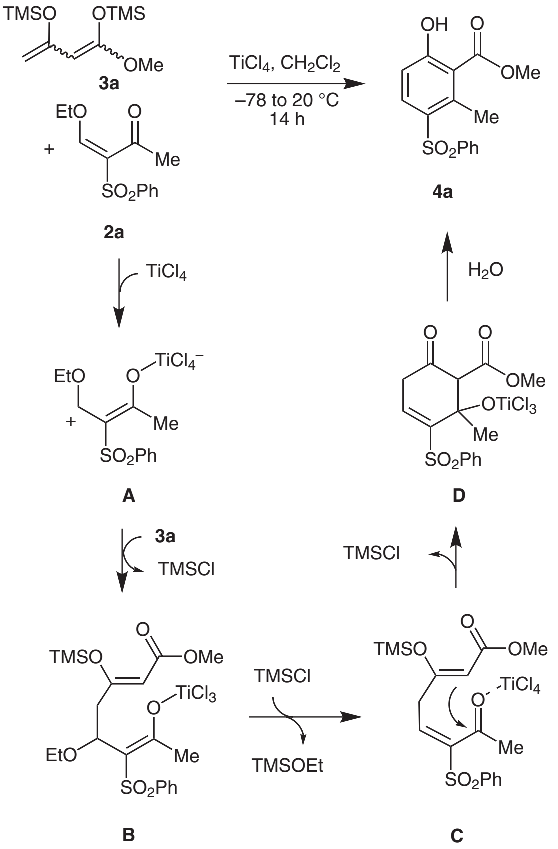


Scheme 1 Synthesis of **2a**–**d**. *Reagents and conditions*: (i) **1** (1.0 equiv), $HC(OEt)_3$ (1.2 equiv), Ac_2O, reflux, 2 h; (ii) LDA, PrI, –78 to 20 °C, 14 h.



Scheme 2 Synthesis of **2e**. *Reagents and conditions*: (i) **1e** (1.0 equiv), $HC(OEt)_3$ (1.2 equiv), Ac_2O, reflux, 2 h.

The cyclization of **2a** with **3a** mediated by titanium(IV) chloride afforded the novel 4-(arylsulfonyl)phenol **4a** in 80% yield (Scheme 3). A thorough optimization was carried out for the synthesis of **4a**. The best yields were obtained when the reaction was carried out in a highly concentrated solution (2 mL per 1.0 mmol of **2a**). The stoichiometry (**2a**/**3a**/$TiCl_4$ = 1.0/1.1/1.1), the temperature (slow warming from –78 to 20 °C), and the reaction time also played an important role. The yields decreased when a different stoichiometry (**2a**/**3a**/$TiCl_4$ = 1.0/2.0/1.0, 1.0/2.0/2.0, or 2.0/1.0/1.0) was used, when the reaction time was too short (2 h), and when the reaction was carried out at 0 °C rather than –78 °C. The use of trimethylsilyl trifluoromethanesulfonate, boron trifluoride–diethyl ether, and tin(IV) chloride resulted in the formation of complex mixtures.



Scheme 3 Possible mechanism of the formation of **4a**

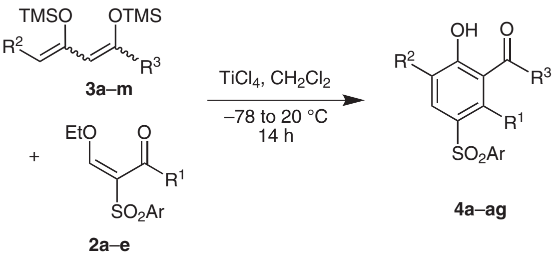
It is worth noting that the cyclization proceeded with excellent regioselectivity. The formation of product **4a** (Scheme 3) might be explained by reaction of **2a** with titanium(IV) chloride to give intermediate **A**, attack of the terminal carbon atom of **3a** at **A** to give intermediate **B**, then formation of intermediate **C**, cyclization via the central carbon (intermediate **D**), and subsequent aromatization. The regioselectivity of the formation of **4a** might be explained by the steric hindrance at the ketone carbonyl group.

The formal [3+3] cyclization of 2-(arylsulfonyl)-3-ethoxy-2-en-1-ones **2a**–**e** with 1,3-bis(siloxy)buta-1,3-dienes **3a**–**m** afforded the 4-(arylsulfonyl)phenols **4a**–**ag** in 42–80% yield (Scheme 4, Table 1). The aryl groups located on the sulfonyl group of enones **2** have some influ-

Table 1 Synthesis of **4a–ag**

Entry	2	3	4	Ar	R^1	R^2	R^3	Yield[a] (%)
1	**2a**	**3a**	**4a**	Ph	Me	H	OMe	80
2	**2a**	**3b**	**4b**	Ph	Me	Me	OMe	80
3	**2a**	**3c**	**4c**	Ph	Me	Et	OEt	77
4	**2a**	**3d**	**4d**	Ph	Me	*n*-Bu	OMe	76
5	**2a**	**3e**	**4e**	Ph	Me	*i*-Bu	OMe	70
6	**2a**	**3f**	**4f**	Ph	Me	$(CH_2)_5Me$	OMe	78
7	**2a**	**3g**	**4g**	Ph	Me	$(CH_2)_6Me$	OMe	75
8	**2a**	**3h**	**4h**	Ph	Me	$(CH_2)_7Me$	OMe	75
9	**2a**	**3i**	**4i**	Ph	Me	$(CH_2)_8Me$	OMe	75
10	**2a**	**3j**	**4j**	Ph	Me	$(CH_2)_9Me$	OMe	78
11	**2b**	**3a**	**4k**	Tol	Me	H	OMe	57
12	**2b**	**3b**	**4l**	Tol	Me	Me	OMe	56
13	**2b**	**3c**	**4m**	Tol	Me	Et	OEt	46
14	**2b**	**3d**	**4n**	Tol	Me	*n*-Bu	OMe	65
15	**2b**	**3f**	**4o**	Tol	Me	$(CH_2)_5Me$	OMe	61
16	**2b**	**3g**	**4p**	Tol	Me	$(CH_2)_6Me$	OMe	60
17	**2b**	**3h**	**4q**	Tol	Me	$(CH_2)_7Me$	OMe	59
18	**2b**	**3k**	**4r**	Tol	Me	OMe	OMe	42
19	**2c**	**3a**	**4s**	$4-ClC_6H_4$	Me	H	OMe	47
20	**2c**	**3b**	**4t**	$4-ClC_6H_4$	Me	Me	OMe	48
21	**2c**	**3c**	**4u**	$4-ClC_6H_4$	Me	Et	OEt	47
22	**2c**	**3d**	**4v**	$4-ClC_6H_4$	Me	*n*-Bu	OMe	54
23	**2c**	**3f**	**4w**	$4-ClC_6H_4$	Me	$(CH_2)_5Me$	OMe	50
24	**2c**	**3g**	**4x**	$4-ClC_6H_4$	Me	$(CH_2)_6Me$	OMe	51
25	**2c**	**3h**	**4y**	$4-ClC_6H_4$	Me	$(CH_2)_7Me$	OMe	52
26	**2c**	**3l**	**4z**	$4-ClC_6H_4$	Me	$4-ClC_6H_4$	OMe	48
27	**2c**	**3m**	**4aa**	$4-ClC_6H_4$	Me	Tol	OMe	53
28	**2d**	**3a**	**4ab**	Ph	*n*-Bu	H	OMe	77
29	**2d**	**3b**	**4ac**	Ph	*n*-Bu	Me	OMe	79
30	**2d**	**3m**	**4ad**	Ph	*n*-Bu	Tol	OMe	75
31	**2e**	**3a**	**4ae**	Tol	$4-O_2NC_6H_4$	H	OMe	45
32	**2e**	**3b**	**4af**	Tol	$4-O_2NC_6H_4$	Me	OMe	49
33	**2e**	**3d**	**4ag**	Tol	$4-O_2NC_6H_4$	*n*-Bu	OMe	47
34	**2f**	**3a**	**4ah**	Ph	Ph	H	OMe	0
35	**2a**	**3n**	**4ai**	Ph	Me	H	Me	0

[a] Yields of isolated products.



Scheme 4 Synthesis of **4a–ag**

ence on the yields. The best yields were obtained for products **4a–j** and **4ab–ad**, which are derived from phenyl-substituted enones **2a** and **2d**, respectively (Table 1, entries 1–10 and 28–30). In contrast, the presence of a substituent at C4 of the 1,3-bis(siloxy)buta-1,3-diene **3** has no significant effect on the yield. This can be seen by comparison of the yield of product **4a** with the yields of products **4b–j** (entry 1 vs 2–10), that of **4ab** with **4ac** and **4ad** (entry 28 vs 29 and 30), and by comparison of the yields of products **4k**, **4s**, and **4ab** with those of the corresponding substituted derivatives (entry 11 vs 12–18, entry 19 vs 20–27, and entry 28 vs 29 and 30, respectively). All products were formed with excellent regioselectivity. The formation of only one regioisomer was observed. It is worth noting that all attempts to carry out cyclizations of enones containing an aryl group R^1 other than 4-nitrophenyl failed (e.g., entry 34). In addition, only β-keto ester-derived dienes could be successfully employed. All attempts to induce a cyclization using 2,4-bis(trimethylsiloxy)-1,3-pentadiene, derived from acetylacetone, failed (e.g., entry 35). For some derivatives **4** the yields are only moderate, which might be explained by oxidative dimerization of the diene mediated by titanium(IV) chloride. This type of reaction has been reported previously.[38] In addition, some hydrolysis of the enone was observed.

The structures of all products were confirmed by spectroscopic methods. The structures of products **4a**, **4k**, **4s**, **4ab**, and **4ae**, all containing a hydrogen atom located at C6, are evident by the presence of large coupling constants for the two neighboring hydrogen atoms. The structure of **4ae** was independently confirmed by X-ray crystal-structure analysis (Figure 1).[39]

The elucidation of the structures of all other derivatives, containing an alkyl group at C6, was not so easy and required extensive 2D NMR experiments (NOESY, HMBC). The structure of **4d** was unambiguously confirmed by X-ray crystal-structure analysis (Figure 2).[39]

In conclusion, we have reported a convenient and regioselective synthesis of 4-(arylsulfonyl)phenols by what are, to the best of our knowledge, the first formal [3+3] cyclizations of 1,3-bis(siloxy)buta-1,3-dienes with 2-(arylsulfonyl)-3-ethoxy-2-en-1-ones. The reactions are easy to carry out and the starting materials are readily available.

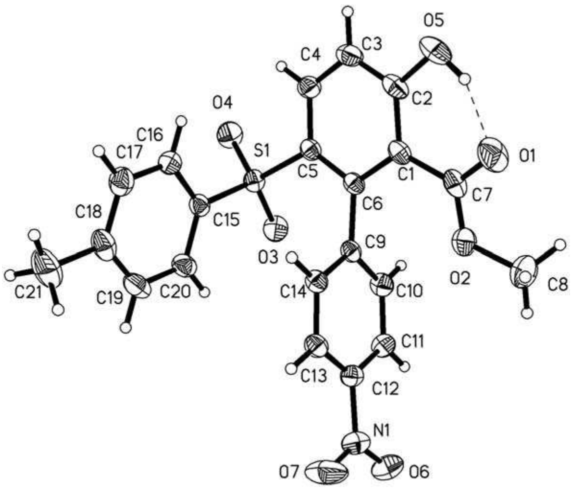


Figure 1 ORTEP plot of **4ae** (30% probability level)

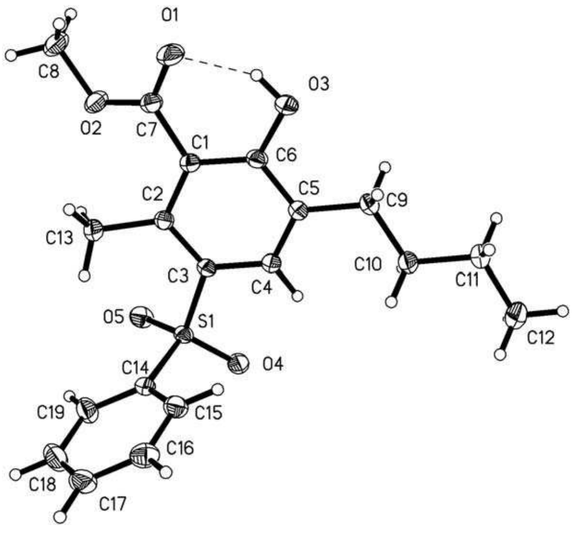


Figure 2 ORTEP plot of **4d** (30% probability level)

The NMR spectra of samples in $CDCl_3$ were recorded at 250, 300, or 500 MHz (^1H), respectively, or 62.5, 75, or 125 MHz (^{13}C), respectively. Chemical shifts are reported relative to the solvent as internal standard [$CDCl_3$, $\delta = 7.26$ (^1H) and 77.0 (^{13}C)]. MS data were obtained by EI (70 eV), CI (isobutane), or ESI methods, respectively. Melting points are uncorrected. Anhyd CH_2Cl_2 (99.8%) was purchased directly from ACROS and used without further purification, and $TiCl_4$ was purchased from Aldrich. Analytical TLC was performed on silica gel plates (0.20 mm, 60 Å). Column chromatography was performed on silica gel (60–200 mesh, 60 Å). All cyclization reactions were carried out in anhyd solvents in Schlenk tubes under an argon atmosphere. Crystallographic data were collected on a Bruker X8Apex system with Mo-Kα radiation ($\lambda = 0.71073$ Å). The structures were solved by direct methods using SHELXS-97 and refined against F^2 on all data by full-matrix least-squares analysis with SHELXL-97. All non-hydrogen atoms were refined anisotropically, and all hydrogen atoms were refined in the model at geometrically calculated positions and refined by use of a riding model. 1,3-Bis(siloxy)buta-1,3-dienes **3a–m** were prepared according to the literature from the corresponding β-keto esters in two steps.[31,35,36]

Enones 2a–e; General Procedure

A soln of the appropriate keto sulfone **1** (1 equiv) in $HC(OEt)_3$ (1.2 equiv) and Ac_2O was stirred for 1.5 h at 120 °C and, subsequently, for 1.5 h at 140 °C. The $\mathrm{Ac_2O}$ was removed in vacuo and the resulting solid residue was recrystallized (EtOH).

