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## Competing Regiodirecting Effects of Ester and Aryl Groups in [3+3] Cyclocondensations of 1,3-Bis(trimethylsilyloxy)-1,3-butadienes: Regioselective Synthesis of 3-Hydroxyphthalates and 2-Hydroxyterephthalates

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3-Hydroxy-5-methylphthalates are prepared by regioselective chelation-controlled cyclization of 1,3-bis(silyloxy)-1,3butadienes with 4-silyloxy-2-oxo-3-butenoates derived from acetylpyruvates. The employment of silylated benzoylpyruvates instead of acetylpyruvates results in a regioselectivity change and the formation of 6-aryl-2-hydroxyterephthalates. The cyclization of 1,3-bis(silyloxy)-1,3-butadienes with 4ethoxy-2-oxo-3-butenoates, readily available by condensation of enol ethers with methyl 2-chloro-2-oxoacetate, provides a convenient approach to 2-hydroxyterephthalates and 3-hydroxyphthalates depending on the substitution pattern of the diene.

#### Introduction

Highly functionalized benzene derivatives, such as hydroxylated benzoates and benzodioates, are of considerable interest as lead structures and synthetic building blocks in medicinal and agricultural chemistry.<sup>[1,2]</sup> Classical syntheses of such compounds are based on electrophilic substitution and oxidation reactions. Despite their great utility, electrophilic substitutions have several drawbacks (e.g., low regioselectivity and low reactivity of electron-poor substrates). Oxidations of toluene derivatives to benzoic acid derivatives often require drastic conditions. Transitionmetal-catalyzed cross-coupling reactions of functionalized benzene derivatives proceed under relatively mild conditions.<sup>[3]</sup> However, the synthesis of the required starting materials, highly functionalized or sterically encumbered benzene derivatives, can be a difficult task.

Functionalized benzene derivatives have been prepared also by application of a "building block" strategy. Examples include base-mediated cyclizations of acetone-1,3-dicarboxylates,<sup>[4]</sup> condensations of 1,3-dicarbonyl dianions with carboxylic acid derivatives and subsequent intramolecular aldol reactions of the polyketides thus formed<sup>[5]</sup> and [4+2] cycloadditions.<sup>[6]</sup> Chan and Brownbridge were the first to report<sup>[7]</sup> the synthesis of salicylates by formal [3+3] cycliza-

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tions of 1,3-bis(silyloxy)-1,3-butadienes<sup>[8]</sup> with 3-silyloxy-2en-1-ones. This strategy has been widely applied in recent years.<sup>[9]</sup> However, its scope is mainly limited to 3-silyloxy-2-en-1-ones derived from symmetrical 1,3-diketones. Although a few exceptions have been reported,<sup>[7]</sup> cyclizations of 3-silyloxy-2-en-1-ones derived from unsymmetrical 1,3diketones often proceed with low regioselectivity.

Recently, we reported<sup>[10]</sup> preliminary results related to the synthesis of 3-hydroxy-5-methylphthalates based on regioselective chelation-controlled<sup>[11,12]</sup> cyclizations of 1,3bis(silyloxy)-1,3-butadienes with 4-silyloxy-2-oxo-3-butenoates derived from acetylpyruvates. Herein, we report a full account related to the scope. During our studies we found that the employment of benzoylpyruvates instead of acetylpyruvates results in a complete regioselectivity change and the formation of 6-aryl-2-hydroxyterephthalates. In addition, we report what are, to the best of our knowledge, the first cyclizations of 1,3-bis(silyloxy)-1,3-butadienes with methyl 4-ethoxy-2-oxo-3-butenoates, which are readily available by condensation of enol ethers with methyl 2chloro-2-oxoacetate. These reactions provide a convenient approach to C5-unsubstituted 3-hydroxyphthalates.

#### **Results and Discussion**

4-Silyloxy-2-oxo-3-butenoates **2a**,**b** were prepared by silylation of acetylpyruvates **1a**,**b** (Scheme 1).

The TiCl<sub>4</sub>-mediated formal [3+3] cyclization of 4-silyloxy-2-oxo-3-butenoate **2a** with 1,3-bis(silyloxy)-1,3-butadiene **3a** (Chan's diene), prepared in two steps from methyl acetoacetate,<sup>[7]</sup> afforded 3-hydroxy-5-methylphthalate **4a** 

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Scheme 1. Synthesis of silyl enol ethers 2a,b; the products were isolated as mixtures of E/Z isomers.

with very good regioselectivity. The best yield was obtained when the reaction was carried out in a highly concentrated solution (Scheme 2).



Scheme 2. Possible mechanism of the formation of 4a.

The formation of 4a can be explained by reaction of 2a with TiCl<sub>4</sub> to give intermediate A. The attack of the terminal carbon atom of 3a onto A results in the formation of intermediate B. The elimination of 1,1,1,3,3,3-hexamethyldisiloxane (intermediate C) and subsequent cyclization gives intermediate D. The elimination of titanium hydroxide and aromatization resulted in the formation of product 4a. The regioselectivity might be explained by TiCl<sub>4</sub>-mediated migration of the TMS group of 2a and formation of intermediate A, which allows chelation of TiCl<sub>4</sub> by the neighbouring oxygen atoms. The reaction of 1,3-bis(silyloxy)-1,3butadienes with 3-silyloxy-2-en-1-ones usually proceeds by attack of the terminal carbon atom of the diene onto the double bond of the 3-silvloxy-2-en-1-one (conjugate addition).<sup>[7–9]</sup> The  $\pi$ -donating effect of the silvloxy group increases the electron density (and thus decreases the electrophilicity) of the carbonyl group of the enone moiety. Therefore, conjugate addition is observed.

The TiCl<sub>4</sub>-mediated cyclization of 4-silyloxy-2-oxo-3butenoates **2a**,**b** with 1,3-bis(silyloxy)-1,3-butadienes **3a**–**i**, available from the corresponding  $\beta$ -keto esters,<sup>[13,14]</sup> afforded 3-hydroxy-5-methylphthalates **4a**–**i** with very good regioselectivity (Scheme 3). The moderate yields can be explained by practical problems during the chromatographic purification (Table 1). The formation of the other regioisomer, a 2-hydroxy-6-methylterphthalate, was not observed.



Scheme 3. Synthesis of 4a-i. Reagents and conditions: (i) TiCl<sub>4</sub> (1.1 equiv.), CH<sub>2</sub>Cl<sub>2</sub>, -78 to 20 °C.

2	3,4	$\mathbb{R}^1$	$\mathbb{R}^2$	<b>R</b> <sup>3</sup>	$\%$ Yield of $4^{[a]}$
a	a	Me	Н	Me	43
a	b	Me	Me	Et	32
a	с	Me	Et	Et	42
b	d	Et	nHex	Me	37
a	e	Me	OMe	Me	45
b	f	Et	OPh	Et	40
b	g	Et	$4-(MeO)C_6H_4$	Me	39
b	h	Et	nNon	Me	42
b	i	Et	nDec	Me	42

[a] Yield of isolated products.

The reaction of **2a** with dienes **5a** and **5b**, prepared from acetylacetone and benzoylacetone, afforded products **6a** and **6b**, respectively (Scheme 4). Treatment of **6b** with concentrated sulfuric acid gave functionalized anthraquinone **7**, which also confirms the constitution of **6b**.



Scheme 4. Synthesis of **6a,b** and **7**. Reagents and conditions: (i)  $TiCl_4$  (1.1 equiv.),  $CH_2Cl_2$ , -78 to 20 °C; (ii) conc. sulfuric acid, 1 h.

The structures of products 4 and 6 were established by NOESY experiments. For 6a, NOE interactions are observed between proton H-4 and the protons of the OH group and of the methyl group located at carbon C-5. In addition, NOE interactions are observed between H-6 and the methyl group located at C-5 and between H-6 and the methyl group of the ester (Scheme 5). Likewise, characteristic NOE effects are observed for **6b**, **4c** and **4e**.



Scheme 5. Characteristic NOESY effects of compounds **4c**,**e** and **6a**,**b**.

The reaction of enol ethers **8a–c** with methyl 2-chloro-2oxoacetate (7) afforded, following a known procedure,<sup>[15]</sup> 4-ethoxy-2-oxo-3-butenoates **9a–c** (Scheme 6, Table 2). The synthesis of derivative **9a** has been previously reported.<sup>[15]</sup>



Scheme 6. Synthesis of **9a–c**. Reagents and conditions: (i) **8a–c** (2.0 equiv.), **7** (1.0 equiv.),  $0 \,^{\circ}$ C, 2–4 h; the products were isolated as mixtures of E/Z isomers.

Table 2. Synthesis of **9a–c**.

8,9	R	% Yield of <b>9</b> <sup>[a]</sup>
a	Н	82
D	Me	97
c	Et	95

[a] Yield of isolated products.

The TiCl<sub>4</sub>-mediated cyclization of 1,3-bis(silyloxy)-1,3butadiene 3a with 4-ethoxy-2-oxo-3-butenoate 9a gave C5unsubstituted 3-hydroxyterephthalate 10a (Scheme 7, Table 3). The product was formed with very good regioselectivity. The formation of the other regioisomer was not observed. The reaction proceeds by attack of the terminal carbon atom of the diene to the carbonyl group and subsequent cyclization. The regioselectivity can be explained by the high electrophilicity of the carbonyl group located next to the ester group. Likewise, the cyclization of 3a with enones 9b and 9c afforded terephthalates 10f and 10i, respectively. In contrast, the reaction of 9a-c with dienes 3c,j-m, containing a substituent located at carbon atom C-4, gave 3-hydroxyphthalates 10b-e,g,h,j instead of the regioisomeric 2-hydroxyterephthalates. The change in the regioselectivity might be explained by steric reasons (interaction of substituent  $\mathbb{R}^2$  with the ester group of the enone). The structure of terephthalate 10a was proved by comparison of the data

with those reported for **10a**<sup>[16]</sup> and for its phthalate regioisomer in the literature.<sup>[17]</sup> The structures of terephthalates **10f** and **10i** were unambiguously proved by the fact that two singlets (instead of two doublets) were observed for the aromatic protons. The phthalate regioisomers of **10f**<sup>[18]</sup> and **10i**<sup>[19]</sup> are known, and their spectroscopic data are, as expected, different from terephthalates **10f** and **10i**. The structure of **10j** was proved by NOESY experiments (Scheme 8). Similar to **10j**, 3-hydroxyphthalates **10b–e,g,h** show a singlet at approx. 7.10 ppm, which can be assigned to proton H-5 located in the *meta* position to the ester group. In contrast, the signals of the protons located in the *ortho* position to an ester group are generally shifted more downfield. The spectroscopic data of **10g** are identical with those reported in the literature.<sup>[20]</sup>

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Scheme 7. Synthesis of 10a-j.

Table 3. Synthesis of **10a**–j.

3	9	10	$\mathbb{R}^1$	R <sup>2</sup>	R <sup>3</sup>	% Yield of 10 <sup>[a]</sup>
a	a	a	Me	Н	Н	40
i	a	b	Me	Me	Η	42
c	a	с	Et	Et	Н	45
k	a	d	Me	<i>n</i> Bu	Η	43
1	a	e	Me	<i>n</i> -Oct	Н	45
a	b	f	Me	Н	Me	45
i	b	g	Me	Me	Me	45
m	b	ĥ	Me	<i>n</i> -Pent	Me	48
a	с	i	Me	Н	Et	47
j	c	j	Me	Me	Et	48
-		2				

[a] Yield of isolated products.



Scheme 8. Characteristic NOESY effects of compound 10j.