4-Ethoxy-3-(phenylsulfonyl)but-3-en-2-one (2a)

Starting with **1a** (2.00 g, 10.1 mmol) and $\mathrm{HC(OEt)_3}$ (1.79 g, 2.0 mL, 12.1 mmol), **2a** was isolated.

Yield: 2.10 g (82%); slightly brown solid; mp 46–48 °C.

IR (KBr): 3066 (w), 2986 (w), 2254 (w), 1667 (m), 1599 (s), 1477 (w), 1446 (m), 1393 (m), 1354 (m), 1302 (s), 1189 (m), 1148 (s), 1090 (m), 1047 $\mathrm{cm^{-1}}$ (m).

^{1}H NMR (300 MHz, $\mathrm{CDCl_3}$): $\delta = 1.40$ (t, $^3J = 7.5$ Hz, 3 H, $\mathrm{OCH_2}\mathit{CH}_3$), 2.25 (s, 3 H, $\mathrm{COCH_3}$), 4.34 (q, $^3J = 7.1$ Hz, 2 H, $\mathrm{O}\mathit{CH}_2\mathrm{CH_3}$), 7.38–7.50 (m, 3 H, $\mathrm{3CH_{Ar}}$), 7.88–7.91 (m, 2 H, $\mathrm{2CH_{Ar}}$), 8.20 (s, 1 H, CH).

^{13}C NMR (75 MHz, $\mathrm{CDCl_3}$): $\delta = 15.4$ ($\mathrm{OCH_2}\mathit{CH}_3$), 31.9 ($\mathrm{CO}\mathit{CH}_3$), 74.6 ($\mathrm{O}\mathit{CH}_2\mathrm{CH_3}$), 122.0 (C), 128.20 ($\mathrm{2CH_{Ar}}$), 128.58 ($\mathrm{2CH_{Ar}}$), 129.4 ($\mathrm{CH_{Ar}}$), 133.4 ($\mathrm{C_{Ar}}$), 167.7 (CH), 191.0 (CO).

MS (EI, 70 eV): *m/z* (%) = 211 (41), 190 (30), 189 (74), 175 (20), 162 (10), 161 (55), 147 (17), 141 (43), 125 (14), 105 (17), 97 (39), 78 (23), 77 (100), 69 (32), 51 (31), 43 (38), 29 (16).

HRMS (EI): *m/z* [M]$^+$ calcd for $\mathrm{C_{12}H_{14}O_4S}$: 254.06073; found: 254.060618.

4-Ethoxy-3-tosylbut-3-en-2-one (2b)

Starting with **1b** (2.00 g, 9.4 mmol) and $\mathrm{HC(OEt)_3}$ (1.67 g, 1.9 mL, 11.3 mmol), **2b** was isolated.

Yield: 2.02 g (80%); slightly brown solid; mp 134–135 °C.

IR (KBr): 3056 (w), 2984 (w), 2925 (w), 2871 (w), 1666 (m), 1597 (s), 1494 (w), 1473 (w), 1394 (m), 1300 (s), 1265 (m), 1187 (m), 1144 (s), 1047 $\mathrm{cm^{-1}}$ (m).

^{1}H NMR (250 MHz, $\mathrm{CDCl_3}$): $\delta = 1.41$ (t, $^3J = 7.4$ Hz, 3 H, $\mathrm{OCH_2}\mathit{CH}_3$), 2.24 (s, 3 H, $\mathrm{COCH_3}$), 2.32 (s, 3 H, $\mathrm{Ph}\mathit{CH}_3$), 4.33 (q, $^3J = 7.3$ Hz, 2 H, $\mathrm{O}\mathit{CH}_2\mathrm{CH_3}$), 7.19–7.22 (m, 2 H, $\mathrm{2CH_{Ar}}$), 7.76–7.79 (m, 2 H, $\mathrm{2CH_{Ar}}$), 8.18 (s, 1 H, CH).

^{13}C NMR (75 MHz, $\mathrm{CDCl_3}$): $\delta = 15.3$ ($\mathrm{OCH_2}\mathit{CH}_3$), 21.5 ($\mathrm{Ph}\mathit{CH}_3$), 32.0 ($\mathrm{CO}\mathit{CH}_3$), 74.5 ($\mathrm{O}\mathit{CH}_2\mathrm{CH_3}$), 122.2 (C), 128.2 ($\mathrm{2CH_{Ar}}$), 129.2 ($\mathrm{2CH_{Ar}}$), 138.4, 143.7 ($\mathrm{C_{Ar}}$), 167.3 (CH), 191.1 (CO).

MS (EI, 70 eV): *m/z* (%) = 225 (25), 204 (20), 203 (16), 190 (10), 189 (75), 175 (36), 161 (15), 155 (48), 139 (15), 119 (12), 97 (80), 92 (24), 91 (100), 89 (11), 77 (10), 69 (47), 65 (35), 63 (10), 43 (32), 39 (11). 29 (15).

HRMS (EI): *m/z* [M]$^+$ calcd for $\mathrm{C_{13}H_{16}O_4S}$: 268.07638; found: 268.076825.

3-(4-Chlorophenylsulfonyl)-4-ethoxybut-3-en-2-one (2c)

Starting with **1c** (2.00 g, 8.6 mmol) and $\mathrm{HC(OEt)_3}$ (1.50 g, 1.7 mL, 10.3 mmol), **2c** was isolated.

Yield: 2.16 g (87%); brown solid; mp 120–121 °C.

IR (KBr): 3087 (w), 2972 (w), 2982 (w), 1657 (m), 1597 (m), 1475 (w), 1438 (w), 1395 (w), 1357 (w), 1330 (m), 1296 (m), 1260 (m), 1193 (m), 1176 (m), 1139 (m), 1085 (m), 1041 (m), 1009 $\mathrm{cm^{-1}}$ (w).

^{1}H NMR (250 MHz, $\mathrm{CDCl_3}$): $\delta = 1.42$ (t, $^3J = 7.8$ Hz, 3 H, $\mathrm{OCH_2}\mathit{CH}_3$), 2.26 (s, 3 H, $\mathrm{COCH_3}$), 4.35 (q, $^3J = 7.3$ Hz, 2 H, $\mathrm{O}\mathit{CH}_2\mathrm{CH_3}$), 7.35–7.41 (m, 2 H, $\mathrm{2CH_{Ar}}$), 7.81–7.86 (m, 2 H, $\mathrm{2CH_{Ar}}$), 8.19 (s, 1 H, CH).

^{13}C NMR (75 MHz, $\mathrm{CDCl_3}$): $\delta = 15.2$ ($\mathrm{OCH_2}\mathit{CH}_3$), 31.9 ($\mathrm{CO}\mathit{CH}_3$), 74.7 ($\mathrm{O}\mathit{CH}_2\mathrm{CH_3}$), 122.1 (C), 129.0 ($\mathrm{2CH_{Ar}}$), 130.0 ($\mathrm{2CH_{Ar}}$), 139.5, 140.1 ($\mathrm{C_{Ar}}$), 168.1 (CH), 191.1 (CO).

MS (EI, 70 eV): *m/z* (%) = 247 (12), 245 (36), 224 (35), 223 (17), 209 (12), 195 (29), 189 (16), 177 (16), 175 (38), 159 (11), 133 (11), 113 (17), 112 (14), 111 (62), 97 (100), 75 (23), 69 (48), 43 (50).

HRMS (EI): *m/z* [M]$^+$ calcd for $\mathrm{C_{12}H_{13}O_4ClS}$: 288.02176; found: 288.021693.

1-Ethoxy-2-(phenylsulfonyl)hept-1-en-3-one (2d)

Starting with **1d** (2.00 g, 8.3 mmol) and $\mathrm{HC(OEt)_3}$ (1.47 g, 1.66 mL, 10.0 mmol), **2d** was isolated.

Yield: 1.97 g (80%); brown solid; mp 79–81 °C.

IR (KBr): 3303 (w), 3071 (w), 2952 (m), 2871 (w), 1721 (w), 1660 (s), 1595 (s), 1448 (m), 1396 (m), 1382 (m), 1340 (m), 1271 (s), 1150 (s), 1113 (s), 1077 (s), 1024 $\mathrm{cm^{-1}}$ (s).

^{1}H NMR (250 MHz, $\mathrm{CDCl_3}$): $\delta = 0.77$ (t, $^3J = 7.4$ Hz, 3 H, $\mathrm{(CH_2)_3}\mathit{CH}_3$), 1.09–1.24 (m, 3 H, $\mathrm{OCH_2}\mathit{CH}_3$), 1.37–1.43 (m, 4 H, $\mathrm{2CH_2}$), 2.57 (t, $^3J = 7.6$ Hz, 2 H, $\mathrm{COCH_2}$), 4.34 (q, $^3J = 7.4$ Hz, 2 H, $\mathrm{O}\mathit{CH}_2\mathrm{CH_3}$), 7.37–7.48 (m, 3 H, $\mathrm{3CH_{Ar}}$), 7.87–7.91 (m, 2 H, $\mathrm{2CH_{Ar}}$), 8.15 (s, 1 H, CH).

^{13}C NMR (75 MHz, $\mathrm{CDCl_3}$): $\delta = 13.8$, 15.4 ($\mathrm{CH_3}$), 22.1, 25.4 ($\mathrm{CH_2}$), 43.6 ($\mathrm{CO}\mathit{CH}_2$), 74.4 ($\mathrm{O}\mathit{CH}_2\mathrm{CH_3}$), 121.3 (C), 128.2 ($\mathrm{2CH_{Ar}}$), 128.5 ($\mathrm{2CH_{Ar}}$), 132.9 ($\mathrm{CH_{Ar}}$), 141.5 ($\mathrm{C_{Ar}}$), 166.6 (CH), 194.2 (CO).

MS (EI, 70 eV): *m/z* (%) = 239 (36), 232 (12), 231 (27), 212 (11), 211 (100), 203 (15), 190 (15), 175 (10), 161 (37), 141 (41), 105 (10), 78 (10), 77 (68), 51 (11), 29 (13).

HRMS (EI): *m/z* [M + H]$^+$ calcd for $\mathrm{C_{15}H_{21}O_4S}$: 297.11551; found: 297.11542; *m/z* [M + Na]$^+$ calcd for $\mathrm{C_{15}H_{20}NaO_4S}$: 319.09745; found: 319.09738; *m/z* [2M + Na]$^+$ calcd for $\mathrm{C_{30}H_{40}NaO_8S_2}$: 615.20568; found: 615.20573.

3-Ethoxy-1-(4-nitrophenyl)-2-tosylprop-2-en-1-one (2e)

Starting with **1e** (2.00 g, 6.3 mmol) and $\mathrm{HC(OEt)_3}$ (1.12 g, 1.3 mL, 7.6 mmol), **2e** was isolated.

Yield: 2.128 g (90%); yellow solid; mp 133–134 °C.

IR (KBr): 3103 (w), 3069 (w), 2999 (w), 2939 (w), 2866 (w), 1658 (m), 1585 (m), 1523 (m), 1444 (w), 1391 (w), 1348 (m), 1269 (m), 1219 (m), 1147 (m), 1073 (m), 1006 $\mathrm{cm^{-1}}$ (m).

^{1}H NMR (250 MHz, $\mathrm{CDCl_3}$): $\delta = 1.11$ (t, $^3J = 7.2$ Hz, 3 H, $\mathrm{OCH_2}\mathit{CH}_3$), 2.30 (s, 3 H, $\mathrm{CH_3}$), 4.07 (q, $^3J = 7.1$ Hz, 2 H, $\mathrm{O}\mathit{CH}_2\mathrm{CH_3}$), 7.24–7.29 (m, 2 H, $\mathrm{2CH_{Ar}}$), 7.74–7.83 (m, 4 H, $\mathrm{4CH_{Ar}}$), 7.97 (s, 1 H, CH), 8.15–8.20 (m, 2 H, $\mathrm{2CH_{Ar}}$).

^{13}C NMR (75 MHz, $\mathrm{CDCl_3}$): $\delta = 15.0$ ($\mathrm{OCH_2}\mathit{CH}_3$), 21.6 ($\mathrm{Ph}\mathit{CH}_3$), 73.6 ($\mathrm{O}\mathit{CH}_2\mathrm{CH_3}$), 120.4 (C), 123.5 ($\mathrm{2CH_{Ar}}$), 128.1 ($\mathrm{2CH_{Ar}}$), 129.64 ($\mathrm{2CH_{Ar}}$), 129.9 ($\mathrm{2CH_{Ar}}$), 138.4, 142.4, 144.3, 150.2 ($\mathrm{C_{Ar}}$), 163.8 (CH), 187.1 (CO).

MS (EI, 70 eV): *m/z* (%) = 312 (11), 311 (68), 310 (11), 296 (64), 283 (11), 282 (38), 204 (93), 176 (100), 155 (10), 150 (25), 139 (14), 104 (19), 92 (19), 91 (73), 76 (11), 65 (16).

HRMS (EI): *m/z* [M]$^+$ calcd for $\mathrm{C_{18}H_{17}NO_6S}$: 375.07711; found: 375.077049.

4-(Arylsulfonyl)phenols 4a–ag; General Procedure

One of **3a**–**m** (1.1 mmol) and subsequently $\mathrm{TiCl_4}$ (1.1 mmol) were added to a soln of the appropriate **2a**–**e** in $\mathrm{CH_2Cl_2}$ (2 mL/1 mmol of **2a**–**e**) at –78 °C. The stirring soln was allowed to warm to 20 °C over 14 h. A 10% aq soln of HCl (20 mL) was added to the reaction mixture, and the organic and aqueous layers were separated. The latter was extracted with $\mathrm{CH_2Cl_2}$ (3 × 20 mL). The combined organic layers were dried ($\mathrm{Na_2SO_4}$) and filtered, and the filtrate was concentrated in vacuo. The residue was purified by chromatography (silica gel, heptanes–EtOAc) to give the corresponding **4**.

Methyl 6-Hydroxy-2-methyl-3-(phenylsulfonyl)benzoate (4a)

Starting with **2a** (0.381 g, 1.5 mmol) and **3a** (0.429 g, 1.7 mmol), **4a** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.365 g (80%); mp 80–83 °C.

IR (KBr): 3070 (w), 3003 (w), 2950 (w), 2923 (w), 2848 (w), 1722 (w), 1667 (m), 1572 (m), 1537 (w), 1461 (w), 1445 (m), 1383 (w), 1349 (m), 1286 (m), 1222 (m), 1140 (s), 1108 (m), 1082 cm^{-1} (m).

^{1}H NMR (300 MHz, CDCl$_3$): δ = 2.52 (s, 3 H, Ph*CH$_3$*), 3.87 (s, 3 H, OCH$_3$), 6.96 (d, ^3J = 7.6 Hz, 1 H, CH$_{Ar}$), 7.40–7.50 (m, 3 H, 3CH$_{Ar}$), 7.73–7.77 (m, 2 H, 2CH$_{Ar}$), 8.30 (d, ^3J = 7.5 Hz, 1 H, CH$_{Ar}$), 11.21 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 19.0 (CH$_3$), 52.8 (OCH$_3$), 115.3 (*C*COOCH$_3$), 115.7 (CH$_{Ar}$), 127.2 (2CH$_{Ar}$), 129.1 (2CH$_{Ar}$), 131.4 (C$_{Ar}$), 132.9 (CH$_{Ar}$), 135.3 (CH$_{Ar}$), 141.9, 142.7 (C$_{Ar}$), 165.3 (COH), 171.0 (CO).

MS (EI, 70 eV): *m/z* (%) = 306 [M]$^+$ (28), 275 (25), 274 (100), 257 (16), 256 (10), 255 (27), 241 (21), 209 (15), 208 (12), 181 (14), 153 (14), 152 (12), 149 (10), 121 (13), 105 (11), 77 (33), 51 (22).

HRMS (EI): *m/z* [M]$^+$ calcd for $C_{15}H_{14}O_5S$: 306.05565; found: 306.055771.

Methyl 2-Hydroxy-3,6-dimethyl-5-(phenylsulfonyl)benzoate (4b)

Starting with **2a** (0.381 g, 1.5 mmol) and **3b** (0.452 g, 1.7 mmol), **4b** was isolated after chromatography (silica gel, heptanes–EtOAc).

White solid; yield: 0.384 g (80%); mp 160–161 °C.

IR (KBr): 3066 (w), 2955 (w), 2255(w), 1736 (w), 1665 (m), 1604 (w), 1571 (w), 1445 (m), 1381 (w), 1344 (m), 1303 (s), 1252 (m), 1201 (m), 1165 (m), 1144 (s), 1087 (m), 1062 (w), 1031 cm^{-1} (w).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 2.24 (s, 3 H, Ph*CH$_3$*), 2.46 (s, 3 H, Ph*CH$_3$)*, 3.85 (s, 3 H, OCH$_3$), 7.37–7.52 (m, 3 H, 3CH$_{Ar}$), 7.71–7.76 (m, 2 H, 2CH$_{Ar}$), 8.19 (s, 1 H, CH$_{Ar}$), 11.39 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 15.9, 18.8 (CH$_3$), 52.7 (OCH$_3$), 114.4 (*C*COOCH$_3$), 125.1 (C$_{Ar}$), 127.1 (2CH$_{Ar}$), 129.0 (2CH$_{Ar}$), 130.3 (C$_{Ar}$), 132.8, 135.5 (CH$_{Ar}$), 139.8, 142.2 (C$_{Ar}$), 163.9 (COH), 171.6 (CO).

MS (EI, 70 eV): *m/z* (%) = 320 [M]$^+$ (26), 289 (22), 288 (100), 260 (30), 77 (13).

HRMS (EI): *m/z* [M]$^+$ calcd for $C_{16}H_{16}O_5S$: 320.07130; found: 320.071232.

Ethyl 3-Ethyl-2-hydroxy-6-methyl-5-(phenylsulfonyl)benzoate (4c)

Starting with **2a** (0.381 g, 1.5 mmol) and **3c** (0.499 g, 1.7 mmol), **4c** was isolated after chromatography (silica gel, heptanes–EtOAc).

White solid; yield: 0.402 g (77%); mp 95–97 °C.

IR (KBr): 3066 (w), 2970 (w), 2934 (w), 2254 (w), 1730 (w), 1658 (m), 1603 (w), 1565 (w), 1445 (m), 1373 (m), 1303 (m), 1288 (m), 1241 (m), 1200 (m), 1143 (s), 1086 (m), 1017 cm^{-1} (m).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 1.26 (t, ^3J = 7.6 Hz, 3 H, CH$_2$*CH$_3$*), 1.36 (t, ^3J = 7.6 Hz, 3 H, OCH$_2$*CH$_3$*), 2.55 (s, 3 H, Ph*CH$_3$*), 2.73 (q, ^3J = 7.7 Hz, 2 H, Ph*CH$_2$*CH$_3$), 4.40 (q, ^3J = 7.2 Hz, 2 H, O*CH$_2$*CH$_3$), 7.45–7.59 (m, 3 H, 3CH$_{Ar}$), 7.79–7.82 (m, 2 H, 2CH$_{Ar}$), 8.26 (s, 1 H, CH$_{Ar}$), 11.53 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 13.4, 14.0, 19.0 (CH$_3$), 23.1 (CH$_2$), 62.4 (OCH$_3$), 114.7 (*C*COOCH$_3$), 127.1 (2CH$_{Ar}$), 129.0 (2CH$_{Ar}$), 130.4, 130.8 (C$_{Ar}$), 132.79, 134.01 (CH$_{Ar}$), 139.7, 142.2 (C$_{Ar}$), 163.5 (COH), 171.16 (CO).

MS (EI, 70 eV): *m/z* (%) = 349 (13), 348 [M]$^+$ (64), 303 (13), 302 (18), 281 (14), 275 (14), 274 (68), 237 (17), 210 (32), 209 (18), 208 (28), 207 (100), 195 (15), 191 (14), 181 (44), 165 (13), 152 (11), 133 (12), 105 (14), 103 (15), 91 (17), 79 (12), 78(14), 77 (33), 51 (15), 45 (12), 44 (90), 39 (10), 32 (36), 31 (15), 29 (11).

HRMS (EI): *m/z* [M]$^+$ calcd for $C_{18}H_{20}O_5S$: 348.10260; found: 348.102403.

Methyl 3-Butyl-2-hydroxy-6-methyl-5-(phenylsulfonyl)benzoate (4d)

Starting with **2a** (0.381 g, 1.5 mmol) and **3d** (0.522 g, 1.7 mmol), **4d** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.413 g (76%); mp 95–97 °C.

IR (KBr): 3078 (w), 2958 (w), 2927 (w), 1666 (s), 1594 (w), 1567 (w), 1461 (w), 1438 (m), 1402 (m), 1381 (w), 1301 (s), 1215 (m), 1141 (s), 1085 (s), 1022 cm^{-1} (w).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 0.83 (t, ^3J = 7.5 Hz, 3 H, CH$_3$), 1.23–1.32 (m, 2 H, CH$_2$), 1.44–1.56 (m, 2 H, CH$_2$), 2.42 (s, 3 H, Ph*CH$_3$*), 2.58 (t, ^3J = 7.6 Hz, 2 H, Ph*CH$_2$*), 3.80 (s, 3 H, OCH$_3$), 7.33–7.43 (m, 3 H, 3CH$_{Ar}$), 7.66–7.69 (m, 2 H, 2CH$_{Ar}$), 8.13 (s, 1 H, CH$_{Ar}$), 11.38 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 13.9, 18.8 (CH$_3$), 22.5, 29.5, 31.2 (CH$_2$), 52.6 (OCH$_3$), 114.6 (*C*COOCH$_3$), 127.1 (2CH$_{Ar}$), 128.9 (2CH$_{Ar}$), 129.6, 130.4 (C$_{Ar}$), 132.7, 134.8 (CH$_{Ar}$), 139.7, 142.2 (C$_{Ar}$), 163.5 (COH), 171.7 (CO).

MS (EI, 70 eV): *m/z* (%) = 363 (12), 362 [M]$^+$ (68), 330 (14), 313 (11), 303 (11), 302 (71), 301 (16), 289 (21), 288 (100), 287 (29), 260 (30), 188 (10), 77 (18).

HRMS (EI): *m/z* [M]$^+$ calcd for $C_{19}H_{22}O_5S$: 362.11825; found: 362.117561

Methyl 2-Hydroxy-3-isobutyl-6-methyl-5-(phenylsulfonyl)benzoate (4e)

Starting with **2a** (0.381 g, 1.5 mmol) and **3e** (0.522 g, 1.7 mmol), **4e** was isolated after chromatography (silica gel, *n*-heptane–EtOAc).

Slightly yellow solid; yield: 0.379 g (70%); mp 109–110 °C.