The silylation of benzoylpyruvates  $11a-d^{[21]}$  afforded 3silyloxy-2-en-1-ones 12a-d (Scheme 9). The TiCl<sub>4</sub>-mediated cyclization of 12a-d with 1,3-bis(trimethylsilyloxy)-1,3butadienes 3a,d,j,k,n,o afforded 6-aryl-2-hydroxyterephthalates 13a-n (Scheme 10, Table 4). Interestingly, the reaction proceeded with different regioselectivity as compared to the reaction of dienes 3 with acetylpyruvate-derived 3-silyloxy-2-en-1-ones 2a,b. The aryl group of 13a-n is located in the *ortho* position to the ester group, whereas the methyl group of 4a-i is located in the para position to the ester group. Chan and Brownbridge reported<sup>[7]</sup> that the reaction of 3a with 4-phenyl-4-(trimethylsilyloxy)but-3-en-2-one, prepared from benzoylacetone, afforded methyl 6phenyl-4-methylsalicylate (whose phenyl group is located ortho to the ester group). This result was explained by TiCl<sub>4</sub>-mediated isomerization of the TMS group of 4phenyl-4-(trimethylsilyloxy)but-3-en-2-one to give 1-phenyl-3-(trimethylsilyloxy)but-2-en-1-one (or its titanium complex) and subsequent conjugate addition of the terminal carbon atom of **3a** onto the enone. This might be explained by an energetically favourable interaction of Ti<sup>IV</sup> with the neighbouring phenyl group. The regioselective formation of 13a-n shows that this effect successfully competes with the chelation discussed above for the synthesis of products 4. The tendency of the aryl group to be located in the ortho position to the ester group is obviously higher than the tendency of the pyruvate-derived ester group to be located in the ortho position to the diene-derived ester group.



Scheme 9. Synthesis of silyl enol ethers 12a-d.



Scheme 10. Synthesis of **13a–n**. Reagents and conditions: (i)  $TiCl_4$  (1.1 equiv.),  $CH_2Cl_2$ , -78 to 20 °C.

Table 4. Synthesis of 13a-n.

3	11,12	13	R <sup>1</sup>	R <sup>2</sup>	% Yield of <b>13</b> <sup>[a]</sup>	δ(OMe) <sup>[b]</sup>
a	a	a	Н	Н	43	3.43
j	a	b	Me	Η	49	3.36
n	a	с	Et	Η	50	3.41
k	a	d	<i>n</i> Bu	Н	46	3.41
a	b	e	Н	Me	44	3.46
j	b	f	Me	Me	46	3.45
n	b	g	Et	Me	46	3.45
j	c	h	Me	$NO_2$	66	3.39
n	c	i	Et	$NO_2$	67	3.45
a	d	j	Η	Br	53	3.43
j	d	k	Me	Br	55	3.47
n	d	1	Et	Br	59	3.47
d	d	m	nHex	Br	50	3.36
0	d	n	nHept	Br	50	3.47

[a] Yield of isolated products. [b] Chemical shift [ppm] ( $^{1}$ H NMR, CDCl<sub>3</sub>) of the CO<sub>2</sub>Me group.



The structures of terephthalates **13** were confirmed by spectroscopic methods (NOESY experiments). The signals (<sup>1</sup>H NMR) of the methyl group of the CO<sub>2</sub>Me moiety of terephthalates **13** ( $\delta$  = 3.36–3.47 ppm) are generally shifted upfield by ca. 0.4 ppm relative to the corresponding signals of phthalates **4** and **10** ( $\delta$  = 3.79–3.94 ppm). This can be explained by the fact that the CO<sub>2</sub>Me groups of terphthalates **13** are located in the anisotropic cone of the neighbouring aryl group (Scheme 11). The structures of **13h** and **13m** were independently confirmed by X-ray crystal structure analyses (Figures 1 and 2).<sup>[22]</sup>



Scheme 11. Location of the  $CO_2Me$  group in the anisotropic cone of the neighbouring aryl group of 13a-n.



Figure 1. Crystal structure of 13h.



Figure 2. Crystal structure of 13m.

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### Conclusions

In conclusion, we have reported the synthesis of 3-hydroxy-5-methylphthalates by regioselective chelation-controlled cyclization of 1,3-bis(silyloxy)-1,3-butadienes with 4silyloxy-2-oxo-3-butenoates derived from acetylpyruvates. The employment of silvlated benzovlpyruvates instead of acetylpyruvates results in a change in the regioselectivity and the formation of 6-aryl-2-hydroxyterphthalates. The regiodirecting effect of the aryl group is stronger than that of the pyruvate-derived ester group. The cyclization of 1,3bis(silyloxy)-1,3-butadienes with 4-ethoxy-2-oxo-3-butenoates, readily available by condensation of enol ethers with methyl 2-chloro-2-oxoacetate, provides a convenient 3-hydroxyphthalates and 2-hydroxyapproach to terephthalates depending on the substitution pattern of the diene.

### **Experimental Section**

**General Comments:** All solvents were dried by standard methods, and all reactions were carried out under an inert atmosphere. <sup>1</sup>H and <sup>13</sup>C NMR spectra were recorded with Bruker AM 250, ARX 300, and ARX 500 spectrometers. Mass spectrometric data (MS) were obtained by electron ionization (EI, 70 eV), chemical ionization (CI, isobutane) or electrospray ionization (ESI). For preparative-scale chromatography silica gel 60 (0.063–0.200 mm, 70–230 mesh) was used.

General Procedure for the Synthesis of Alkyl 4-Ethoxy-2-oxo-3-butbutenoates 9a-c: To alkyl vinyl ether 8a-c (2.0 equiv.) was dropwise added, over 20 min, methyl chlorooxoacetate (1.0 equiv.) under an atmosphere of argon at 0 °C. The mixture was stirred at 0 °C for 3 h. The temperature was warmed to 20 °C over 15 h with stirring. The mixture was distilled in vacuo to give 9a-c. The synthesis of 9a has been previously reported.<sup>[15]</sup>

**Methyl 4-Ethoxy-3-methyl-2-oxobut-3-butenoate (9b):** Starting with **8b** (11.75 mL, 106.1 mmol) and methyl chlorooxoacetate (4.89 mL, 53.1 mmol), the product was collected after drying under vacuum as a reddish oil (8.86 g, 97%). <sup>1</sup>H NMR (250 MHz, CDCl<sub>3</sub>):  $\delta = 1.33$  (t, <sup>3</sup>*J* = 7.1 Hz, 3 H, OCH<sub>2</sub>*CH*<sub>3</sub>), 1.70 (s, 3 H, CH<sub>3</sub>), 3.81 (s, 3 H, OCH<sub>3</sub>), 4.14 (q, <sup>3</sup>*J* = 7.1 Hz, 2 H, O*CH*<sub>2</sub>CH<sub>3</sub>), 7.54 (s, 1 H, CH<sub>Olf</sub>) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta = 7.4$ , 15.2 (CH<sub>3</sub>), 52.4 (OCH<sub>3</sub>), 71.3 (OCH<sub>2</sub>), 114.7 (C), 164.6 (CO), 165.7 (CH<sub>Olf</sub>), 185.6 (CO) ppm. IR (neat):  $\tilde{v} = 2985$  (w), 2956 (w), 2903 (w), 2254 (w), 2254 (w), 1731 (m), 1617 (s), 1476 (w), 1437 (w), 1388 (w), 1369 (w), 1330 (w), 1210 (s), 1146 (m), 1108 (m), 1049 (m), 1025 (m), 971 (m), 910 (m), 845 (w), 824 (w), 779 (w), 726 (s), 647 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): *m/z* (%) = 172 (3) [M]<sup>+</sup>, 144 (1), 113 (82), 85 (100), 83 (5), 55 (5), 39 (4), 29 (20). HRMS (EI): calcd. for C<sub>8</sub>H<sub>12</sub>O<sub>4</sub> [M]<sup>+</sup> 172.07301; found 172.073090

**Methyl 3-(Ethoxymethylene)-2-oxopentanoate (9c):** Starting with **8c** (13.64 mL, 106.1 mmol) and methyl chlorooxoacetate (4.89 mL, 53.1 mmol), the product was collected after drying under vacuum as a reddish oil (9.38 g, 95%). <sup>1</sup>H NMR (250 MHz, CDCl<sub>3</sub>):  $\delta = 0.91$  (t,  ${}^{3}J = 7.6$  Hz, 3 H, CH<sub>2</sub>*CH*<sub>3</sub>), 1.31 (t,  ${}^{3}J = 7.1$  Hz, 3 H, OCH<sub>2</sub>*CH*<sub>3</sub>), 2.24 (q,  ${}^{3}J = 7.5$  Hz, 2 H, *CH*<sub>2</sub>CH<sub>3</sub>), 3.79 (s, 3 H, OCH<sub>3</sub>), 4.12 (q,  ${}^{3}J = 7.5$  Hz, 2 H, O*CH*<sub>2</sub>CH<sub>3</sub>), 7.46 (s, 1 H, CH<sub>Olf</sub>) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta = 12.6$ , 15.0 (CH<sub>3</sub>), 16.0 (CH<sub>2</sub>), 52.3 (OCH<sub>3</sub>), 71.1 (OCH<sub>2</sub>), 120.7 (C), 164.5 (CO), 165.7 (CH<sub>Olf</sub>), 185.3 (CO) ppm. IR (neat):  $\tilde{v} = 2970$  (w), 2937 (w), 2878

(w), 1731 (m), 1652 (w), 1615 (s), 1456 (w), 1439 (w), 1388 (w), 1370 (w), 1321 (m), 1301 (m), 1273 (m), 1207 (s), 1146 (m), 1108 (m), 1083 (s), 1021 (m), 965 (m), 898 (m), 871 (m), 798 (w), 777 (w), 732 (m), 706 (m), 648 (w), 547 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 186 (4) [M]<sup>+</sup>, 127 (100), 99 (90), 83 (4), 69 (4), 53 (7), 43 (10), 29 (6). HRMS (ESI): calcd. for C<sub>9</sub>H<sub>15</sub>O<sub>4</sub> [M + H]<sup>+</sup> 187.09649; found 187.09595.

Synthesis of Benzoylpyruvates 11a-d: Products 11a-d were prepared as previously reported.<sup>[21]</sup> The spectroscopic data of 11d have not been previously reported: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 1.34 (t,  ${}^{3}J = 7.1 \text{ Hz}$ , 3 H, OCH<sub>2</sub>CH<sub>3</sub>), 4.33 (q,  ${}^{3}J = 7.3 \text{ Hz}$ , 2 H, OCH<sub>2</sub>CH<sub>3</sub>), 6.96 (s, 1 H, CH), 7.55–7.60 (m, 2 H, CH<sub>Ar</sub>), 7.77– 7.81 (m, 2 H, CH<sub>Ar</sub>), 15.10 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta = 14.1$  (CH<sub>3</sub>), 62.7 (OCH<sub>2</sub>), 97.7 (CH), 129.0 (C<sub>Ar</sub>), 129.3 (2 CH<sub>Ar</sub>), 132.3 (2 CH<sub>Ar</sub>), 133.7 (C<sub>Ar</sub>), 162.0 (COH), 170.2, 189.5 (CO) ppm. IR (neat):  $\tilde{v} = 3414$  (w), 3107 (w), 2982 (w), 2935 (w), 2910 (w), 2868 (w), 1718 (m), 1585 (m), 1478 (m), 1446 (w), 1392 (m), 1365 (m), 1300 (m), 1260 (s), 1247 (s), 1175 (m), 1132 (m), 1104 (m), 1070 (m), 1004 (m), 933 (m), 910 (m), 857 (m), 809 (m), 764 (m), 679 (m), 626 (m), 537 (m) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 300 (4) [M<sup>+</sup>, <sup>81</sup>Br], 298 (4) [M<sup>+</sup>, <sup>79</sup>Br], 227 (98), 225 (100), 183 (33), 155 (12), 118 (9), 89 (11), 75 (10), 69 (42). HRMS (EI): calcd. for C<sub>12</sub>H<sub>11</sub>O<sub>4</sub>Br [M<sup>+</sup>, <sup>81</sup>Br] 299.98148; found 299.981660. HRMS (EI): calcd. for C<sub>12</sub>H<sub>11</sub>O<sub>4</sub>Br [M<sup>+</sup>, <sup>79</sup>Br] 297.98352; found 297.983698.