IR (KBr): 2955 (w), 2932 (w), 2870 (w), 1716 (w), 1659 (m), 1600 (w), 1556 (w), 1427 (m), 1383 (w), 1355 (m), 1300 (s), 1254 (m), 1216 (m), 1165 (m), 1141 (s), 1084 (m), 1064 cm^{-1} (m).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 0.87 (d, ^3J = 6.8 Hz, 6 H, 2CH$_3$), 1.88–1.99 (m, 1 H, CH), 2.47 (s, 3 H, Ph*CH$_3$*), 2.52 (d, ^3J = 7.2 Hz, 2 H, Ph*CH$_2$*), 3.85 (s, 3 H, OCH$_3$), 7.37–7.52 (m, 3 H, 3CH$_{Ar}$), 7.69–7.76 (m, 2 H, 2CH$_{Ar}$), 8.14 (s, 1 H, CH$_{Ar}$), 11.33 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 17.9, 21.4, 21.4 (CH$_3$), 27.1 (CH), 37.9 (CH$_2$), 51.7 (OCH$_3$), 113.7 (*C*COOCH$_3$), 126.1 (2CH$_{Ar}$), 127.4 (C$_{Ar}$), 128.0 (2CH$_{Ar}$), 129.2 (C$_{Ar}$), 131.7, 134.8 (CH$_{Ar}$), 138.8, 141.1 (C$_{Ar}$), 162.6 (COH), 170.6 (CO).

MS (EI, 70 eV): *m/z* (%) = 362 [M]$^+$ (40), 331 (12), 330 (28), 315 (15), 303 (18), 302 (100), 288 (33), 287 (84), 260 (13), 238 (14), 219 (25), 188 (11), 129 (17), 125 (11), 116 (22), 99 (33), 97 (10), 81 (32), 71 (15), 69 (19), 57 (18), 55 (12).

HRMS (EI): *m/z* [M]$^+$ calcd for $C_{19}H_{22}O_5S$: 362.11825; found: 362.117994.

Methyl 3-Hexyl-2-hydroxy-6-methyl-5-(phenylsulfonyl)benzoate (4f)

Starting with **2a** (0.381 g, 1.5 mmol) and **3f** (0.568 g, 1.7 mmol), **4f** was isolated after chromatography (silica gel, heptanes–EtOAc).

Slightly yellow viscous oil; yield: 0.456 g (78%).

IR (KBr): 3067 (w), 2926 (m), 2856 (w), 2256 (w), 1737 (w), 1665 (m), 1602 (w), 1567 (w), 1444 (m), 1345 (m), 1303 (m), 1245 (m), 1201 (m), 1143 (s), 1086 cm^{-1} (m).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 0.82 (t, ^3J = 7.1 Hz, 3 H, CH$_3$), 1.17–1.35 (m, 6 H, 3CH$_2$), 1.50–1.62 (m, 2 H, CH$_2$), 2.45 (s, 3 H, Ph*CH$_3$*), 2.62 (t, ^3J = 7.5 Hz, 2 H, Ph*CH$_2$*), 3.91 (s, 3 H, OCH$_3$), 7.37–7.47 (m, 3 H, 3CH$_{Ar}$), 7.70–7.74 (m, 2 H, 2CH$_{Ar}$), 8.17 (s, 1 H, CH$_{Ar}$), 11.38 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 14.1, 18.9 (CH$_3$), 22.6, 29.0, 29.1, 29.8, 31.6 (CH$_2$), 52.7 (OCH$_3$), 114.6 (*C*COOCH$_3$), 127.1 (2CH$_{Ar}$), 129.0 (2CH_{Ar}), 129.6, 130.4 (C_{Ar}), 132.7, 134.8 (CH_{Ar}), 139.7, 142.2 (C_{Ar}), 163.5 (COH), 171.6 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 390 $[M]^+$ (41), 359 (10), 358 (27), 341 (10), 330 (51), 329 (20), 301 (12), 289 (18), 288 (100), 287 (30), 260 (34), 97 (10), 85 (10), 83 (15), 71 (16), 70 (10), 69 (23), 57 (22), 55 (10), 43 (10).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{21}H_{26}O_5S$: 390.14955; found: 390.149235.

Methyl 3-Heptyl-2-hydroxy-6-methyl-5-(phenylsulfonyl)benzoate (4g)

Starting with **2a** (0.254 g, 1.0 mmol) and **3g** (0.395 g, 1.1 mmol), **4g** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish oil; yield: 0.303 g (75%).

IR (KBr): 3066 (w), 2955 (w), 2926 (m), 2855 (w), 2257 (w), 1734 (w), 1666 (m), 1603 (w), 1568 (w), 1446 (m), 1346 (m), 1305 (m), 1248 (w), 1202 (m), 1161 (m), 1145 (s), 1087 (m), 1064 (w), 1025 cm^{-1} (w).

^1H NMR (250 MHz, $CDCl_3$): δ = 0.82 (t, ^3J = 7.4 Hz, 3 H, CH_3), 1.19–1.28 (m, 8 H, 4CH_2), 1.54–1.60 (m, 2 H, CH_2), 2.46 (s, 3 H, PhCH_3), 2.63 (t, ^3J = 7.4 Hz, 2 H, PhCH_2), 3.85 (s, 3 H, OCH_3), 7.37–7.49 (m, 3 H, 3CH_{Ar}), 7.71–7.75 (m, 2 H, 2CH_{Ar}), 8.18 (s, 1 H, CH_{Ar}), 11.36 (s, 1 H, OH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 13.1, 17.9 (CH_3), 21.7, 28.1, 28.2, 28.5, 28.9, 30.8 (CH_2), 51.7 (OCH_3), 113.7 (*C*$COOCH_3$), 126.2 (2CH_{Ar}), 128.0 (2CH_{Ar}), 128.6, 129.4 (C_{Ar}), 131.8, 133.9 (CH_{Ar}), 138.7, 141.2 (C_{Ar}), 162.6 (COH), 170.7 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 404 $[M^+]$ (81), 372 (40), 355 (15), 344 (61), 329 (28), 301 (19), 288 (100), 260 (40), 230 (9), 188 (8), 165 (7), 146 (8), 125 (7), 91 (8), 77 (13), 41 (9).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{22}H_{28}O_5S$: 404.16520; found: 404.165132.

Methyl 2-Hydroxy-6-methyl-3-octyl-5-(phenylsulfonyl)benzoate (4h)

Starting with **2a** (0.381 g, 1.5 mmol) and **3h** (0.614 g, 1.7 mmol), **4h** was isolated after chromatography (silica gel, heptanes–EtOAc).

Slightly yellow viscous oil; yield: 0.471 g (75%).

IR (KBr): 3066 (w), 2925 (m), 2854 (w), 2255 (w), 1737 (w), 1665 (m), 1602 (w), 1567 (w), 1445 (m), 1304 (m), 1247 (w), 1144 (s), 1087 (m), 1064 cm^{-1} (w).

^1H NMR (250 MHz, $CDCl_3$): δ = 0.82 (t, ^3J = 7.4 Hz, 3 H,CH_3), 1.19–1.27 (m, 10 H, 5CH_2), 1.51–1.60 (m, 2 H, CH_2), 2.46 (s, 3 H, PhCH_3), 2.63 (t, ^3J = 7.4 Hz, 2 H, PhCH_2), 3.85 (s, 3 H, OCH_3), 7.38–7.49 (m, 3 H, 3CH_{Ar}), 7.71–7.75 (m, 2 H, 2CH_{Ar}), 8.18 (s, 1 H, CH_{Ar}), 11.31 (s, 1 H, OH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 14.0, 18.8 (CH_3), 22.6, 29.0, 29.2, 29.4, 29.4, 29.8, 31.8 (CH_2), 52.7 (O*C*H_3), 114.6 (*C*$COOCH_3$), 127.1 (2CH_{Ar}), 128.9 (2CH_{Ar}), 129.6, 130.40 (C_{Ar}), 132.7, 134.8 (CH_{Ar}), 139.6, 142.2 (C_{Ar}), 163.5 (COH), 171.6 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 419 (13), 418 $[M]^+$ (52), 387 (13), 386 (31), 369 (12), 359 (11), 358 (45), 329 (26), 301 (12), 289 (21), 288 (100), 287 (40), 274 (16), 261 (12), 260 (26).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{23}H_{30}O_5S$: 418.18085; found: 418.180994.

Methyl 2-Hydroxy-6-methyl-3-nonyl-5-(phenylsulfonyl)benzoate (4i)

Starting with **2a** (0.381 g, 1.5 mmol) and **3i** (0.638 g, 1.7 mmol), **4i** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.485 g (75%); mp 70–71 °C.

IR (KBr): 2952 (w), 2922 (m), 2852 (w), 1737 (w), 1663 (m), 1602 (w), 1566 (w), 1441 (m), 1344 (m), 1303 (s), 1247 (m), 1200 (m), 1142 (s), 1086 (s), 1062 cm^{-1} (m).

^1H NMR (250 MHZ, $CDCl_3$): δ = 0.81 (t, ^3J = 7.8 Hz, 3 H, (CH_3), 1.18–1.26 (m, 12 H, 6CH_2), 1.50–1.60 (m, 2 H, CH_2), 2.46 (s, 3 H, PhCH_3), 2.63 (t, ^3J = 7.2 Hz, 2 H, PhCH_2), 3.85 (s, 3 H, OCH_3), 7.38–7.50 (m, 3 H, 3CH_{Ar}), 7.71–7.75 (m, 2 H, 2CH_{Ar}), 8.18 (s, 1 H, CH_{Ar}), 11.35 (s, 1 H, OH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 14.0, 18.8 (CH_3), 22.6, 29.0, 29.2, 29.4, 29.4, 29.5, 29.8, 31.8 (CH_2), 52.7 (OCH_3), 114.5 (*C*$COOCH_3$), 127.1 (2CH_{Ar}), 128.9 (2CH_{Ar}), 129.6, 130.4 (C_{Ar}), 132.7 (CH_{Ar}), 134.8 (CH_{Ar}), 139.7, 142.2 (C_{Ar}), 163.5 (COH), 171.6 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 432 $[M]^+$ (49), 401 (12), 400 (28), 383 (10), 372 (32), 331 (10), 329 (23), 301 (12), 289 (21), 288 (100), 287 (38), 274 (16), 261 (13), 260 (20).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{24}H_{32}O_5S$: 432.19650; found: 432.196759.

Methyl 3-Decyl-2-hydroxy-6-methyl-5-(phenylsulfonyl)benzoate (4j)

Starting with **2a** (0.381 g, 1.5 mmol) and **3j** (0.661 g, 1.7 mmol), **4j** was isolated after chromatography (silica gel, heptanes–EtOAc).

White solid; yield: 0.521 g (78%); mp 94–95 °C.

IR (KBr): 2953 (w), 2923 (m), 2853 (w), 1734 (w), 1664 (m), 1602 (w), 1567 (w), 1444 (m), 1344 (w), 1303 (s), 1246 (m), 1201 (m), 1143 (s), 1086 (m), 1063 cm^{-1} (w).

^1H NMR (250 MHz, $CDCl_3$): δ = 0.80 (t, ^3J = 6.8 Hz, 3 H, CH_3), 1.15–1.26 (m, 14 H, 7CH_2), 1.50–1.56 (m, 2 H, CH_2), 2.46 (s, 3 H, PhCH_3), 2.62 (t, ^3J = 7.7 Hz, 2 H, PhCH_2), 3.86 (s, 3 H, OCH_3), 7.37–7.52 (m, 3 H, 3CH_{Ar}), 7.69–7.74 (m, 2 H, 2CH_{Ar}), 8.17 (s, 1 H, CH_{Ar}), 11.35 (s, 1 H, OH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 14.1, 18.9 (CH_3), 22.7, 29.0, 29.3, 29.4, 29.4, 29.5, 29.5, 29.8, 31.8 (CH_2), 52.6 (OCH_3), 114.7 (*C*$COOCH_3$), 127.2 (2CH_{Ar}), 129.0 (2CH_{Ar}), 129.6, 130.4 (C_{Ar}), 132.7, 134.8 (CH_{Ar}), 139.7, 142.2 (C_{Ar}), 163.5 (COH), 171.6 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 446 $[M]^+$ (46), 415 (12), 414 (26), 386 (12), 378 (18), 331 (39), 330 (10), 329 (28), 318 (14), 302 (14), 301 (15), 289 (25), 288 (100), 287 (44), 275 (13), 274 (19), 261 (19), 260 (20), 234 (25), 233 (17), 206 (21), 187 (14), 147 (11), 121 (11), 43 (10).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{25}H_{34}O_5S$: 446.21215; found: 446.211947.

Methyl 6-Hydroxy-2-methyl-3-tosylbenzoate (4k)

Starting with **2b** (0.402 g, 1.5 mmol) and **3a** (0.429 g, 1.7 mmol), **4k** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.274 g (57%); mp 109–110 °C.