General Procedure for the Synthesis of 4a–i, 6a,b, 10a–j and 13a–n: To a CH<sub>2</sub>Cl<sub>2</sub> solution (2 mL/1 mmol of enone) of enones 2, 9 or 12 was added diene 3 or 5 (1.1 mmol) and, subsequently, TiCl<sub>4</sub> (1.1 mmol) at -78 °C. The temperature of the solution was warmed to 20 °C over 14 h with stirring. To the solution was added hydrochloric acid (10%, 20 mL) and the organic and aqueous layers were separated. The latter was extracted with CH<sub>2</sub>Cl<sub>2</sub> (3 × 20 mL). The combined organic layer was dried (Na<sub>2</sub>SO<sub>4</sub>) and filtered, and the filtrate was concentrated in vacuo. The residue was purified by chromatography (silica gel, heptanes/EtOAc) to give the product.

**Dimethyl 3-Hydroxy-5-methylphthalate (4a):** Starting with **2a** (0.433 g, 2.0 mmol) and **3a** (0.573 g, 2.2 mmol), **4a** was isolated as a brownish solid (0.193 g, 43%). M.p. 88–91 °C. <sup>1</sup>H NMR (250 MHz, CDCl<sub>3</sub>):  $\delta$  = 2.33 (s, 3 H, PhCH<sub>3</sub>), 3.86 (s, 3 H, OCH<sub>3</sub>), 3.89 (s, 3 H, OCH<sub>3</sub>), 6.74–6.75 (m, 1 H, CH<sub>Ar</sub>), 6.86–6.87 (m, 1 H, CH<sub>Ar</sub>), 10.62 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 21.6 (CH<sub>3</sub>), 52.5, 52.7 (OCH<sub>3</sub>), 107.2 (C<sub>Ar</sub>), 119.7, 120.2 (CH<sub>Ar</sub>), 135.3, 146.2 (C<sub>Ar</sub>), 161.3 (COH), 169.3, 169.6 (CO) ppm. IR (Nujol):  $\hat{v}$  = 3163 (w), 1725 (s), 1686 (s), 1618 (w), 1574 (w), 1339 (s), 1303 (m), 1270 (s), 1201 (s), 1160 (s), 1096 (m), 1035 (m) cm<sup>-1</sup>. MS (EI, 70 eV): calcd. for C<sub>11</sub>H<sub>12</sub>O<sub>5</sub> [M]<sup>+</sup> 224.0679; found 224.0676.

**2-Ethyl 1-Methyl 3-Hydroxy-4,5-dimethylphthalate (4b):** Starting with **2b** (0.461 g, 2.0 mmol) and **3b** (0.635 g, 2.2 mmol), **4b** was isolated as a reddish viscous oil (0.161 g, 32%). <sup>1</sup>H NMR (250 MHz, CDCl<sub>3</sub>):  $\delta = 1.27$  (t, <sup>3</sup>J = 7.6 Hz, 3 H, OCH<sub>2</sub> $CH_3$ ), 2.26 (s, 3 H, PhCH<sub>3</sub>), 2.39 (s, 3 H, PhCH<sub>3</sub>), 3.85 (s, 3 H, OCH<sub>3</sub>), 4.24 (q, <sup>3</sup>J = 7.4 Hz, 2 H,  $OCH_2$ CH<sub>3</sub>), 6.94 (s, 1 H, CH<sub>Ar</sub>), 11.54 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (62 MHz, CDCl<sub>3</sub>):  $\delta = 11.5$ , 13.4, 21.6 (CH<sub>3</sub>), 51.3 (OCH<sub>3</sub>), 60.2 (OCH<sub>2</sub>), 112.4 (C<sub>Ar</sub>), 121.4 (CH<sub>Ar</sub>), 124.0, 134.7, 136.7 (C<sub>Ar</sub>), 160.3 (COH), 166.7, 171.2 (CO) ppm. IR (neat):  $\tilde{v} = 1660$  (s), 1619 (m), 1452 (s), 1343 (s), 1219 (m), 1136 (s), 966 (m), 882 (m), 694 (m) cm<sup>-1</sup>. MS (EI, 70 eV): m/z (%) = 252 (55) [M]<sup>+</sup>, 220 (100), 207 (37), 192 (87), 175 (13), 164 (82), 147 (17), 119 (15), 91 (25), 77 (11), 65 (18). HRMS (EI): calcd. for C<sub>13</sub>H<sub>16</sub>O<sub>5</sub> 252.10056; found 252.09998.



**2-Ethyl 1-Methyl 4-Ethyl-3-hydroxy-5-methylphthalate (4c):** Starting with **2a** (0.433 g, 2.0 mmol) and **3c** (0.666 g, 2.2 mmol), **4c** was isolated as a slightly yellow oil (0.225 g, 42%). <sup>1</sup>H NMR (500.13 MHz, CDCl<sub>3</sub>):  $\delta = 1.09$  (t, <sup>3</sup>*J* = 7.6 Hz, 3 H, CH<sub>2</sub>CH<sub>3</sub>), 1.34 (t, <sup>3</sup>*J* = 7.3 Hz, 3 H, OCH<sub>2</sub>CH<sub>3</sub>), 2.31 (s, 3 H, PhCH<sub>3</sub>), 2.69 (q, <sup>3</sup>*J* = 7.6 Hz, 2 H, PhCH<sub>2</sub>CH<sub>3</sub>), 3.84 (s, 3 H, OCH<sub>3</sub>), 4.34 (q, <sup>3</sup>*J* = 7.3 Hz, 2 H, OCH<sub>2</sub>CH<sub>3</sub>), 6.74 (s, 1 H, CH<sub>Ar</sub>) 10.03 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (125.8 MHz, CDCl<sub>3</sub>):  $\delta = 12.8$ , 13.9 (CH<sub>3</sub>), 19.4 (PhCH<sub>3</sub>), 19.5 (PhCH<sub>2</sub>), 52.3 (OCH<sub>3</sub>), 61.9 (OCH<sub>2</sub>), 107.2 (C<sub>Ar</sub>), 120.7 (CH<sub>Ar</sub>), 132.3, 133.2, 143.1 (C<sub>Ar</sub>), 159.4 (COH), 169.6, 169.8 (CO) ppm. MS (EI, 70 eV): *mlz* (%) = 266 (23) [M]<sup>+</sup>, 220 (100), 205 (28), 188 (17), 162 (57), 134 (30). HRMS (EI): calcd. for C<sub>14</sub>H<sub>18</sub>O<sub>5</sub> [M]<sup>+</sup> 266.1145; found 266.1149.

**1-Ethyl 2-Methyl 4-Hexyl-3-hydroxy-5-methylphthalate (4d):** Starting with **2b** (0.461 g, 2.0 mmol) and **3d** (0.758 g, 2.2 mmol), **4d** was isolated as a reddish viscous oil (0.238 g, 37%). <sup>1</sup>H NMR (250 MHz, CDCl<sub>3</sub>):  $\delta = 0.81$  (br. t, <sup>3</sup>J = 7.1 Hz, 3 H, CH<sub>3</sub>), 1.02–1.25 (m, 8 H, CH<sub>2</sub>), 1.31 (t, <sup>3</sup>J = 7.6 Hz, 3 H, OCH<sub>2</sub>CH<sub>3</sub>), 2.24 (s, 3 H, PhCH<sub>3</sub>), 2.58 (t, <sup>3</sup>J = 7.4 Hz, 2 H, PhCH<sub>2</sub>), 3.81 (s, 3 H, OCH<sub>3</sub>), 4.25 (q, <sup>3</sup>J = 7.2 Hz, 2 H, OCH<sub>2</sub>CH<sub>3</sub>), 6.69 (s, 1 H, CH<sub>Ar</sub>), 10.84 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (62 MHz, CDCl<sub>3</sub>):  $\delta = 15.2$ , 15.4 (CH<sub>3</sub>), 23.7 (CH<sub>2</sub>), 25.1 (CH<sub>3</sub>), 28.3, 30.3, 30.1, 32.7 (CH<sub>2</sub>), 34.4 (OCH<sub>3</sub>), 64.4 (OCH<sub>2</sub>CH<sub>3</sub>), 114.8 (C<sub>Ar</sub>), 123.7 (CH<sub>Ar</sub>), 130.8, 137.1, 139.1 (C<sub>Ar</sub>), 162.4 (COH), 168.4, 173.4 (CO) ppm. MS (EI, 70 eV): *m/z* (%) = 322 (20) [M]<sup>+</sup>, 290 (7), 261 (11), 233 (5), 220 (100), 206 (32), 192 (32), 174 (8), 161 (6), 148 (7), 119 (8), 91 (6), 69 (7). HRMS (EI): calcd. for C<sub>18</sub>H<sub>26</sub>O<sub>5</sub> 322.17747; found 322.17730.

**Dimethyl 3-Hydroxy-4-methoxy-5-methylphthalate (4e):** Starting with **2a** (0.433 g, 2.0 mmol) and **3e** (0.639 g, 2.2 mmol), **4e** was isolated as a colourless oil (0.229 g, 45%). <sup>1</sup>H NMR (500.13 MHz, CDCl<sub>3</sub>):  $\delta$  = 2.28 (s, 3 H, CH<sub>3</sub>), 3.84 (s, 3 H, OCH<sub>3</sub>), 3.86 (s, 3 H, OCH<sub>3</sub>), 3.89 (s, 3 H, OCH<sub>3</sub>), 6.83 (s, 1 H, CH<sub>Ar</sub>), 10.36 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (125.8 MHz, CDCl<sub>3</sub>):  $\delta$  = 16.2 (CH<sub>3</sub>), 52.6, 52.8, 60.2 (OCH<sub>3</sub>), 110.2 (C<sub>Ar</sub>), 121.4 (CH<sub>Ar</sub>), 129.3, 137.3, 148.2 (C<sub>Ar</sub>), 154.1 (COH), 169.1, 169.4 (CO) ppm. IR (neat):  $\tilde{v}$  = 3410 (m), 2999 (m), 2954 (s), 2846 (w), 1734 (s), 1674 (s), 1611 (m), 1575 (m) cm<sup>-1</sup>. MS (EI, 70 eV): *m/z* (%) = 254 (71) [M]<sup>+</sup>, 223 (70), 222 (100), 207 (37), 194 (64), 163 (71), 136 (48). C<sub>12</sub>H<sub>14</sub>O<sub>6</sub> (254.24): calcd. C 56.69, H 5.55; found C 56.76, H 5.59.

Diethyl 3-Hydroxy-5-methyl-4-phenoxyphthalate (4f): Starting with 2b (0.461 g, 2.0 mmol) and 3f (0.807 g, 2.2 mmol), 4f was isolated as a reddish viscous oil (0.275 g, 40%). <sup>1</sup>H NMR (250 MHz, CDCl<sub>3</sub>):  $\delta = 0.91$  (t,  ${}^{3}J = 7.2$  Hz, 3 H, OCH<sub>2</sub>CH<sub>3</sub>), 1.27 (t,  ${}^{3}J =$ 7.5 Hz, 3 H, OCH<sub>2</sub>CH<sub>3</sub>), 2.42 (s, 3 H, PhCH<sub>3</sub>), 4.01 (q,  ${}^{3}J$  = 7.6 Hz, 2 H,  $OCH_2CH_3$ ), 4.28 (q,  ${}^{3}J$  = 7.4 Hz, 2 H,  $OCH_2CH_3$ ), 6.66 (m,1 H, CH<sub>Ar</sub>), 6.67-6.83 (m, 2 H, 2 CH<sub>Ar</sub>), 7.04 (m, 1 H, CH<sub>Ar</sub>), 7.07-7.08 (m, 2 H, CH\_{\rm Ar}), 11.16 (s, 1 H, OH) ppm.  $^{13}{\rm C}$  NMR (62 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.7, 14.1, 23.6 (CH<sub>3</sub>), 61.4, 62.3 (CH<sub>2</sub>), 114.8 (2 CH<sub>Ar</sub>), 116.4 (C<sub>Ar</sub>), 121.7, 122.2 (CH<sub>Ar</sub>), 129.3 (CH<sub>Ar</sub>), 129.8, 132.1, 137.1, 140.0 (C<sub>Ar</sub>), 156.3 (COH), 158.4 (C<sub>Ar</sub>), 165.1, 170.8 (CO) ppm. IR (neat):  $\tilde{v} = 2980$  (w), 1727 (m), 1661 (m), 1489 (m), 1412 (m), 1371 (m), 1296 (m), 1236 (s), 1016 (s), 747 (m), 687 (m) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 372 (2) [M]<sup>+</sup>, 344 (63), 298 (38), 269 (8), 253 (20), 226 (100), 197 (13), 177 (5), 148 (6), 121 (6), 105 (48).

**4-Ethyl 3-Methyl 2-Hydroxy-4'-methoxy-6-methylbiphenyl-3,4-dicarboxylate (4g):** Starting with **2b** (0.461 g, 2.0 mmol) and **3g** (0.842 g, 2.2 mmol), **4g** was isolated as a yellowish oil (0.268 g, 39%). <sup>1</sup>HNMR (250 MHz, CDCl<sub>3</sub>):  $\delta = 1.27$  (t, <sup>3</sup>J = 7.1 Hz, 3 H, OCH<sub>2</sub>CH<sub>3</sub>), 2.51 (s, 3 H, PhCH<sub>3</sub>), 3.76 (s, 3 H, PhOCH<sub>3</sub>), 3.91 (s, 3 H, OCH<sub>3</sub>), 3.99 (q, <sup>3</sup>J = 6.2 Hz, 2 H, OCH<sub>2</sub>CH<sub>3</sub>), 6.76 (s, 1 H, CH<sub>Ar</sub>), 6.85–6.88 (m, 2 H, CH<sub>Ar</sub>), 7.10–7.12 (m, 2 H, CH<sub>Ar</sub>), 11.43 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta = 12.6$ , 19.0 (CH<sub>3</sub>), 51.4, 54.2 (OCH<sub>3</sub>), 60.1 (OCH<sub>2</sub>), 112.5 (C<sub>Ar</sub>), 113.1 (2 CH<sub>Ar</sub>), 121.2 (CH<sub>Ar</sub>), 127.0, 129.1 (C<sub>Ar</sub>), 129.4 (2 CH<sub>Ar</sub>), 129.8, 136.2, 157.6 (C<sub>Ar</sub>), 159.2 (COH), 170.4, 170.9 (CO) ppm. IR (neat): v = 3034 (w), 2953 (w), 2931 (w), 2871 (w), 2836 (w), 1720 (w), 1661 (w), 1608 (m), 1510 (m), 1438 (w), 1392 (w), 1368 (w), 1299 (w), 1243 (s), 1193 (w), 1174 (m), 1156 (m), 1109 (w), 1078 (w), 1031 (m), 969 (w), 902 (w), 831 (m), 788 (w), 689 (w), 643 (w), 597 (w), 578 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): *m/z* (%) = 344 (53) [M]<sup>+</sup>, 313 (21), 312 (100), 283 (18), 256 (13), 239 (8), 211 (6), 197 (5), 149 (7), 135 (10), 121 (12), 73 (12). HRMS (EI): calcd. for C<sub>19</sub>H<sub>20</sub>O<sub>6</sub> [M]<sup>+</sup> 344.125; found 349.071546.

1-Ethyl 2-Methyl 3-Hydroxy-5-methyl-4-nonylphthalate (4h): Starting with 2b (0.461 g, 2.0 mmol) and 3h (0.851 g, 2.2 mmol), 4h was isolated as a yellowish oil (0.306 g, 42%). <sup>1</sup>H NMR (250 MHz, CDCl<sub>3</sub>):  $\delta = 0.81$  (t,  ${}^{3}J = 6.3$  Hz, 3 H, CH<sub>3</sub>), 1.16–1.19 (m, 14 H,  $7CH_2$ ), 1.32 (t,  ${}^{3}J$  = 6.7 Hz, 3 H,  $OCH_2CH_3$ ), 2.44 (s, 3 H, PhCH<sub>3</sub>), 2.53 (t,  ${}^{3}J$  = 7.5 Hz, 2 H, CH<sub>2</sub>), 3.83 (s, 3 H, OCH<sub>3</sub>), 4.29 (q,  ${}^{3}J$  = 7.5 Hz, 2 H, OCH<sub>2</sub>CH<sub>3</sub>), 6.12 (s, 1 H, CH<sub>Ar</sub>), 11.84 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.0, 13.1, 21.6 (CH<sub>3</sub>), 22.7, 25.9, 28.5, 29.0, 29.3, 29.6, 30.8, 31.8 (CH<sub>2</sub>), 50.7 (OCH<sub>3</sub>), 60.3 (OCH<sub>2</sub>), 112.9 (C<sub>Ar</sub>), 121.4 (CH<sub>Ar</sub>), 128.6, 134.8, 144.3, (C<sub>Ar</sub>), 159.9 (COH), 165.0, 171.4 (CO) ppm. IR (neat):  $\tilde{v} = 3336$  (w), 3107 (w), 2953 (w), 2919 (m), 2848 (w), 1725 (w), 1660 (w), 1612 (m), 1493 (w), 1462 (m), 1415 (m), 1284 (m), 1259 (m), 1201 (m), 1225 (m), 1089 (m), 1014 (m), 977 (m), 840 (w), 795 (s), 754 (m), 722 (w), 682 (w), 622 (w), 551 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): *m/z* (%)  $= 364 (22) [M]^+$ , 260 (19), 259 (100), 192 (12), 191 (34). HRMS (EI): calcd. for C<sub>21</sub>H<sub>32</sub>O<sub>5</sub> [M]<sup>+</sup> 364.22443; found 364.224257.

1-Ethyl 2-Methyl 4-Decyl-3-hydroxy-5-methylphthalate (4i): Starting with 2b (0.461 g, 2.0 mmol) and 3i (0.882 g, 2.2 mmol), 4i was isolated as a yellowish oil (0.318 g, 42%). <sup>1</sup>H NMR (250 MHz, CDCl<sub>3</sub>):  $\delta = 0.80$  (t,  ${}^{3}J = 6.7$  Hz, 3 H, CH<sub>3</sub>), 1.16–1.19 (m, 16 H,  $8CH_2$ , 1.32 (t,  ${}^{3}J = 6.2$  Hz, 3 H,  $OCH_2CH_3$ ), 2.44 (s, 3 H, PhCH<sub>3</sub>), 2.76 (t,  ${}^{3}J$  = 7.2 Hz, 2 H, PhCH<sub>2</sub>), 3.89 (s, 3 H, OCH<sub>3</sub>), 4.29 (q,  ${}^{3}J$  $= 6.2 \text{ Hz}, 2 \text{ H}, \text{ O}CH_2\text{CH}_3), 6.94 (s, 1 \text{ H}, \text{CH}_{\text{Ar}}), 11.54 (s, 1 \text{ H}, \text{OH})$ ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.0, 13.2, 21.6 (CH<sub>3</sub>), 22.8, 25.9, 26.2, 28.2, 28.4, 28.5, 29.0, 30.8, 31.8 (CH<sub>2</sub>), 51.3 (OCH<sub>3</sub>), 60.2 (OCH<sub>2</sub>), 112.6 (C<sub>Ar</sub>), 121.4 (CH<sub>Ar</sub>), 128.6, 134.7, 136.8 (C<sub>Ar</sub>), 160.2 (COH), 166.9, 171.2 (CO) ppm. IR (neat):  $\tilde{v}$  = 2953 (w), 2922 (s), 2852 (m), 1724 (m), 1662 (m), 1624 (w), 1561 (w), 1445 (m), 1395 (m), 1367 (m), 1298 (m), 1229 (s), 1193 (m), 1148 (m), 1104 (m), 1058 (m), 1011 (m), 843 (m), 800 (m), 780 (m), 721 (w), 602 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 378 (21) [M]<sup>+</sup>, 274 (20), 273 (100), 192 (12), 191 (32). HRMS (EI): calcd. for C<sub>22</sub>H<sub>34</sub>O<sub>5</sub> [M]<sup>+</sup> 378.24008; found 378.239759.

**Methyl 2-Acetyl-3-hydroxy-5-methylbenzoate (6a):** Starting with **2a** (0.433 g, 2.0 mmol) and **5a** (0.538 g, 2.2 mmol), **6a** was isolated as a yellow solid (0.142 g, 34%). M.p. 88–89 °C. <sup>1</sup>H NMR (250.13 MHz):  $\delta$  = 2.32 (s, 3 H, PhCH<sub>3</sub>), 2.46 (s, 3 H, COCH<sub>3</sub>), 3.82 (s, 3 H, OCH<sub>3</sub>), 6.97 (br. s, 1 H, CH<sub>Ar</sub>), 7.16 (br. s, 1 H, CH<sub>Ar</sub>), 9.50 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (125.8 MHz):  $\delta$  = 21.1 (CH<sub>3</sub>), 31.2 (COCH<sub>3</sub>), 52.6 (OCH<sub>3</sub>), 121.3, 122.3, 127.9, 131.1, 142.0 (C<sub>Ar</sub>), 155.9 (COH), 167.9, 203.0 (CO) ppm. MS (EI, 70 eV): *mlz* (%) = 208 (60) [M]<sup>+</sup>, 193 (100), 177 (54), 161 (28), 148 (18), 133 (15), 77 (15). C<sub>11</sub>H<sub>12</sub>O<sub>4</sub> (208.21): calcd. C 63.45, H 5.81; found C 63.12, H 5.90.

**Methyl 2-Benzoyl-3-hydroxy-5-methylbenzoate (6b):** Starting with **2a** (0.433 g, 2.0 mmol) and **5b** (0.674 g, 2.2 mmol), **6b** was isolated as a yellow solid (0.222 g, 41%). M.p. 158–159 °C. <sup>1</sup>H NMR (500.13 MHz, CDCl<sub>3</sub>):  $\delta$  = 2.40 (s, 3 H, PhCH<sub>3</sub>), 3.16 (s, 3 H, OCH<sub>3</sub>), 7.03–7.09 (br. m, 1 H, CH<sub>Ar</sub>), 7.18–7.20 (br. d, <sup>4</sup>*J* = 1.5 Hz,

1 H, CH<sub>Ar</sub>), 7.42–7.46 (m, 2 H, CH<sub>Ar</sub>), 7.51–7.63 (m, 3 H, CH<sub>Ar</sub>), 9.78 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (125.8 MHz, CDCl<sub>3</sub>):  $\delta$  = 21.6 (PhCH<sub>3</sub>), 51.9 (OCH<sub>3</sub>), 117.8 (C-2), 121.7 (C-4), 122.5 (C-6), 128.4 (*o*-Ph), 128.5 (*m*-Ph), 132.6 (*p*-Ph), 133.9 (C-1), 139.6 (*i*-Ph), 144.9 (C-5), 159.6 (COH), 167.7 (OCO), 199.0 (CO) ppm. IR (Nujol):  $\tilde{v}$  = 3182 (m), 3083 (w), 1715 (m), 1645 (s), 1614 (m), 1581 (m) cm<sup>-1</sup>. MS (EI, 70 eV): *m/z* (%) = 270 (27) [M]<sup>+</sup>, 237 (100), 193 (39), 105 (20), 77 (27). C<sub>16</sub>H<sub>14</sub>O<sub>4</sub> (270.28): calcd. C 70.84, H 5.57; found C 70.53, H 5.22.