IR (KBr): 3072 (w), 3029 (w), 2953 (w), 2922 (w), 2852 (w), 1715 (w), 1673 (m), 1592 (m), 1574 (m), 1495 (w), 1435 (m), 1348 (m), 1300 (m), 1286 (m), 1218 (m), 1188 (m), 1155 (m), 1142 (s), 1109 (m), 1081 (m), 1040 (w), 1018 cm^{-1} (w).

^1H NMR (250 MHz, $CDCl_3$): δ = 2.28 (s, 3 H, PhCH_3), 2.47 (s, 3 H, PhCH_3), 3.81 (s, 3 H, OCH_3), 6.87 (d, ^3J = 8.4 Hz, 1 H, CH_{Ar}), 7.14–7.17 (m, 2 H, 2 CH_{Ar}), 7.35–7.58 (m, 2 H, 2CH_{Ar}), 8.22 (d, ^3J = 8.7 Hz, 1 H, CH_{Ar}), 11.03 (s, 1 H, OH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 19.0, 21.5 (CH_3), 52.7 (OCH_3), 115.1 (*C*$COOCH_3$), 115.6 (CH_{Ar}), 127.3 (2CH_{Ar}), 129.6 (2CH_{Ar}), 131.8 (C_{Ar}), 135.2 (CH_{Ar}), 138.9, 142.6, 143.8 (C_{Ar}), 165.2 (COH), 171.0 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 320 $[M]^+$ (34), 289 (27), 288 (100), 271 (23), 269 (18), 256 (9), 255 (48), 224 (16), 223 (20), 222 (17), 181

(10), 152 (11), 149 (12), 121 (12), 105 (10), 91 (19), 77 (22), 65 (20), 51 (14).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{16}H_{16}O_5S$: 320.07130; found: 320.071076.

Methyl 2-Hydroxy-3,6-dimethyl-5-tosylbenzoate (4l)

Starting with **2b** (0.402 g, 1.5 mmol) and **3b** (0.452 g, 1.7 mmol), **4l** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.327 g (65%); mp 175–177 °C.

IR (KBr): 3091 (w), 3054 (w), 2963 (w), 2921 (w), 2853 (w), 1667 (m), 1596 (w), 1568 (w), 1496 (w), 1434 (m), 1374 (m), 1337 (m), 1288 (m), 1247 (m), 1198 (m), 1138 (m), 1120 (m), 1088 (m), 1030 cm^{-1} (m).

^1H NMR (250 MHz, $CDCl_3$): δ = 2.23 (s, 3 H, PhCH_3), 2.33 (s, 3 H, PhCH_3), 2.47 (s, 3 H, PhCH_3), 3.81 (s, 3 H, OCH_3), 7.18–7.21 (m, 2 H, $2CH_{Ar}$), 7.60–7.63 (m, 2 H, $2CH_{Ar}$), 8.17 (s, 1 H, CH_{Ar}), 11.37 (s, 1 H, OH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 15.9, 18.8, 21.5 (CH_3), 52.7 (OCH_3), 114.3 ($\mathit{C}COOCH_3$), 124.9 (C_{Ar}), 127.2 ($2CH_{Ar}$), 129.5 ($2CH_{Ar}$), 130.8 (C_{Ar}), 135.4 (CH_{Ar}), 139.2, 139.7, 143.6 (C_{Ar}), 163.7 (COH), 171.5 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 334 $[M]^+$ (31), 303 (23), 302 (100), 274 (31), 91 (12).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{17}H_{18}O_5S$: 334.08695; found: 334.087082.

Ethyl 3-Ethyl-2-hydroxy-6-methyl-5-tosylbenzoate (4m)

Starting with **2b** (0.402 g, 1.5 mmol) and **3c** (0.500 g, 1.7 mmol), **4m** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.250 g (46%); mp 112–114 °C.

IR (KBr): 3078 (w), 2968 (w), 2927 (w), 2872 (w), 1650 (m), 1597 (w), 1556 (w), 1496 (w), 1450 (w), 1417 (m), 1372 (m), 1334 (m), 1287 (m), 1243 (m), 1180 (m), 1141 (m), 1087 (m), 1055 (m), 1017 cm^{-1} (m).

^1H NMR (250 MHz, $CDCl_3$): δ = 1.13 (t, ^3J = 7.3 Hz, 3 H, $CH_2\mathit{CH}_3$), 1.24 (t, ^3J = 7.2 Hz, 3 H, $OCH_2\mathit{CH}_3$), 2.28 (s, 3 H, PhCH_3), 2.43 (s, 3 H, PhCH_3), 2.59 (q, ^3J = 7.5 Hz, 2 H, CH_2CH_3), 4.27 (q, ^3J = 7.2 Hz, 2 H, $O\mathit{CH}_2CH_3$), 7.13–7.17 (m, 2 H, $2CH_{Ar}$), 7.55–7.58 (m, 2 H, $2CH_{Ar}$), 8.12 (s, 1 H, CH_{Ar}), 11.38 (s, 1 H, OH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 15.8, 15.9, 18.8, 21.5 (CH_3), 23.0 (CH_2), 62.4 (OCH_2), 114.3 ($\mathit{C}COOCH_3$), 124.9 (C_{Ar}), 127.2 ($2CH_{Ar}$), 129.5 ($2CH_{Ar}$), 130.8 (C_{Ar}), 135.4 (CH_{Ar}), 139.2, 139.7, 143.6 (C_{Ar}), 163.7 (COH), 171.5 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 362 $[M]^+$ (36), 317 (31), 316 (96), 290 (10), 289 (19), 288 (100), 91 (25), 77 (13), 57 (33), 289 (19), 41 (10).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{19}H_{22}O_5S$: 362.11825; found: 362.117378.

Methyl 3-Butyl-2-hydroxy-6-methyl-5-tosylbenzoate (4n)

Starting with **2b** (0.402 g, 1.5 mmol) and **3d** (0.522 g, 1.7 mmol), **4n** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.367 g (65%); mp 95–96 °C.

IR (KBr): 3068 (w), 2932 (w), 2875 (w), 1665 (m), 1595 (w), 1566 (w), 1495 (w), 1439 (m), 1377 (w), 1349 (m), 1299 (m), 1246 (m), 1200 (m), 1161 (m), 1138 (s), 1086 (m), 1002 cm^{-1} (w).

^1H NMR (300 MHz, $CDCl_3$): δ = 0.83 (t, ^3J = 7.4 Hz, 3 H,CH_3), 1.21–1.33 (m, 2 H, $2CH_2$), 1.44–1.52 (m, 2 H, CH_2), 2.27 (s, 3 H, PhCH_3), 2.41 (s, 3 H, PhCH_3), 2.57 (t, ^3J = 7.5 Hz, 2 H, PhCH_2), 3.89 (s, 3 H, OCH_3), 7.13–7.17 (m, 2 H, $2CH_{Ar}$), 7.53–7.57 (m, 2 H, $2CH_{Ar}$), 8.10 (s, 1 H, CH_{Ar}), 11.12 (s, 1 H, OH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 13.9, 18.9, 21.5 (CH_3), 22.5, 29.6 31.2 (CH_2), 52.7 (OCH_3), 114.5 ($\mathit{C}COOCH_3$), 127.2 ($2CH_{Ar}$), 129.4 (C_{Ar}), 129.6 ($2CH_{Ar}$), 130.8 (C_{Ar}), 134.7 (CH_{Ar}), 139.2, 139.5, 143.6 (C_{Ar}), 163.3 (COH), 171.6 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 377 (12), 376 $[M]^+$ (49), 344 (16), 327 (12), 317 (19), 316 (87), 315 (16), 303 (19), 302 (100), 301 (23), 274 (32), 188 (11), 91 (14).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{20}H_{24}O_5S$: 376.13390; found: 376.133616.

Methyl 3-Hexyl-2-hydroxy-6-methyl-5-tosylbenzoate (4o)

Starting with **2b** (0.402 g, 1.5 mmol) and **3f** (0.568 g, 1.7 mmol), **4o** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.370 g (61%); mp 95–97 °C.

IR (KBr): 3086 (w), 2954 (w), 2925 (w), 2859 (w), 1660 (m), 1596 (w), 1564 (w), 1495 (w), 1434 (m), 1369 (w), 1335 (m), 1300 (m), 1289 (m), 1243 (m), 1220 (m), 1189 (m), 1138 (s), 1086 (m), 1062 cm^{-1} (m).

^1H NMR (300 MHz, $CDCl_3$): δ = 0.83 (t, ^3J = 7.1 Hz, 3 H, CH_3), 1.21–1.32 (m, 6 H, $3CH_2$), 1.49–1.56 (m, 2 H, CH_2), 2.33 (s, 3 H, PhCH_3), 2.46 (s, 3 H, PhCH_3), 2.62 (t, ^3J = 7.4 Hz, 2 H, PhCH_2), 3.85 (s, 3 H, OCH_3), 7.19–7.21 (m, 2 H, $2CH_{Ar}$), 7.59–7.62 (m, 2 H, $2CH_{Ar}$), 8.16 (s, 1 H, CH_{Ar}), 11.21 (s, 1 H, OH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 14.0, 18.8, 21.5 (CH_3), 22.6, 29.0, 29.1, 29.8, 31.6 (CH_2), 52.6 (OCH_3), 114.5 ($\mathit{C}COOCH_3$), 127.2 ($2CH_{Ar}$), 129.5 (C_{Ar}), 129.6 ($2CH_{Ar}$), 130.8 (C_{Ar}), 134.79 (CH_{Ar}), 139.2, 139.6, 143.6 (C_{Ar}), 163.3 (COH), 171.6 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 405 (13), 404 $[M]^+$ (51), 373 (11), 372 (23), 355 (12), 345 (14), 344 (62), 343 (17), 316 (10), 315 (15), 303 (21), 302 (100), 301 (29), 274 (29), 91 (13).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{22}H_{28}O_5S$: 404.16250; found: 404.165338.

Methyl 3-Heptyl-2-hydroxy-6-methyl-5-tosylbenzoate (4p)

Starting with **2b** (0.268 g, 1.0 mmol) and **3g** (0.395 g, 1.1 mmol), **4p** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.251 g (60%); mp 67–69 °C.

IR (KBr): 2954 (w), 2925 (w), 2855 (w), 2256 (w), 1737 (w), 1665 (m), 1599 (w), 1567 (w), 1494 (w), 1439 (m), 1345 (w), 1311 (m), 1301 (m), 1288 (m), 1247 (w), 1201 (m), 1160 (m), 1142 (s), 1087 (m), 1063 (w), 1000 cm^{-1} (w).

^1H NMR (250 MHz, $CDCl_3$): δ = 0.83 (t, ^3J = 7.03 Hz, 3 H, CH_3), 1.19–1.28 (m, 8 H, $4CH_2$), 1.54–1.60 (m, 2 H, CH_2), 2.34 (s, 3 H, PhCH_3), 2.48 (s, 3 H, PhCH_3), 2.64 (t, ^3J = 7.5 Hz, 2 H, PhCH_2), 3.86 (s, 3 H, OCH_3), 7.22 (d, ^3J = 6.0 Hz, 2 H, $2CH_{Ar}$), 7.62 (d, ^3J = 9.0 Hz, 2 H, $2CH_{Ar}$), 8.17 (s, 1 H, CH_{Ar}), 11.33 (s, 1 H, OH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 14.1, 18.9, 21.5 (CH_3), 22.6, 29.1, 29.2, 29.4, 29.9, 31.8 (CH_2), 52.7 (OCH_3), 114.6 ($\mathit{C}COOCH_3$), 127.2 ($2CH_{Ar}$), 129.5 (C_{Ar}), 129.6 ($2CH_{Ar}$), 130.8 (C_{Ar}), 134.8 (CH_{Ar}), 139.2, 139.6, 143.7 (C_{Ar}), 163.4 (COH), 171.7 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 418 $[M^+]$ (90), 386 (32), 358 (82), 343 (25), 315 (20), 302 (100), 288 (15), 274 (34), 230 (8), 188 (8), 165 (8), 139 (11), 121 (6), 91 (21), 77 (9), 43 (10).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{23}H_{30}O_5S$: 418.18085; found: 418.180657.

Methyl 2-Hydroxy-6-methyl-3-octyl-5-tosylbenzoate (4q)

Starting with **2b** (0.402 g, 1.5 mmol) and **3h** (0.614 g, 1.7 mmol), **4q** was isolated after chromatography (silica gel, heptanes–EtOAc).

White solid; yield: 0.383 g (59%); mp 79–81 °C.

IR (KBr): 3077 (w), 2921 (m), 2851 (m), 1659 (m), 1597 (m), 1495 (w), 1438 (m), 1385 (w), 1348 (m), 1298 (s), 1247 (m), 1199 (s), 1142 (s), 1086 cm^{-1} (s).

^{1}H NMR (300 MHz, CDCl$_3$): δ = 0.76 (t, ^3J = 7.4 Hz, 3 H, CH$_3$), 1.14–1.26 (m, 10 H, 5CH$_2$), 1.45–1.56 (m, 2 H, CH$_2$), 2.27 (s, 3 H, Ph*CH$_3$*), 2.41 (s, 3 H, Ph*CH$_3$*), 2.56 (t, ^3J = 7.6 Hz, 2 H, Ph*CH$_2$*), 3.92 (s, 3 H, OCH$_3$), 7.13–7.16 (m, 2 H, 2CH$_{Ar}$), 7.52–7.58 (m, 2 H, 2CH$_{Ar}$), 8.13 (s, 1 H, CH$_{Ar}$), 11.22 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 14.1 18.8, 21.5 (CH$_3$), 22.6, 29.1, 29.2, 29.4, 29.4, 29.8, 31.8 (CH$_2$), 52.6 (OCH$_3$), 114.5 (*C*COOCH$_3$), 127.2 (2CH$_{Ar}$), 129.5 (C$_{Ar}$), 129.6 (2CH$_{Ar}$), 130.8 (C$_{Ar}$), 134.8 (CH$_{Ar}$), 139.2, 139.5, 143.6 (C$_{Ar}$), 163.3 (COH), 171.6 (CO).

MS (EI, 70 eV): *m/z* (%) = 433 (17), 432 [M]$^+$ (60), 401 (13), 400 (25), 383 (12), 373 (14), 372 (56), 343 (21), 316 (20), 315 (15), 303 (23), 302 (100), 301 (40), 288 (17), 275 (13), 274 (25), 91 (14).

HRMS (EI): *m/z* [M]$^+$ calcd for C$_{24}$H$_{32}$O$_5$S: 432.19650; found: 432.196903.

Methyl 2-Hydroxy-3-methoxy-6-methyl-5-tosylbenzoate (4r)

Starting with **2b** (0.402 g, 1.5 mmol) and **3k** (0.479 g, 1.7 mmol), **4r** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.221 g (42%); mp 179–181 °C.

IR (KBr): 3411 (w), 3090 (w), 2946 (w), 2845 (w), 1709 (m), 1580 (w), 1483 (m), 1440 (m), 1345 (w), 1289 (m), 1203 (m), 1138 (m), 1089 (m), 1069 (m), 1018 cm^{-1} (w).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 2.30 (s, 3 H, Ph*CH$_3$*), 2.33 (s, 3 H, Ph*CH$_3$*), 3.84 (s, 3 H, OCH$_3$), 3.93 (s, 3 H, CO$_2$*CH$_3$*), 7.19–7.23 (m, 2 H, 2CH$_{Ar}$), 7.60–7.63 (m, 2 H, 2CH$_{Ar}$), 7.86 (s, 1 H, CH$_{Ar}$), 9.36 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 17.4, 21.5 (CH$_3$), 52.7 (COO*C*H$_3$), 56.6 (OCH$_3$), 114.4 (CH$_{Ar}$), 118.4 (*C*COOCH$_3$), 127.30 (2CH$_{Ar}$), 129.6 (2CH$_{Ar}$), 130.8, 131.6, 138.8, 143.8, 145.6 (C$_{Ar}$), 152.4 (COH), 169.52 (CO).

MS (EI, 70 eV): *m/z* (%) = 350 [M]$^+$ (50), 320 (11), 319 (40), 318 (100), 290 (45), 289 (11), 288 (11).

HRMS (EI): *m/z* [M]$^+$ calcd for C$_{17}$H$_{18}$O$_6$S: 350.08186; found: 350.081087.

Methyl 3-(4-Chlorophenylsulfonyl)-6-hydroxy-2-methylbenzoate (4s)

Starting with **2c** (0.433 g, 1.5 mmol) and **3a** (0.429 g, 1.7 mmol), **4s** was isolated after chromatography (silica gel, heptanes–EtOAc).

White solid; yield: 0.240 g (47%); mp 126–127 °C.

IR (KBr): 3078 (w), 3024 (w), 2956 (w), 2848 (w), 2789 (w), 1673 (m), 1578 (m), 1503 (w), 1478 (w), 1435 (m), 1351 (m), 1309 (s), 1292 (m), 1223 (m), 1191 (m), 1158 (m), 1145 (s), 1109 (m), 1080 (s), 1031 cm^{-1} (m).

^{1}H NMR (300 MHz, CDCl$_3$): δ = 2.46 (s, 3 H, Ph*CH$_3$*), 3.82 (s, 3 H, OCH$_3$), 6.90 (d, ^3J = 7.5 Hz, 1 H, CH$_{Ar}$), 7.33–7.35 (m, 2 H, 2CH$_{Ar}$), 7.60–7.63 (m, 2 H, 2CH$_{Ar}$), 8.23 (d, ^3J = 7.5 Hz, 1 H, CH$_{Ar}$), 11.11 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 19.2 (CH$_3$), 52.9 (OCH$_3$), 115.2 (*C*COOCH$_3$), 116.0 (CH$_{Ar}$), 128.7 (2CH$_{Ar}$), 129.4 (2CH$_{Ar}$), 131.0 (C$_{Ar}$), 135.3 (CH$_{Ar}$), 139.5, 140.4, 142.7 (C$_{Ar}$), 165.5 (COH), 171.0 (CO).

MS (EI, 70 eV): *m/z* (%) = 342 [M$^+$] (^{37}Cl) (10), 340 [M$^+$] (^{35}Cl) (25), 310 (40), 309 (24), 308 (100), 291 (16), 289 (12), 275 (11), 255 (28), 243 (10), 242 (11), 152 (14), 149 (10), 121 (13), 111 (14), 105 (22), 77 (24), 76 (13), 75 (16), 51(17).

HRMS (EI): *m/z* [M]$^+$ calcd for C$_{15}$H$_{13}$O$_5$ClS: 340.01667; found: 340.017220.

Methyl 3-(4-Chlorophenylsulfonyl)-6-hydroxy-2,5-dimethylbenzoate (4t)

Starting with **2c** (0.433 g, 1.5 mmol) and **3b** (0.452 g, 1.7 mmol), **4t** was isolated after chromatography (silica gel, heptanes–EtOAc).

White solid; yield: 0.255 g (48%); mp 180–182 °C.

IR (KBr): 3099 (w), 2969 (w), 2872 (w), 1665 (m), 1602 (w), 1580 (w), 1471 (w), 1415 (m), 1393 (m), 1370 (m), 1304 (m), 1280 (m), 1244 (m), 1202 (m), 1176 (m), 1145 (s), 1086 (s), 1011 cm^{-1} (m).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 2.24 (s, 3 H, Ph*CH$_3$*), 2.46 (s, 3 H, Ph*CH$_3$*), 3.86 (s, 3 H, OCH$_3$), 7.35–7.41 (m, 2 H, 2CH$_{Ar}$), 7.64–7.70 (m, 2 H, 2CH$_{Ar}$), 8.16 (s, 1 H, CH$_{Ar}$), 11.38 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 15.9, 18.9 (CH$_3$), 52.8 (OCH$_3$), 114.43 (*C*COOCH$_3$), 125.30 (C$_{Ar}$), 128.68 (2CH$_{Ar}$), 129.32 (2CH$_{Ar}$), 129.94 (C$_{Ar}$), 135.45 (CH$_{Ar}$), 139.37, 139.79, 140.69 (C$_{Ar}$), 164.04 (COH), 171.48 (CO).

MS (EI, 70 eV): *m/z* (%) = 356 (17), 354 [M]$^+$ (51), 325 (11), 324 (78), 323 (36), 322 (100), 296 (12), 294 (39), 91 (10).

HRMS (EI): *m/z* [M]$^+$ calcd for C$_{16}$H$_{15}$O$_5$ClS: 354.03232; found: 354.031731.

Ethyl 3-(4-Chlorophenylsulfonyl)-5-ethyl-6-hydroxy-2-methylbenzoate (4u)

Starting with **2c** (0.433 g, 1.5 mmol) and **3c** (0.500 g, 1.7 mmol), **4u** was isolated after chromatography (silica gel, heptanes–EtOAc).

White solid; yield: 0.269 g (47%); mp 144–146 °C.

IR (KBr): 3100 (w), 2968 (w), 2872 (w), 1666 (m), 1603 (w), 1564 (w), 1471 (w), 1416 (w), 1393 (m), 1370 (m), 1304 (m), 1280 (m), 1254 (m), 1203 (m), 1177 (m), 1145 (s), 1085 (s), 1010 cm^{-1} (m).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 1.19 (t, ^3J = 7.5 Hz, 3 H, CH$_2$*CH$_3$*), 1.31 (t, ^3J = 7.1 Hz, 3 H, OCH$_2$*CH$_3$*), 2.48 (s, 3 H, Ph*CH$_3$*), 2.66 (q, ^3J = 7.6 Hz, 2 H, *CH$_2$*CH$_3$), 4.35 (q, ^3J = 7.1 Hz, 2 H, O*CH$_2$*CH$_3$), 7.36–7.42 (m, 2 H, 2CH$_{Ar}$), 7.65–7.70 (m, 2 H, 2CH$_{Ar}$), 8.16 (s, 1 H, CH$_{Ar}$), 11.51 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 12.3, 13.3, 17.9 (CH$_3$), 22.0, 61.5 (CH$_2$), 113.7 (*C*COOCH$_3$), 127.6 (2CH$_{Ar}$), 128.3 (2CH$_{Ar}$), 129.0, 130.6 (C$_{Ar}$), 132.9 (CH$_{Ar}$), 138.3, 138.7, 139.7 (C$_{Ar}$), 162.8 (COH), 170.0 (CO).

MS (EI, 70 eV): *m/z* (%) = 384 (16), 382 [M]$^+$ (46), 339 (10), 338 (52), 337 (31), 336 (100), 310 (43), 309 (16), 308 (94).

HRMS (EI): *m/z* [M]$^+$ calcd for C$_{18}$H$_{19}$O$_5$ClS: 382.06362; found: 382. 063783.

Methyl 5-Butyl-3-(4-chlorophenylsulfonyl)-6-hydroxy-2-methylbenzoate (4v)

Starting with **2c** (0.433g, 1.5mmol) and **3d** (0.522g, 1.7 mmol), **4v** was isolated after chromatography (silica gel, heptanes–EtOAc).

White solid; yield: 0.321 g (54%); mp 88–90 °C.

IR (KBr): 2956 (w), 2929 (w), 2860 (w), 2257 (w), 1737 (w), 1665 (m), 1602 (w), 1572 (w), 1477 (w), 1439 (m), 1394 (w), 1346 (m), 1310 (m), 1294 (m), 1278 (m), 1245 (w), 1201 (m), 1162 (m), 1144 (s), 1086 (s), 1064 (w), 1014 (w), 1002 (w) cm^{-1}.

^{1}H NMR (250 MHz, CDCl$_3$): δ = 0.81 (t, ^3J = 6.9 Hz, 3 H, CH$_3$), 1.18–1.33 (m, 2 H, CH$_2$), 1.42–1.54 (m, 2 H, CH$_2$), 2.39 (s, 3 H, Ph*CH$_3$*), 2.56 (t, ^3J = 8.1 Hz, 2 H, Ph*CH$_2$*), 3.79 (s, 3 H, OCH$_3$), 7.21–7.42 (m, 2 H, 2CH$_{Ar}$), 7.52–7.67 (m, 2 H, 2CH$_{Ar}$), 8.08 (s, 1 H, CH$_{Ar}$), 11.31 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 13.9, 18.9 (CH$_3$), 22.5, 29.6, 31.2 (CH$_2$), 52.8 (OCH$_3$), 114.7 (*C*COOCH$_3$), 128.7 (2CH$_{Ar}$), 129.3

(2CH$_{Ar}$), 129.8, 130.0 (C$_{Ar}$), 134.8 (CH$_{Ar}$), 139.4, 139.7, 140.7 (C$_{Ar}$), 163.8 (COH), 171.5 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 398 [M$^+$] (^{37}Cl) (13), 396 [M$^+$] (^{35}Cl) (35), 364 (18), 336 (53), 322 (100), 294 (28), 220 (3), 188 (15), 165 (5), 116 (3), 91 (5), 77 (5), 57 (4), 43 (5).