**Dimethyl 2-Hydroxyterephthalate (10a):** Starting with **9a** (0.237 g, 1.5 mmol) and 3a (0.429 g, 1.65 mmol), 10a was isolated after chromatography (silica gel, n-heptane/EtOAc) as a white solid (0.127 g, 40%). M.p. 85–87 °C. <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 3.85 (s, 3 H, OCH<sub>3</sub>), 3.90 (s, 3 H, OCH<sub>3</sub>), 7.45 (dd,  ${}^{3}J$  = 8.1 Hz,  ${}^{4}J = 1.6 \text{ Hz}, 1 \text{ H}, \text{ CH}_{\text{Ar}}), 7.56-7.57 \text{ (m, 1 H, CH}_{\text{Ar}}), 7.83 \text{ (d, }{}^{3}J =$ 8.4 Hz, 1 H, CH<sub>Ar</sub>), 10.67 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 51.4, 51.6 (OCH<sub>3</sub>), 114.6 (C<sub>Ar</sub>), 117.9, 118.6, 129.0 (CH<sub>Ar</sub>), 135.4 (C<sub>Ar</sub>), 160.3 (COH), 164.9, 168.9 (CO) ppm. IR (neat):  $\tilde{v} = 3115$  (w), 3079 (w), 2959 (w), 2916 (m), 2848 (m), 1725 (m), 1678 (s), 1579 (m), 1504 (m), 1435 (m), 1393 (w), 1343 (m), 1297 (s), 1209 (s), 1104 (s), 980 (m), 953 (m), 923 (m), 845 (w), 823 (m), 795 (m), 750 (s), 706 (m), 690 (s), 570 (m), 564 (m) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 210 (42) [M]<sup>+</sup>, 178 (100), 147 (10), 120 (10), 119 (63), 63 (12). HRMS (EI): calcd. for C<sub>10</sub>H<sub>10</sub>O<sub>5</sub> [M]<sup>+</sup> 210.05227; found 210.052499.

Dimethyl 3-Hydroxy-4-methylphthalate (10b): Starting with 9a (0.237 g, 1.5 mmol) and 3j (0.453 g, 1.65 mmol), 10b was isolated after chromatography (silica gel, n-heptane/EtOAc) as a yellowish solid (0.141 g, 42%). M.p. 76-78 °C. <sup>1</sup>HNMR (300 MHz, CDCl<sub>3</sub>):  $\delta = 2.37$  (s, 3 H, PhCH<sub>3</sub>), 3.83 (s, 3 H, OCH<sub>3</sub>), 3.98 (s, 3 H, OCH<sub>3</sub>), 7.17 (d,  ${}^{3}J$  = 7.6 Hz, 1 H, CH<sub>Ar</sub>), 7.64 (d,  ${}^{3}J$  = 8.3 Hz, 1 H, CH<sub>Ar</sub>), 11.11 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 11.45 (CH<sub>3</sub>), 51.2, 51.5 (OCH<sub>3</sub>), 112.4 (C<sub>Ar</sub>), 118.3, 125.6 (CH<sub>Ar</sub>), 126.9, 136.2 (C<sub>Ar</sub>), 159.3 (COH), 166.4, 169.9 (CO) ppm. IR (neat):  $\tilde{v}$  = 3152 (w), 2954 (w), 2924 (m), 2852 (w), 1724 (m), 1674 (m), 1616 (w), 1573 (w), 1439 (m), 1380 (w), 1327 (m), 1285 (m), 1249 (s), 1191 (m), 1148 (s), 1098 (m), 1050 (s), 1006 (m), 966 (w), 910 (w), 869 (w), 821 (w), 803 (m), 755 (s), 728 (m), 644 (w), 578 (w) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 224 (40) [M]<sup>+</sup>, 193 (29), 192 (47), 165 (10), 164 (100), 133 (13), 105 (14), 77 (12), 51 (10). HRMS (EI): calcd. for  $C_{11}H_{12}O_5$  [M]<sup>+</sup> 224.06792; found 224.068299.

2-Ethyl 1-Methyl 4-Ethyl-3-hydroxyphthalate (10c): Starting with 9a (0.237 g, 1.5 mmol) and 3c (0.499 g, 1.65 mmol), 10c was isolated after chromatography (silica gel, n-heptane/EtOAc) as a yellowish oil (0.170 g, 45%). <sup>1</sup>HNMR (300 MHz, CDCl<sub>3</sub>):  $\delta = 0.78$  (t,  ${}^{3}J = 7.5 \text{ Hz}, 3 \text{ H}, \text{CH}_{2}CH_{3}), 1.18 (t, {}^{3}J = 7.2 \text{ Hz}, 3 \text{ H}, \text{OCH}_{2}CH_{3}),$ 2.84 (q,  ${}^{3}J$  = 8.4 Hz, 2 H, PhCH<sub>2</sub>), 3.84 (s, 3 H, OCH<sub>3</sub>), 4.33 (q,  ${}^{3}J$  = 7.8 Hz, 2 H, OCH<sub>2</sub>CH<sub>3</sub>), 7.11 (d,  ${}^{3}J$  = 8.4 Hz, 1 H, CH<sub>Ar</sub>), 7.65 (d,  ${}^{3}J$  = 8.0 Hz, 1 H, CH<sub>Ar</sub>), 11.18 (s, 1 H, OH) ppm.  ${}^{13}C$ NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.0, 13.1 (CH<sub>3</sub>), 19.3 (CH<sub>2</sub>), 51.2 (OCH<sub>3</sub>), 60.7 (OCH<sub>2</sub>), 112.8 (C<sub>Ar</sub>), 118.1, 125.7 (CH<sub>Ar</sub>), 132.4 (C<sub>Ar</sub>), 135.9 (C<sub>Ar</sub>), 159.2 (COH), 166.7, 169.2 (CO) ppm. IR (neat):  $\tilde{v} = 3133$  (w), 2956 (w), 2923 (m), 2853 (w), 1727 (m), 1673 (m), 1615 (w), 1572 (w), 1461 (m), 1398 (w), 1372 (m), 1330 (m), 1291 (s), 1267 (m), 1240 (s), 1222 (m), 1148 (s), 1077 (s), 1018 (m), 952 (w), 864 (w), 806 (m), 757 (s), 732 (m), 644 (w), 577 (w) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 252 (30) [M]<sup>+</sup>, 221 (11), 207 (10), 206 (10), 191 (11), 179 (12), 178 (100), 146 (28), 91 (11). HRMS (EI): calcd. for C13H16O5 [M]+ 252.09923; found 252.098543.

**Dimethyl 4-Butyl-3-hydroxyphthalate (10d):** Starting with **9a** (0.237 g, 1.5 mmol) and **3k** (0.522 g, 1.65 mmol), **10d** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as a yellowish

oil (0.171 g, 43%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta = 0.86$  (t, <sup>3</sup>J = 6.8 Hz, 3 H, CH<sub>3</sub>), 1.30–1.32 (m, 2 H, CH<sub>2</sub>), 1.46–1.48 (m, 2 H, CH<sub>2</sub>), 2.83 (t, <sup>3</sup>J = 7.7 Hz, 2 H, PhCH<sub>2</sub>), 3.83 (s, 3 H, OCH<sub>3</sub>), 3.89 (s, 3 H, OCH<sub>3</sub>), 7.11 (d,  ${}^{3}J$  = 8.2 Hz, 1 H, CH<sub>Ar</sub>), 7.64 (d,  ${}^{3}J$  = 8.0 Hz, 1 H, CH<sub>Ar</sub>), 11.08 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>): *δ* = 12.9 (CH<sub>3</sub>), 22.0, 29.3, 30.9 (CH<sub>2</sub>), 51.2, 51.5 (OCH<sub>3</sub>), 112.5 (CAr), 118.1, 125.7 (CHAr), 131.3 (CAr), 136.2 (CAr), 159.2 (COH), 166.7, 169.5 (CO) ppm. IR (neat):  $\tilde{v} = 3152$  (w), 2954 (m), 2924 (m), 2854 (m), 1727 (m), 1677 (m), 1616 (w), 1572 (w), 1440 (m), 1366 (w), 1335 (m), 1296 (m), 1252 (s), 1199 (m), 1149 (s), 1093 (s), 1025 (m), 958 (w), 841 (m), 806 (m), 758 (s), 722 (m), 659 (w), 578 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 266 (60) [M]<sup>+</sup>, 235 (33), 233 (12), 224 (17), 223 (36), 207 (41), 206 (56), 205 (23), 192 (24), 191 (100), 176 (12), 175 (81), 174 (23), 173 (11), 164 (52), 145 (11), 133 (20), 131 (10), 105 (13), 104 (12), 77 (15). HRMS (EI): calcd. for C<sub>14</sub>H<sub>18</sub>O<sub>5</sub> [M]<sup>+</sup> 266.11488; found 266.114803.

Dimethyl 3-Hydroxy-4-octylphthalate (10e): Starting with 9a (0.237 g, 1.5 mmol) and 31 (0.614 g, 1.65 mmol), 10e was isolated after chromatography (silica gel, n-heptane/EtOAc) as a yellowish oil (0.217 g, 45%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta = 0.82$  (t, <sup>3</sup>J = 6.9 Hz, 3 H, CH<sub>3</sub>), 1.30–1.37 (m, 10 H, 5CH<sub>2</sub>), 1.48–1.54 (m, 2 H, CH<sub>2</sub>), 2.81 (t,  ${}^{3}J$  = 7.8 Hz, 2 H, PhCH<sub>2</sub>), 3.83 (s, 3 H, OCH<sub>3</sub>), 3.89 (s, 3 H, OCH<sub>3</sub>), 7.11 (d,  ${}^{3}J$  = 8.2 Hz, 1 H, CH<sub>Ar</sub>), 7.64 (d,  ${}^{3}J$  =  $8.5~\mathrm{Hz},\,1~\mathrm{H},\,\mathrm{CH}_{\mathrm{Ar}}),\,11.08$  (s,  $1~\mathrm{H},\,\mathrm{OH})$  ppm.  $^{13}\mathrm{C}$  NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.0 (CH<sub>3</sub>), 21.6, 26.2, 28.2, 28.3, 28.6, 30.8, 30.8 (CH<sub>2</sub>), 51.2, 51.6 (OCH<sub>3</sub>), 112.5 (C<sub>Ar</sub>), 118.3, 125.7 (CH<sub>Ar</sub>), 131.3, 136.2 (C<sub>Ar</sub>), 159.2 (COH), 166.6, 169.6 (CO) ppm. IR (neat):  $\tilde{v} =$ 2953 (m), 2922 (s), 2853 (m), 1727 (m), 1678 (m), 1619 (w), 1441 (m), 1376 (w), 1336 (w), 1291 (m), 1254 (m), 1229 (s), 1193 (m), 1148 (m), 1101 (m), 1026 (m), 841 (m), 803 (m), 759 (m), 721 (m), 660 (w), 578 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 322 (53) [M]<sup>+</sup>, 291 (27), 289 (16), 264 (16), 263 (85), 247 (22), 232 (17), 231 (97), 224 (28), 223 (45), 205 (27), 192 (41), 191 (100), 178 (14), 177 (14), 173 (12), 165 (10), 164 (42), 160 (10), 133 (16), 105 (10), 77 (10), 41 (12). HRMS (EI): calcd. for C<sub>18</sub>H<sub>26</sub>O<sub>5</sub> [M]<sup>+</sup> 322.17748; found 322.177861.