HRMS (EI): *m*/*z* [M]$^+$ (^{35}Cl) calcd for $C_{19}H_{21}O_5ClS$: 396.07927; found: 396.079088.

Methyl 3-(4-Chlorophenylsulfonyl)-5-hexyl-6-hydroxy-2-methylbenzoate (4w)

Starting with **2c** (0.288 g, 1.0 mmol) and **3f** (0.379 g, 1.1 mmol), **4w** was isolated after chromatography (silica gel, heptanes–EtOAc).

White solid; yield: 0.212 g (50%); mp 91–93 °C.

IR (KBr): 3076 (w), 2954 (w), 2923 (w), 2858 (w), 1660 (m), 1564 (w), 1503 (w), 1479 (w), 1430 (m), 1414 (m), 1395 (m), 1336 (m), 1277 (m), 1243 (m), 1199 (m), 1158 (m), 1139 (s), 1086 (m), 1064 (m), 1011 cm^{-1} (m).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 0.83 (t, ^3J = 7.0 Hz, 3 H, CH$_3$), 1.21–1.31 (m, 6 H, 3CH$_2$), 1.53–1.57 (m, 2 H, CH$_2$), 2.46 (s, 3 H, PhCH_3), 2.63 (t, ^3J = 7.4 Hz, 2 H, PhCH_2), 3.87 (s, 3 H, OCH$_3$), 7.36–7.42 (m, 2 H, 2CH$_{Ar}$), 7.46–7.70 (m, 2 H, 2CH$_{Ar}$), 8.15 (s, 1 H, CH$_{Ar}$), 11.40 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 14.0, 18.9 (CH$_3$), 22.6, 29.0, 29.1, 29.8, 31.6 (CH$_2$), 52.7 (OCH$_3$), 114.3 (*C*COOCH$_3$), 128.6 (2CH$_{Ar}$), 129.3 (2CH$_{Ar}$), 129.8, 130.0 (C$_{Ar}$), 134.8 (CH$_{Ar}$), 139.3, 139.6, 140.7 (C$_{Ar}$), 163.7 (COH), 171.5 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 426 [M$^+$] (^{37}Cl) (25), 424 [M$^+$] (^{35}Cl) (73), 394 (14), 392 (35), 375 (15), 366 (16), 365 (17), 364 (47), 363 (25), 336 (12), 335 (18), 324 (61), 323 (45), 322 (100), 321 (44), 296 (14), 294 (40).

HRMS (EI): *m*/*z* [M]$^+$ (^{35}Cl) calcd for $C_{21}H_{25}O_5ClS$: 424.11057; found: 424.109531.

Methyl 3-(4-Chlorophenylsulfonyl)-5-heptyl-6-hydroxy-2-methylbenzoate (4x)

Starting with **2c** (0.433 g, 1.5 mmol) and **3g** (0.591 g, 1.7 mmol), **4x** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish oil; yield: 0.335 g (51%).

IR (KBr): 2954 (w), 2926 (m), 2855 (w), 2257 (w), 1737 (w), 1666 (m), 1602 (w), 1572 (w), 1477 (w), 1439 (w), 1346 (w), 1314 (m), 1247 (w), 1202 (m), 1146 (m), 1088 (m), 1013 cm^{-1} (w).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 0.82 (t, ^3J = 7.3 Hz, 3 H, CH$_3$), 1.18–1.28 (m, 8 H, 4CH$_2$), 1.51–1.59 (m, 2 H, CH$_2$), 2.46 (s, 3 H, PhCH_3), 2.62 (t, ^3J = 7.5 Hz, 2 H, PhCH_2), 3.84 (s, 3 H, OCH$_3$), 7.37–7.40 (m, 2 H, 2CH$_{Ar}$), 7.65–7.68 (m, 2 H, 2CH$_{Ar}$), 8.15 (s, 1 H, CH$_{Ar}$), 11.38 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 13.0, 17.9 (CH$_3$), 21.6, 28.0, 28.1, 28.4, 28.9, 30.8 (CH$_2$), 51.8 (OCH$_3$), 113.6 (*C*COOCH$_3$), 127.6 (2CH$_{Ar}$), 128.3 (2CH$_{Ar}$), 128.8, 129.0 (C$_{Ar}$), 133.8 (CH$_{Ar}$), 138.3, 138.7, 139.7 (C$_{Ar}$), 162.7 (COH), 170.5 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 440 (18), 439 (11), 438 [M]$^+$ (46), 408 (14), 407 (14), 406 (31), 389 (13), 380 (13), 379 (10), 378 (35), 365 (11), 364 (10), 363 (27), 336 (11), 335 (14), 324 (37), 323 (31), 322 (100), 321 (33), 308 (12), 296 (14), 295 (12), 294 (31), 288 (11), 231 (10), 230 (11), 111 (11), 97 (13), 85 (12), 83 (13), 71 (17), 69 (17), 59 (15), 57 (24), 55 (16).

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{22}H_{27}ClO_5S$: 438.12622; found: 438.126117.

Methyl 3-(4-Chlorophenylsulfonyl)-6-hydroxy-2-methyl-5-octylbenzoate (4y)

Starting with **2c** (0.288 g, 1.0 mmol) and **3h** (0.409 g, 1.1 mmol), **4y** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.235 g (52%); mp 82–82 °C.

IR (KBr): 2953 (w), 2923 (m), 2853 (w), 1663 (m), 1568 (w), 1476 (w), 1436 (m), 1393 (w), 1345 (m), 1312 (m), 1293 (m), 1246 (m), 1200 (m), 1143 (s), 1085 (s), 1062 (m), 1012 (m), 1000 cm^{-1} (m).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 0.81 (t, ^3J = 6.8 Hz, 3 H, CH$_3$), 1.16–1.25 (m, 10 H, 5CH$_2$), 1.50–1.55 (m, 2 H, CH$_2$), 2.46 (s, 3 H, PhCH$_3$), 2.62 (t, ^3J = 7.6 Hz, 2 H, PhCH$_2$), 3.86 (s, 3 H, OCH$_3$), 7.36–7.41 (m, 2 H, 2CH$_{Ar}$), 7.63–7.69 (m, 2 H, 2CH$_{Ar}$), 8.15 (s, 1 H, CH$_{Ar}$), 11.39 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 13.0, 17.9 (CH$_3$), 21.6, 28.0, 28.2, 28.4, 28.5, 28.8, 30.8 (CH$_2$), 51.7 (OCH$_3$), 113.6 (*C*COOCH$_3$), 127.6 (2CH$_{Ar}$), 128.3 (2CH$_{Ar}$), 128.8, 129.0 (C$_{Ar}$), 133.7 (CH$_{Ar}$), 138.3, 138.6, 139.7 (C$_{Ar}$), 162.7 (COH), 170.5 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 454 [M$^+$] (^{37}Cl) (23), 452 [M$^+$] (^{35}Cl) (68), 422 (13), 420 (30), 403 (11), 394 (10), 392 (28), 363 (23), 335 (13), 324 (44), 322 (100), 308 (15).

HRMS (EI): *m*/*z* [M]$^+$ (^{35}Cl) calcd for $C_{23}H_{29}O_5ClS$: 452.14187; found: 452.141122.

Methyl 4′-Chloro-5-(4-chlorophenylsulfonyl)-2-hydroxy-4-methylbiphenyl-3-carboxylate (4z)

Starting with **2c** (0.433 g, 1.5 mmol) and **3l** (0.612 g, 1.7 mmol), **4z** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellow solid; yield: 0.325 g (48%); mp 178–180 °C.

IR (KBr): 3070 (w), 3004 (w), 2955 (w), 2929 (w), 2852 (w), 2256 (w), 1741 (w), 1723 (w), 1665 (m), 1583 (w), 1552 (w), 1492 (w), 1477 (w), 1434 (m), 1393 (m), 1311 (m), 1279 (w), 1206 (m), 1178 (m), 1148 (m), 1090 (m), 1042 (w), 1014 cm^{-1} (m).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 2.53 (s, 3 H, PhCH_3), 3.90 (s, 3 H, OCH$_3$), 7.33–7.48 (m, 6 H, 6CH$_{Ar}$), 7.54–7.82 (m, 2 H, 2CH$_{Ar}$), 8.35 (s, 1 H, CH$_{Ar}$), 11.55 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 19.1 (CH$_3$), 53.1 (OCH$_3$), 115.9 (*C*COOCH$_3$), 127.6 (C$_{Ar}$), 128.6 (2CH$_{Ar}$), 128.8 (2CH$_{Ar}$), 129.5 (2CH$_{Ar}$), 130.7 (2CH$_{Ar}$), 130.9, 131.1, 134.1 (C$_{Ar}$), 135.4 (CH$_{Ar}$), 139.7, 140.3, 141.6 (C$_{Ar}$), 162.4 (COH), 171.3 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 452 [M$^+$] (^{37}Cl) (9), 450 [M$^+$] (^{35}Cl) (12), 422 (10), 421 (14), 420 (66), 419 (23), 418 (100), 384 (2), 291 (3), 214 (12), 186 (13), 152 (26), 139 (12), 111 (11), 86 (12), 67 (15), 43 (27).

HRMS (EI): *m*/*z* [M]$^+$ (^{35}Cl) calcd for $C_{21}H_{16}O_5Cl_2S$: 450.00900; found: 450.008249.

Methyl 5-(4-Chlorophenylsulfonyl)-2-hydroxy-4,4′-dimethylbiphenyl-3-carboxylate (4aa)

Starting with **2c** (0.433 g, 1.5 mmol) and **3m** (0.578 g, 1.7 mmol), **4aa** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellow solid; yield: 0.342 g (53%); mp 186–189 °C.

IR (KBr): 3101 (w), 3007 (w), 2951 (w), 2919 (w), 2855 (w), 1738 (w), 1664 (m), 1631 (w), 1604 (w), 1573 (w), 1547 (w), 1514 (w), 1477 (w), 1441 (m), 1431 (m), 1394 (w), 1348 (w), 1308 (s), 1281 (m), 1206 (m), 1178 (m), 1148 (s), 1120 (w), 1090 (m), 1043 (w), 1021 (w), 1012 (w), 1000 cm^{-1} (w).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 2.34 (s, 3 H, PhCH_3), 2.52 (s, 3 H, PhCH_3), 3.89 (s, 3 H, OCH$_3$), 7.18–7.22 (m, 2 H, 2CH$_{Ar}$), 7.37–7.40 (m, 2 H, 2CH$_{Ar}$), 7.41–7.42 (m, 2 H, 2CH$_{Ar}$), 7.62–7.73 (m, 2 H, 2CH$_{Ar}$), 8.35 (s, 1 H, CH$_{Ar}$), 11.19 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 19.0, 21.3 (CH$_3$), 53.0 (OCH$_3$), 116.2 (*C*COOCH$_3$), 128.7 (C$_{Ar}$), 128.9 (2CH$_{Ar}$), 129.2 (2CH$_{Ar}$), 129.3 (2CH$_{Ar}$), 129.4 (2CH$_{Ar}$), 130.9, 132.6 (C$_{Ar}$), 135.4 (CH$_{Ar}$), 138.1, 139.6, 140.4, 140.7 (C$_{Ar}$), 162.1 (COH), 171.2 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 432 [M$^+$] (^{37}Cl) (8), 430 [M$^+$] (^{35}Cl) (20), 398 (100), 362 (4), 320 (19), 293 (4), 275 (6), 233 (26), 219 (10), 189 (10), 165 (14), 128 (57), 105 (37), 97 (6), 86 (73), 69 (16).

HRMS (EI): *m*/*z* [M]$^+$ (^{35}Cl) calcd for $C_{22}H_{19}O_5ClS$: 430.07145; found: 430.07204.

Methyl 2-Butyl-6-hydroxy-3-(phenylsulfonyl)benzoate (4ab)
Starting with **2d** (0.445 g, 1.5 mmol) and **3a** (0.429 g, 1.7 mmol), **4ab** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish oil; yield: 0.403 g (77%).