Dimethyl 2-Hydroxy-5-methylterephthalate (10f): Starting with 9b (0.258 g, 1.5 mmol) and 3a (0.429 g, 1.65 mmol), 10f was isolated after chromatography (silica gel, n-heptane/EtOAc) as a yellowish oil (0.150 g, 45%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 2.41 (s, 3 H, PhCH<sub>3</sub>), 3.83 (s, 3 H, OCH<sub>3</sub>), 3.98 (s, 3 H, OCH<sub>3</sub>), 7.41 (s, 1 H, CH<sub>Ar</sub>), 7.62 (s,1 H, CH<sub>Ar</sub>), 10.37 (s, 1 H, OH) ppm. <sup>13</sup>C NMR  $(75 \text{ MHz}, \text{CDCl}_3)$ :  $\delta = 19.3 (\text{CH}_3), 51.1, 51.5 (\text{OCH}_3), 113.7 (\text{C}_{\text{Ar}}),$ 118.4 (CH<sub>Ar</sub>), 128.5 (C<sub>Ar</sub>), 131.2 (CH<sub>Ar</sub>), 139.3 (C<sub>Ar</sub>), 157.0 (COH), 166.0, 168.9 (CO) ppm. IR (neat):  $\tilde{v} = 3112$  (w), 2956 (w), 2922 (m), 2852 (w), 1723 (m), 1682 (m), 1619 (w), 1572 (w), 1388 (w), 1435 (m), 1387 (w), 1368 (w), 1287 (m), 1249 (m), 1205 (m), 1192 (m), 1102 (s), 1046 (m), 1016 (m), 958 (m), 910 (w), 888 (w), 849 (w), 784 (s), 740 (m), 676 (m), 603 (w), 578 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 224 (46) [M]<sup>+</sup>, 193 (39), 192 (100), 133 (24), 132 (32), 77 (10), 51 (9). HRMS (EI): calcd. for  $C_{11}H_{12}O_5$  [M]<sup>+</sup> 224.06792; found 224.067938.

**Dimethyl 3-Hydroxy-4,6-dimethylphthalate (10g):** Starting with **9b** (0.258 g, 1.5 mmol) and **3j** (0.453 g, 1.65 mmol), **10g** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as a yellowish oil (0.160 g, 45%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 2.11 (s, 3 H, PhCH<sub>3</sub>), 2.14 (s, 3 H, PhCH<sub>3</sub>), 3.85 (s, 3 H, OCH<sub>3</sub>), 3.87 (s, 3 H, OCH<sub>3</sub>), 7.46 (s, 1 H, CH<sub>Ar</sub>), 10.86 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 11.6, 17.6 (CH<sub>3</sub>), 51.1, 51.4 (OCH<sub>3</sub>), 110.8 (C<sub>Ar</sub>), 122.6, 123.1 (C<sub>Ar</sub>), 127.1 (CH<sub>Ar</sub>), 139.6 (C<sub>Ar</sub>), 157.0 (COH), 168.4, 169.5 (CO) ppm. IR (neat):  $\tilde{v}$  = 2953 (m), 2922 (s), 2852 (m), 1735 (m), 1677 (m), 1618 (w), 1440 (m), 1378 (w), 1343 (m), 1283



(m), 1259 (m), 1233 (s), 1204 (m), 1146 (s), 1094 (m), 1052 (m), 1020 (m), 840 (w), 795 (s), 755 (m), 722 (m), 610 (w), 563 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 238 (45) [M]<sup>+</sup>, 207 (38), 206 (65), 179 (12), 178 (100), 147 (12), 91 (11). HRMS (EI): calcd. for C<sub>12</sub>H<sub>14</sub>O<sub>5</sub> [M]<sup>+</sup> 238.08358; found 238.0833769.

Dimethyl 3-Hydroxy-6-methyl-4-pentylphthalate (10h): Starting with 9b (0.258 g, 1.5 mmol) and 3m (0.546 g, 1.65 mmol), 10h was isolated after chromatography (silica gel, n-heptane/EtOAc) as a yellowish oil (0.203 g, 46%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 0.82  $(t, {}^{3}J = 6.6 \text{ Hz}, 3 \text{ H}, \text{ CH}_{3}), 1.23-1.29 \text{ (m, 4 H, 2 CH}_{2}), 1.47-1.57$ (m, 2 H, CH<sub>2</sub>), 2.12 (s, 3 H, PhCH<sub>3</sub>), 2.54 (t,  ${}^{3}J$  = 7.7 Hz, 2 H, PhCH<sub>2</sub>), 3.81 (s, 3 H, OCH<sub>3</sub>), 3.83 (s, 3 H, OCH<sub>3</sub>), 7.08 (s, 1 H, CH<sub>Ar</sub>), 10.92 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.0, 17.4 (CH<sub>3</sub>), 21.6, 27.7, 28.8, 30.6 (CH<sub>2</sub>), 50.8, 51.9 (OCH<sub>3</sub>), 107.8, 124.1, 130.9, 131.8 (CAr), 136.2 (CHAr), 157.1 (COH), 168.8, 168.9 (CO) ppm. IR (neat):  $\tilde{v} = 2954$  (w), 2928 (w), 2859 (w), 1735 (m), 1672 (m), 1610 (w), 1587 (w), 1433 (s), 1342 (m), 1253 (s), 1207 (s), 1179 (m), 1160 (m), 1097 (w), 1049 (m), 992 (w), 962 (w), 898 (w), 869 (w), 846 (w), 801 (m), 744 (m), 650 (w), 529 (w) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 294 (24) [M]<sup>+</sup>, 263 (20), 247 (19), 219 (31), 206 (100), 148 (8), 91 (5). HRMS (ESI): calcd. for  $C_{16}H_{23}O_5 [M + H]^+$  295.154; found 295.1532.

Dimethyl 5-Ethyl-2-hydroxyterephthalate (10i): Starting with 9c (0.279 g, 1.5 mmol) and 3a (0.429 g, 1.65 mmol), 10i was isolated after chromatography (silica gel, n-heptane/EtOAc) as a yellowish oil (0.168 g, 47%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta = 1.13$  (t, <sup>3</sup>J = 7.2 Hz, 3 H, CH<sub>3</sub>), 2.79 (q,  ${}^{3}J$  = 8.4 Hz, 2 H, PhCH<sub>2</sub>), 3.83 (s, 3 H, OCH<sub>3</sub>), 3.90 (s, 3 H, OCH<sub>3</sub>), 7.34 (s, 1 H, CH<sub>Ar</sub>), 7.65 (s, 1 H, CH<sub>Ar</sub>), 10.39 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 14.8 (CH<sub>3</sub>), 25.6 (CH<sub>2</sub>), 51.1, 51.5 (OCH<sub>3</sub>), 113.7 (C<sub>Ar</sub>), 118.3, 129.9 (CH<sub>Ar</sub>), 134.4, 135.2 (C<sub>Ar</sub>), 157.9 (COH), 168.8, 168.9 (CO) ppm. IR (neat):  $\tilde{v} = 3205$  (w), 2957 (w), 2929 (w), 2872 (w), 1729 (m), 1682 (m), 1636 (w), 1572 (w), 1487 (m), 1439 (m), 1375 (w), 1319 (w), 1281 (m), 1203 (s), 1103 (s), 1066 (m), 961 (m), 908 (w), 844 (w), 794 (m), 759 (m), 697 (m), 647 (w), 622 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 238 (45) [M]<sup>+</sup>, 223 (9), 206 (100), 191 (56), 174 (11), 146 (27), 133 (8), 119 (7), 91 (11), 65 (6). HRMS (EI): calcd. for C<sub>12</sub>H<sub>14</sub>O<sub>5</sub> [M]<sup>+</sup> 238.08358; found 238.083603.

Dimethyl 6-Ethyl-3-hydroxy-4-methylphthalate (10j): Starting with 9c (0.279 g, 1.5 mmol) and 3j (0.453 g, 1.65 mmol), 10j was isolated after chromatography (silica gel, n-heptane/EtOAc) as a yellowish oil (0.181 g, 48%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta = 1.10$  (t, <sup>3</sup>J = 7.5 Hz, 3 H, CH<sub>3</sub>), 2.19 (s, 3 H, CH<sub>3</sub>), 2.40 (q,  ${}^{3}J$  = 7.7 Hz, 2 H, PhCH<sub>2</sub>), 3.81 (s, 3 H, OCH<sub>3</sub>), 3.83 (s, 3 H, OCH<sub>3</sub>), 7.13 (s, 1 H,  $CH_{Ar}$ ), 10.98 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 14.8, 14.9 (CH<sub>3</sub>), 24.9 (CH<sub>2</sub>), 51.2, 51.8 (OCH<sub>3</sub>), 107.1, 127.6, 130.3, 130.4 (C<sub>Ar</sub>), 135.7 (CH<sub>Ar</sub>), 157.3 (COH), 168.6, 168.9 (CO) ppm. IR (neat):  $\tilde{v} = 3116$  (w), 2953 (w), 2875 (w), 1732 (s), 1672 (s), 1612 (w), 1588 (w), 1431 (m), 1378 (m), 1351 (m), 1277 (s), 1255 (m), 1204 (s), 1177 (s), 1160 (s), 1046 (m), 988 (m), 895 (m), 867 (w), 805 (m), 789 (m), 734 (m), 639 (m), 563 (m) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 252 (30) [M]<sup>+</sup>, 220 (100), 205 (16), 188 (18), 162 (40), 134 (27), 103 (10), 91 (8), 77 (13). HRMS (EI): calcd. for C<sub>13</sub>H<sub>16</sub>O<sub>5</sub> [M]<sup>+</sup> 252.09923; found 252.099036.

**5-Ethyl 2-Methyl 3-Hydroxybiphenyl-2,5-dicarboxylate (13a):** Starting with **12a** (0.439 g, 1.5 mmol) and **3a** (0.429 g, 1.65 mmol), **13a** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as a pale-yellowish oil (0.194 g, 43%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta = 1.31$  (t, <sup>3</sup>*J* = 7.5 Hz, 3 H, CH<sub>3</sub>), 3.43 (s, 3 H, OCH<sub>3</sub>), 4.31 (q, <sup>3</sup>*J* = 7.1 Hz, 2 H, OCH<sub>2</sub>), 7.14–7.18 (m, 2 H, CH<sub>Ar</sub>), 7.26–7.33 (m, 3 H, CH<sub>Ar</sub>), 7.39 (d, <sup>4</sup>*J* = 1.7 Hz, 1 H, CH<sub>Ar</sub>), 7.57 (d, <sup>4</sup>*J* = 1.8 Hz, 1 H, CH<sub>Ar</sub>), 10.41 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (62.5 MHz,

CDCl<sub>3</sub>):  $\delta = 14.33$  (CH<sub>3</sub>), 52.19 (OCH<sub>3</sub>), 60.38 (OCH<sub>2</sub>) 115.51 (C<sub>Ar</sub>), 117.67, 122.90, 127.16 (CH<sub>Ar</sub>), 127.75 (2 CH<sub>Ar</sub>), 128.13 (2 CH<sub>Ar</sub>), 134.76, 141.93, 145.00 (C<sub>Ar</sub>), 160.96 (COH), 165.38, 170.82 (CO) ppm. IR (KBr):  $\tilde{v} = 3065$  (w), 3026 (w), 2959 (w), 2904 (w), 1713 (s), 1671 (s), 1611 (m), 1567 (m), 1497 (w), 1433 (m), 1410 (m), 1367 (m), 1341 (m), 1321 (m), 1307 (w), 1264 (m), 1238 (s), 1201 (s), 1155 (m), 1139 (m), 1113 (m), 1081 (m), 1025 (m), 982 (m), 948 (m), 922 (w), 892 (m), 870 (w), 828 (m), 806 (m), 766 (s), 699 (s), 666 (m), 648 (m), 621 (m), 607 (m), 563 (m) cm<sup>-1</sup>. GC–MS (EI, 70 eV): *m/z* (%) = 300 (28) [M]<sup>+</sup>, 269 (20), 268 (100), 196 (12), 195 (14), 168 (10), 139 (20). HRMS (EI): calcd. for C<sub>17</sub>H<sub>16</sub>O<sub>5</sub> [M]<sup>+</sup> 300.09923; found 300.099353.

5-Ethyl 2-Methyl 3-Hydroxy-4-methylbiphenyl-2,5-dicarboxylate (13b): Starting with 12a (0.439 g, 1.5 mmol) and 3j (0.453 g, 1.65 mmol), 13b was isolated after chromatography (silica gel, nheptane/EtOAc) as a yellowish oil (0.231 g, 49%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 1.24 (t, <sup>3</sup>J = 7.5 Hz, 3 H, CH<sub>3</sub>), 2.35 (s, 3 H, PhCH<sub>3</sub>), 3.36 (s, 3 H, OCH<sub>3</sub>), 4.24 (q,  ${}^{3}J$  = 7.4 Hz, 2 H, OCH<sub>2</sub>), 7.06 (s, 1 H, CH<sub>Ar</sub>), 7.11–7.18 (m, 2 H, CH<sub>Ar</sub>), 7.21–7.27 (m, 3 H, CH<sub>Ar</sub>), 10.82 (s, 1 H, OH) ppm.  $^{13}\mathrm{C}$  NMR (62.5 MHz, CDCl<sub>3</sub>):  $\delta$  $= 12.71, 14.34 (CH_3), 51.96 (OCH_3), 60.37 (OCH_2) 113.34 (C_{Ar}),$ 122.36 (CH<sub>Ar</sub>), 126.75 (C<sub>Ar</sub>), 126.95 (CH<sub>Ar</sub>), 127.78 (2 CH<sub>Ar</sub>), 128.13 (2 CH<sub>Ar</sub>), 135.43, 141.49, 142.28 (C<sub>Ar</sub>), 159.98 (COH), 167.47, 171.51 (CO) ppm. IR (KBr):  $\tilde{v} = 3025$  (w), 2952 (w), 2929 (w), 2871 (w), 1723 (s), 1665 (s), 1600 (w), 1561 (w), 1499 (w), 1437 (m), 1394 (m), 1380 (m), 1367 (m), 1341 (m), 1298 (m), 1261 (s), 1230 (s), 1194 (s), 1158 (s), 1138 (m), 1095 (s), 1049 (s), 1003 (m), 967 (m), 937 (m), 843 (m), 810 (m), 800 (m), 785 (m), 759 (m), 699 (s), 628 (w), 613 (m), 581 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%)  $= 315 (11), 314 (53) [M]^+, 283 (21), 282 (100), 281 (13), 269 (23),$ 254 (13), 253 (57), 226 (19), 210 (15), 209 (24), 197 (16), 182 (17), 181 (23), 153 (17), 152 (32), 151 (10). HRMS (EI): calcd. for C<sub>18</sub>H<sub>18</sub>O<sub>5</sub> [M]<sup>+</sup> 314.11488; found 314.114942.

5-Ethyl 2-Methyl 4-Ethyl-3-hydroxybiphenyl-2,5-dicarboxylate (13c): Starting with 12a (0.439 g, 1.5 mmol) and 3n (0.476 g, 1.65 mmol), 13c was isolated after chromatography (silica gel, nheptane/EtOAc) as a pale-yellowish oil (0.246 g, 50%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta = 1.17$  (t,  ${}^{3}J = 7.3$  Hz, 3 H, CH<sub>3</sub>), 1.30 (t,  ${}^{3}J$ = 7.3 Hz, 3 H, CH<sub>3</sub>), 2.88 (q,  ${}^{3}J$  = 7.3 Hz, 2 H, PhCH<sub>2</sub>), 3.41 (s, 3 H, OCH<sub>3</sub>), 4.29 (q,  ${}^{3}J$  = 7.2 Hz, 2 H, OCH<sub>2</sub>), 7.07 (s, 1 H, CH<sub>Ar</sub>), 7.13-7.17 (m, 2 H, CHAr), 7.22-7.31 (m, 3 H, CHAr), 10.81 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (62.5 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.06, 13.20 (CH<sub>3</sub>), 19.45 (PhCH<sub>2</sub>), 50.90 (OCH<sub>3</sub>), 60.31 (OCH<sub>2</sub>) 112.50 (C<sub>Ar</sub>), 121.49, 125.94 (CH<sub>Ar</sub>), 126.70 (2 CH<sub>Ar</sub>), 127.14 (2 CH<sub>Ar</sub>), 131.29, 134.30, 140.69, 141.22 (CAr), 159.13 (COH), 166.83, 170.47 (CO) ppm. IR (KBr):  $\tilde{v} = 3025$  (w), 2953 (w), 2934 (w), 2874 (w), 1723 (s), 1665 (s), 1600 (w), 1558 (w), 1495 (w), 1437 (m), 1390 (m), 1367 (m), 1346 (m), 1283 (m), 1247 (s), 1222 (s), 1193 (s), 1157 (s), 1138 (m), 1076 (s), 1028 (m), 1007 (m), 966 (m), 947 (m), 887 (w), 844 (m), 815 (m), 800 (m), 785 (m), 759 (m), 699 (s), 627 (w), 581 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 329 (21), 328 (100) [M]<sup>+</sup>, 297 (22), 296 (94), 295 (22), 283 (35), 268 (39), 276 (67), 253 (19), 251 (11), 249 (23), 240 (11), 225 (19), 224 (35), 223 (28), 221 (13), 197 (49), 196 (42), 195 (25), 194 (10), 167 (10), 166 (14), 165 (51), 153 (12), 152 (34), 151 (11), 139 (14), 129 (11), 115 (12). HRMS (EI): calcd. for C<sub>19</sub>H<sub>20</sub>O<sub>5</sub> [M]<sup>+</sup> 328.13053; found 328.130470.

**5-Ethyl 2-Methyl 4-Butyl-3-hydroxybiphenyl-2,5-dicarboxylate** (13d): Starting with 12a (0.439 g, 1.5 mmol) and 3k (0.522 g, 1.65 mmol), 13d was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as a yellowish oil (0.245 g, 46%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 1.24 (t, <sup>3</sup>J = 7.7 Hz, 3 H, CH<sub>3</sub>), 1.30 (t, <sup>3</sup>J = 7.8 Hz, 3 H, CH<sub>3</sub>), 1.35–1.40 (m, 2 H, CH<sub>2</sub>), 1.49–1.57 (m, 2 H,

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CH<sub>2</sub>), 2.87 (q,  ${}^{3}J$  = 7.5 Hz, 2 H, PhCH<sub>2</sub>), 3.41 (s, 3 H, OCH<sub>3</sub>), 4.28 (q,  ${}^{3}J$  = 7.2 Hz, 2 H, OCH<sub>2</sub>), 7.07 (s, 1 H, CH<sub>Ar</sub>), 7.13–7.17 (m, 2 H, CH<sub>Ar</sub>), 7.24–7.30 (m, 3 H, CH<sub>Ar</sub>), 10.81 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (62.5 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.02, 13.24 (CH<sub>3</sub>), 22.10, 28.67, 30.93 (CH<sub>2</sub>) 50.91 (OCH<sub>3</sub>), 60.53 (OCH<sub>2</sub>) 112.55 (C<sub>Ar</sub>), 121.40, 125.93 (CH<sub>Ar</sub>), 126.74 (2 CH<sub>Ar</sub>), 127.14 (2 CH<sub>Ar</sub>), 130.20, 134.46, 140.66, 141.28 (CAr), 158.75 (COH), 166.61, 170.42 (CO) ppm. IR (KBr):  $\tilde{v} = 3058$  (w), 3026 (w), 2954 (m), 2925 (m), 2856 (m), 1724 (s), 1666 (s), 1600 (m), 1555 (w), 1438 (m), 1391 (m), 1367 (m), 1345 (m), 1316 (m), 1290 (m), 1262 (s), 1232 (s), 1194 (s), 1156 (s), 1138 (m), 1092 (s), 1030 (m), 1007 (m), 964 (m), 921 (w), 911 (w), 887 (w), 846 (m), 814 (w), 760 (m), 699 (s), 653 (w), 631 (w), 583 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 356 (38) [M]<sup>+</sup>, 296 (13), 254 (10), 253 (41), 252 (20), 251 (100), 225 (10), 224 (17), 209 (13), 152 (14). HRMS (EI): calcd. for C<sub>21</sub>H<sub>24</sub>O<sub>5</sub> [M]<sup>+</sup> 356.16183; found 356.162654.

5-Ethyl 2-Methyl 3-Hydroxy-4'-methylbiphenyl-2,5-dicarboxylate (13e): Starting with 12b (0.460 g, 1.5 mmol) and 3a (0.429 g, 1.65 mmol), 13e was isolated after chromatography (silica gel, nheptane/EtOAc) as a yellowish oil (0.207 g, 44%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 1.30 (t, <sup>3</sup>J = 7.2 Hz, 3 H, CH<sub>3</sub>), 2.33 (s, 3 H, PhCH<sub>3</sub>), 3.46 (s, 3 H, OCH<sub>3</sub>), 4.30 (q, <sup>3</sup>*J* = 7.2 Hz, 2 H, OCH<sub>2</sub>), 7.04–7.08 (m, 2 H, CH<sub>Ar</sub>), 7.09–7.13 (m, 2 H, CH<sub>Ar</sub>), 7.39 (d,  ${}^{4}J$  = 1.6 Hz, 1 H, CH<sub>Ar</sub>), 7.55 (d,  ${}^{4}J$  = 1.7 Hz, 1 H, CH<sub>Ar</sub>), 10.31 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (62.5 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.26, 20.10 (CH<sub>3</sub>), 51.12 (OCH<sub>3</sub>), 60.31 (OCH<sub>2</sub>) 114.68 (C<sub>Ar</sub>), 116.37, 122.02 (CH<sub>Ar</sub>), 126.92 (2 CH<sub>Ar</sub>), 127.50 (2 CH<sub>Ar</sub>), 133.73, 136.00, 138.00, 144.07 (CAr), 159.84 (COH), 164.48, 169.92 (CO) ppm. IR (KBr):  $\tilde{v} = 3305$  (w), 2952 (w), 2870 (w), 1720 (s), 1669 (s), 1610 (w), 1567 (m), 1515 (w), 1492 (w), 1437 (m), 1402 (m), 1369 (m), 1343 (m), 1314 (m), 1236 (s), 1198 (s), 1112 (s), 1079 (m), 1022 (s), 976 (m), 949 (m), 892 (m), 863 (w), 831 (m), 806 (m), 770 (s), 726 (m), 707 (m), 649 (w), 625 (m), 614 (m), 583 (m), 558 (w) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 314 (37) [M]<sup>+</sup>, 283 (24), 282 (100), 254 (10), 210 (12), 209 (10), 153 (14), 152 (10). HRMS (EI): calcd. for C<sub>18</sub>H<sub>18</sub>O<sub>5</sub> [M]<sup>+</sup> 314.11488; found 314.114722.

5-Ethyl 2-Methyl 3-Hydroxy-4,4'-dimethylbiphenyl-2,5-dicarboxylate (13f): Starting with 12b (0.460 g, 1.5 mmol) and 3j (0.453 g, 1.65 mmol), 13f was isolated after chromatography (silica gel, nheptane/EtOAc) as a pale-yellowish oil (0.227 g, 46%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta = 1.29$  (t, <sup>3</sup>J = 7.2 Hz, 3 H, CH<sub>3</sub>), 2.32 (s, 3 H, PhCH<sub>3</sub>), 2.40 (s, 3 H, PhCH<sub>3</sub>), 3.45 (s, 3 H, OCH<sub>3</sub>), 4.29 (q, <sup>3</sup>J  $= 7.1 \text{ Hz}, 2 \text{ H}, \text{ OCH}_2$ , 7.02–7.06 (m, 2 H, CH<sub>Ar</sub>), 7.08–7.11 (m, 3 H, CH<sub>Ar</sub>), 10.79 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (62.5 MHz, CDCl<sub>3</sub>):  $\delta$  = 12.68, 14.24, 21.20 (CH<sub>3</sub>), 51.96 (OCH<sub>3</sub>), 61.32 (OCH<sub>2</sub>) 113.47 (CAr), 122.51 (CHAr), 126.42 (CAr), 128.04 (2 CHAr), 128.43 (2 CH<sub>Ar</sub>), 135.39, 136.63, 139.23, 141.50 (C<sub>Ar</sub>), 159.77 (COH), 167.47, 171.75 (CO) ppm. IR (KBr):  $\tilde{v} = 2951$  (w), 2924 (w), 2854 (w), 1723 (s), 1664 (s), 1606 (w), 1561 (w), 1517 (w), 1436 (m), 1392 (m), 1367 (m), 1340 (m), 1312 (w), 1297 (w), 1261 (s), 1229 (s), 1194 (s), 1157 (s), 1137 (s), 1111 (m), 1048 (s), 1003 (m), 932 (w), 888 (w), 847 (m), 821 (m), 809 (m), 782 (m), 723 (m), 624 (w), 600 (w), 545 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 329 (12), 328 (56) [M]<sup>+</sup>, 297 (21), 296 (100), 283 (21), 281 (10), 268 (10), 267 (49), 253 (39), 240 (11), 224 (10), 223 (27), 196 (13), 195 (14), 165 (18), 152 (18). HRMS (EI): calcd. for C<sub>19</sub>H<sub>20</sub>O<sub>5</sub> [M]<sup>+</sup> 328.13053; found 328.130451.