IR (KBr): 3339 (w, br), 3065 (w), 2956 (w), 2931 (w), 2872 (w), 2256 (w), 1732 (m), 1665 (m), 1598 (m), 1576 (m), 1446 (m), 1396 (w), 1380 (w), 1347 (w), 1302 (s), 1225 (m), 1210 (m), 1143 (s), 1107 (s), 1076 (m), 1012 cm^{-1} (m).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 0.68 (t, ^3J = 7.4 Hz, 3 H, CH$_3$), 1.05–1.17 (m, 2 H, CH$_2$), 1.31–1.43 (m, 2 H, CH$_2$), 3.01 (t, ^3J = 8.03 Hz, 2 H, Ph*CH$_2$*), 3.82 (s, 3 H, OCH$_3$), 6.90 (d, ^3J = 9.0 Hz, 1 H, CH$_{Ar}$), 7.35–7.47 (m, 3 H, 3CH$_{Ar}$), 7.68–7.72 (m, 2 H, 2CH$_{Ar}$), 8.28 (d, ^3J = 9.0 Hz, 1 H, CH$_{Ar}$), 10.97 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 13.7 (CH$_3$), 23.3, 30.9, 33.9 (CH$_2$), 52.9 (OCH$_3$), 115.1 (*C*COOCH$_3$), 115.9 (CH$_{Ar}$), 127.2 (2CH$_{Ar}$), 129.2 (2CH$_{Ar}$), 131.1 (C$_{Ar}$), 132.9 (CH$_{Ar}$), 135.6 (C$_{Ar}$), 142.5, 147.8 (C$_{Ar}$), 165.3 (COH), 170.9 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 348 [M$^+$] (9), 331 (6), 313 (18), 306 (6), 281 (22), 254 (8), 239 (50), 231 (14), 211 (100), 198 (12), 165 (55), 141 (82), 125 (54), 98 (18), 85 (29), 77 (97), 69 (28), 57 (38), 43 (28).

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{18}H_{20}O_5S$: 348.11042; found: 348.11064.

Methyl 2-Butyl-6-hydroxy-5-methyl-3-(phenylsulfonyl)benzoate (4ac)
Starting with **2d** (0.445 g, 1.5 mmol) and **3b** (0.452 g, 1.7 mmol), **4ac** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.430 g (79%); mp 113–115 °C.

IR (KBr): 3067 (w), 2957 (w), 2930 (w), 2872 (w), 1737 (w), 1664 (w), 1604 (w), 1568 (w), 1446 (w), 1439 (w), 1381 (w), 1347 (w), 1304 (m), 1250 (w), 1200 (w), 1163 (m), 1144 (m), 1087 (m), 1042 cm^{-1} (w).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 0.71 (t, ^3J = 7.4 Hz, 3 H, CH$_3$), 0.91–0.99 (m, 2 H, CH$_2$), 1.10–1.18 (m, 2 H, CH$_2$), 2.25 (s, 3 H, Ph*CH$_3$*), 3.04 (t, ^3J = 7.4 Hz, 2 H, Ph*CH$_2$*), 3.86 (s, 3 H, OCH$_3$), 7.39–7.52 (m, 3 H, 3CH$_{Ar}$), 7.72–7.75 (m, 2 H, 2CH$_{Ar}$), 8.23 (s, 1 H, CH$_{Ar}$), 11.41 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 13.7, 16.1 (CH$_3$), 23.4, 30.8, 34.0 (CH$_2$), 52.8 (OCH$_3$), 113.7 (*C*COOCH$_3$), 125.3 (C$_{Ar}$), 127.1 (2CH$_{Ar}$), 129.1 (2CH$_{Ar}$), 130.1 (C$_{Ar}$), 132.8 (CH$_{Ar}$), 136.0 (CH$_{Ar}$), 142.9, 145.1(C$_{Ar}$), 164.2 (COH), 171.6 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 362 [M$^+$] (37), 345 (6), 330 (90), 313 (8), 295 (26), 260 (6), 239 (4), 211 (10), 189 (89), 179 (100), 161 (34), 147 (55), 125 (26), 119 (12), 91 (15), 69 (26), 57 (16), 43 (22).

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{19}H_{22}O_5S$: 362.12607; found: 362.12619.

Methyl 4-Butyl-2-hydroxy-4′-methyl-5-(phenylsulfonyl)biphenyl-3-carboxylate (4ad)
Starting with **2d** (0.445 g, 1.5 mmol) and **3m** (0.578 g, 1.7 mmol), **4ad** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish oil; yield: 0.494 g (75%).

IR (KBr): 2956 (w), 2929 (w), 2872 (w), 2255 (w), 1736 (w), 1664 (m), 1601 (w), 1573 (w), 1551 (w), 1514 (w), 1446 (m), 1437 (m), 1399 (w), 1307 (m), 1202 (m), 1178 (m), 1147 (s), 1093 (m), 1023 cm^{-1} (w).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 0.69 (t, ^3J = 7.0 Hz, 3 H, CH$_3$), 0.91–1.04 (m, 2 H, CH$_2$), 1.09–1.18 (m, 2 H, CH$_2$), 2.28 (s, 3 H, Ph*CH$_3$*), 3.01 (t, ^3J = 8.0 Hz, 2 H, Ph*CH$_2$*), 3.82 (s, 3 H, OCH$_3$), 7.15 (d, ^3J = 7.8 Hz, 2 H, 2CH$_{Ar}$), 7.34–7.44 (m, 5 H, 5CH$_{Ar}$), 7.70–7.74 (m, 2 H, 2CH$_{Ar}$), 8.35 (s, 1 H, CH$_{Ar}$), 10.93 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 13.72, 21.3 (CH$_3$), 23.4, 30.9, 33.9 (CH$_2$), 52.9 (OCH$_3$), 115.8 (*C*COOCH$_3$), 127.2 (2CH$_{Ar}$), 128.6 (C$_{Ar}$), 129.1 (2CH$_{Ar}$), 129.2 (4CH$_{Ar}$), 131.1, 132.8 (C$_{Ar}$), 132.9, 135.8 (CH$_{Ar}$), 138.0, 142.7, 145.8 (C$_{Ar}$), 161.9 (COH), 171.2 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 438 [M$^+$] (60), 408 (21), 407 (73), 406 (100), 377 (8), 335 (3), 223 (15), 195 (62), 165 (14), 119 (10), 91 (7).

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{25}H_{26}O_5S$: 438.15737; found: 438.15819.

Methyl 3-Hydroxy-4′-nitro-6-tosylbiphenyl-2-carboxylate (4ae)
Starting with **2e** (0.563 g, 1.5 mmol) and **3a** (0.429 g, 1.7 mmol), **4ae** was isolated after chromatography (silica gel, heptanes–EtOAc).

White solid; yield: 0.289 g (45%); mp 196–198 °C.

IR (KBr): 3400 (w), 3106 (w), 3018 (w), 2924 (w), 2857 (w), 1703 (m), 1650 (w), 1593 (w), 1576 (m), 1515 (m), 1445 (w), 1433 (w), 1380 (w), 1347 (m), 1286 (m), 1183 (w), 1147 (m), 1119 (m), 1079 (m), 1017 cm^{-1} (w).

^{1}H NMR (300 MHz, CDCl$_3$): δ = 2.30 (s, 3 H, Ph*CH$_3$*), 3.20 (s, 3 H, OCH$_3$), 6.91–6.94 (m, 2 H, 2CH$_{Ar}$), 6.96–7.02 (m, 4 H, 4CH$_{Ar}$), 7.19 (d, ^3J = 8.5 Hz, 1 H, CH$_{Ar}$), 7.89–7.92 (m, 2 H, 2CH$_{Ar}$), 8.47 (d, ^3J = 8.5 Hz, 1 H, CH$_{Ar}$), 11.28 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 21.7 (CH$_3$), 52.9 (OCH$_3$), 113.9 (*C*COOCH$_3$), 118.4 (CH$_{Ar}$), 121.5 (2CH$_{Ar}$), 127.2 (2CH$_{Ar}$), 129.2 (2CH$_{Ar}$), 130.8 (2CH$_{Ar}$), 132.2 (C$_{Ar}$), 135.0 (CH$_{Ar}$), 138.2., 142.4, 143.4, 144.1, 147.0 (C$_{Ar}$), 165.0 (COH), 169.7 (CO).

MS (EI, 70 eV): *m*/*z* (%) = 427 [M]$^+$ (36), 396 (19), 395 (100), 139 (12), 91 (8).

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{21}H_{17}O_7NS$: 427.07202; found: 427.071814.

Methyl 3-Hydroxy-4-methyl-4′-nitro-6-tosylbiphenyl-2-carboxylate (4af)
Starting with **2e** (0.563 g, 1.5 mmol) and **3b** (0.452 g, 1.7 mmol), **4af** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellow solid; yield: 0.324 g (49%); mp 180–182 °C.

IR (KBr): 3078 (w), 2925 (w), 2854 (w), 2256 (w), 1668 (m), 1597 (w), 1564 (w), 1518 (m), 1440 (w), 1380 (w), 1346 (s), 1302 (m), 1251 (m), 1148 (s), 1117 (m), 1084 (w), 1017 cm^{-1} (w).

^{1}H NMR (250 MHz, CDCl$_3$): δ = 2.30 (s, 3 H, Ph*CH$_3$*), 2.35 (s, 3 H, Ph*CH$_3$*), 3.24 (s, 3 H, OCH$_3$), 6.87–7.02 (m, 6 H, 6CH$_{Ar}$), 7.86–7.91 (m, 2 H, 2CH$_{Ar}$), 8.35 (s, 1 H, CH$_{Ar}$), 11.53 (s, 1 H, OH).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 16.2, 21.6 (CH$_3$), 52.5 (OCH$_3$), 113.1 (*C*COOCH$_3$), 121.5 (2CH$_{Ar}$), 127.1 (2CH$_{Ar}$), 128.2 (C$_{Ar}$), 129.2 ($2CH_{Ar}$), 131.0 (CH_{Ar}), 131.2 (C_{Ar}), 135.1($2CH_{Ar}$), 138.4, 139.8, 143.8, 143.9, 146.9 (C_{Ar}), 163.5 (COH), 170.3 (CO).

MS (EI, 70 eV): m/z (%) = 441 $[M]^+$ (37), 411 (10), 410 (23), 409 (100), 363 (20), 254 (22), 253 (19).

HRMS (EI): m/z $[M]^+$ calcd for $C_{22}H_{19}NO_7S$: 441.08767; found: 441.087563.

Methyl 4-Butyl-3-hydroxy-4′-nitro-6-tosylbiphenyl-2-carboxylate (4ag)

Starting with **2e** (0.563 g, 1.5 mmol) and **3d** (0.522 g, 1.7 mmol), **4ag** was isolated after chromatography (silica gel, heptanes–EtOAc).

Yellowish solid; yield: 0.340 g (47%); mp 130–133 °C.

IR (KBr): 3115 (w), 3088 (w), 2917 (w), 2850 (w), 1731 (w), 1651 (m), 1596 (m), 1516 (m), 1493 (w), 1465 (w), 1398 (m), 1344 (m), 1288 (m), 1181 (m), 1149 (m), 1121 (m), 1081 (m), 1012 cm^{-1} (m).

^1H NMR (250 MHz, $CDCl_3$): $\delta = 0.60$ (t, $^3J = 6.3$ Hz, 3 H, CH_3), 1.22–1.30 (m, 2 H, CH_2), 1.59–1.63 (m, 2 H, CH_2), 2.30 (s, 3 H, $PhCH_3$), 2.75 (t, $^3J = 6.9$ Hz, 2 H, $PhCH_2$), 3.25 (s, 3 H, OCH_3), 6.90–6.93 (m, 2 H, $2CH_{Ar}$), 6.95–7.02 (m, 4 H, $4CH_{Ar}$), 7.83–7.91 (m, 2 H, $2CH_{Ar}$), 8.36 (s, 1 H, CH_{Ar}), 11.70 (s, 1 H, OH).

^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 12.2$, 20.5 (CH_3), 22.2, 28.6, 32.3 (CH_2), 52.8 (OCH_3), 112.2 ($CCOOCH_3$), 120.5 ($2CH_{Ar}$), 126.1 ($2CH_{Ar}$), 126.9 (C_{Ar}), 128.2 ($2CH_{Ar}$), 130.2 ($2CH_{Ar}$), 132.5 (CH_{Ar}), 132.8, 137.5, 138.7, 142.9, 143.0, 146.0 (C_{Ar}), 163.7 (COH), 169.0 (CO).

MS (EI, 70 eV): m/z (%) = 483 $[M]^+$ (35), 424 (33), 406 (27), 395 (100), 165 (11), 139 (16), 91 (16).

HRMS (EI): m/z $[M]^+$ calcd for $C_{25}H_{25}O_7NS$: 483.13485; found: 483.133950.

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