**5-Ethyl 2-Methyl 4-Ethyl-3-hydroxy-4'-methylbiphenyl-2,5-dicarboxylate (13g):** Starting with **12b** (0.460 g, 1.5 mmol) and **3n** (0.476 g, 1.65 mmol), **13g** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as a pale-yellowish oil (0.236 g, 46%). <sup>1</sup>H NMR (250 MHz, CDCl<sub>3</sub>):  $\delta = 1.15$  (t, <sup>3</sup>*J* = 7.6 Hz, 3 H, CH<sub>3</sub>), 1.30

(t,  ${}^{3}J = 7.5 \text{ Hz}$ , 3 H, CH<sub>3</sub>), 2.32 (s, 3 H, PhCH<sub>3</sub>), 2.87 (q,  ${}^{3}J =$ 7.6 Hz, 2 H, PhCH<sub>2</sub>), 3.45 (s, 3 H, OCH<sub>3</sub>), 4.29 (q,  ${}^{3}J$  = 7.2 Hz, 2 H, OCH<sub>2</sub>), 7.01–7.11 (m, 5 H, 5CH<sub>Ar</sub>), 10.72 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (62.5 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.10, 13.22 (CH<sub>3</sub>), 19.55 (CH<sub>2</sub>), 20.17 (CH<sub>3</sub>), 50.95 (OCH<sub>3</sub>), 60.37 (OCH<sub>2</sub>) 112.64 (C<sub>Ar</sub>), 121.50 (CH<sub>Ar</sub>), 127.00 (2 CH<sub>Ar</sub>), 127.42 (2 CH<sub>Ar</sub>), 131.04, 134.33, 135.63, 138.23, 140.71 (CAr), 158.56 (COH), 166.67, 170.58 (CO) ppm. IR (KBr): v = 3023 (w), 2971 (w), 2933 (w), 2874 (w), 1723 (s), 1664 (s), 1604 (m), 1555 (w), 1517 (w), 1437 (m), 1389 (m), 1367 (m), 1344 (m), 1312 (w), 1282 (m), 1247 (s), 1222 (s), 1193 (s), 1156 (s), 1137 (m), 1111 (w), 1075 (s), 1030 (m), 1007 (m), 967 (w), 949 (m), 908 (w), 888 (w), 846 (w), 823 (m), 784 (m), 723 (w), 709 (w), 670 (w), 654 (w), 627 (w), 598 (w), 567 (w) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 343 (22), 342 (98) [M]<sup>+</sup>, 311 (23), 310 (100), 309 (16), 297 (31), 295 (30), 282 (25), 281 (49), 267 (38), 265 (10), 263 (26), 254 (13), 239 (14), 238 (28), 237 (32), 235 (10), 211 (33), 210 (37), 209 (18), 179 (10), 178 (12), 166 (16), 165 (38), 153 (10), 152 (14). HRMS (EI): calcd. for C<sub>20</sub>H<sub>22</sub>O<sub>5</sub> [M]<sup>+</sup> 342.14618; found 342.146471.

5-Ethyl 2-Methyl 3-Hydroxy-4-methyl-4'-nitrobiphenyl-2,5-dicarboxylate (13h): Starting with 12c (0.506 g, 1.5 mmol) and 3j (0.453 g, 1.65 mmol), 13h was isolated after chromatography (silica gel, nheptane/EtOAc) as a pale-yellowish solid (0.356 g, 66%). M.p. 123-125. <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta = 1.27$  (t, <sup>3</sup>J = 7.3 Hz, 3 H, CH<sub>3</sub>), 2.37 (s, 3 H, CH<sub>3</sub>), 3.39 (s, 3 H, OCH<sub>3</sub>), 4.25 (q,  ${}^{3}J$  = 7.4 Hz, 2 H, OCH<sub>2</sub>), 6.99 (s, 1 H, CH<sub>Ar</sub>), 7.24–7.28 (m, 2 H, CH<sub>Ar</sub>), 8.09– 8.13 (m, 2 H, CH<sub>Ar</sub>), 11.13 (s, 1 H, OH) ppm. <sup>13</sup>C NMR  $(62.5 \text{ MHz}, \text{CDCl}_3)$ :  $\delta = 11.48, 12.85 (\text{CH}_3), 50.83 (\text{OCH}_3), 60.18$ (OCH<sub>2</sub>) 110.90 (C<sub>Ar</sub>), 120.52 (CH<sub>Ar</sub>), 121.58 (2 CH<sub>Ar</sub>), 127.12 (C<sub>Ar</sub>) 127.71 (2  $CH_{Ar}$ ), 134.37, 137.57, 145.50, 147.74 ( $C_{Ar}$ ), 159.35 (COH), 165.62, 169.25 (CO) ppm. IR (KBr):  $\tilde{v} = 3115$  (w), 3053 (w), 2988 (w), 2954 (m), 2906 (w), 2849 (w), 1730 (s), 1671 (s), 1594 (m), 1567 (w), 1513 (m), 1471 (w), 1435 (m), 1393 (m), 1377 (m), 1366 (m), 1342 (s), 1312 (m), 1194 (s), 1166 (s), 1137 (m), 1105 (m), 1050 (m), 1002 (s), 936 (m), 898 (w), 840 (s), 809 (s), 789 (s), 747 (s), 701 (s), 656 (w), 617 (w), 586 (m), 559 (m) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 395 (44) [M]<sup>+</sup>, 328 (21), 327 (100), 314 (18), 299 (11), 298 (38), 271 (18), 255 (17), 254 (9), 253 (10), 242 (22), 227 (13), 226 (15), 152 (17), 151 (12), 139 (10). HRMS (EI): calcd. for  $C_{18}H_{17}O_7N$  [M]<sup>+</sup> 359.09995; found 359.100038.

5-Ethyl 2-Methyl 4-Ethyl-3-hydroxy-4'-nitrobiphenyl-2,5-dicarboxylate (13i): Starting with 12c (0.506 g, 1.5 mmol) and 3n (0.476 g, 1.65 mmol), 13i was isolated after chromatography (silica gel, nheptane/EtOAc) as a vellowish solid (0.375 g, 67%). M.p. 90–92 °C. <sup>1</sup>H NMR (250 MHz, CDCl<sub>3</sub>):  $\delta$  = 1.19 (t, <sup>3</sup>J = 7.7 Hz, 3 H, CH<sub>3</sub>), 1.31 (t,  ${}^{3}J$  = 7.7 Hz, 3 H, CH<sub>3</sub>), 2.90 (q,  ${}^{3}J$  = 7.2 Hz, 2 H, PhCH<sub>2</sub>), 3.45 (s, 3 H, OCH<sub>3</sub>), 4.31 (q,  ${}^{3}J$  = 7.2 Hz, 2 H, OCH<sub>2</sub>), 7.00 (s, 1 H,  $CH_{Ar}$ ), 7.28–7.34 (m, 2 H,  $CH_{Ar}$ ), 8.14–8.20 (m, 2 H,  $CH_{Ar}$ ), 11.12 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (62.5 MHz, CDCl<sub>3</sub>):  $\delta$  = 12.95, 13.19 (CH<sub>3</sub>), 19.65 (CH<sub>2</sub>), 51.34 (OCH<sub>3</sub>), 60.70 (OCH<sub>2</sub>) 111.80 (CAr), 121.16 (CHAr), 122.12 (2 CHAr), 128.36 (2 CHAr), 133.16, 134.60, 138.44, 146.11, 148.27 (CAr), 159.79 (COH), 166.27, 169.63 (CO) ppm. IR (KBr):  $\tilde{v} = 3071$  (w), 3049 (w), 2963 (m), 2930 (m), 2871 (m), 2852 (m), 2450 (w), 2357 (w), 2123 (w), 2123 (w), 1935 (w), 1804 (w), 1730 (s), 1669 (s), 1594 (m), 1562 (m), 1504 (s), 1446 (m), 1412 (m), 1390 (m), 1345 (s), 1315 (m), 1290 (m), 1257 (s), 1227 (s), 1195 (s), 1153 (s), 1135 (s), 1106 (s), 1074 (s), 1062 (s), 1027 (m), 1008 (m), 970 (m), 944 (s), 897 (m), 852 (s), 913 (m), 776 (s), 749 (s), 702 (s), 672 (m), 644 (w), 622 (m), 588 (m), 573 (m) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 374 (22), 373 (100) [M]<sup>+</sup>, 342 (20), 341 (84), 328 (38), 314 (14), 313 (74), 312 (57), 298 (16), 296 (13), 295 (10), 285 (10), 270 (23), 269 (60), 268 (13), 267 (12), 243 (10), 242 (68), 241 (38), 240 (22), 239 (13), 223 (12), 222 (14), 221

(51), 220 (10), 194 (11), 193 (10), 166 (10), 165 (42), 164 (13), 163 (12), 152 (15), 151 (10), 139 (15). HRMS (EI): calcd. for  $C_{19}H_{19}O_7N$  [M]<sup>+</sup> 373.11560; found 373.115597.

5-Ethyl 2-Methyl 4'-Bromo-3-hydroxybiphenyl-2,5-dicarboxylate (13j): Starting with 12d (0.557 g, 1.5 mmol) and 3a (0.429 g, 1.65 mmol), 13j was isolated after chromatography (silica gel, nheptane/EtOAc) as a pale-brownish oil (0.301 g, 53%). <sup>1</sup>H NMR  $(300 \text{ MHz}, \text{CDCl}_3)$ :  $\delta = 1.26 \text{ (t, } {}^{3}J = 7.0 \text{ Hz}, 3 \text{ H}, \text{CH}_3)$ , 3.43 (s, 3 H, OCH<sub>3</sub>), 4.25 (q,  ${}^{3}J$  = 7.1 Hz, 2 H, OCH<sub>2</sub>), 6.97–7.01 (m, 2 H,  $CH_{Ar}$ ), 7.28 (d,  ${}^{4}J$  = 1.7 Hz, 1 H,  $CH_{Ar}$ ), 7.36–7.41 (m, 2 H,  $CH_{Ar}$ ), 7.54 (d,  ${}^{4}J$  = 1.8 Hz, 1 H, CH<sub>Ar</sub>), 10.47 (s, 1 H, OH) ppm. {}^{13}C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 14.2 (CH<sub>3</sub>), 52.2 (OCH<sub>3</sub>), 61.6 (OCH<sub>2</sub>), 115.1 (C<sub>Ar</sub>), 118.2 (CH<sub>Ar</sub>), 121.4 (C<sub>Ar</sub>), 122.7 (CH<sub>Ar</sub>), 129.8 (2 CH<sub>Ar</sub>), 130.9 (2 CH<sub>Ar</sub>), 135.0, 140.9, 143.6, (C<sub>Ar</sub>), 161.3 (COH), 165.2, 170.5 (CO) ppm. IR (neat):  $\tilde{v} = 3064$  (w), 2980 (w), 2953 (w), 2905 (w), 2872 (w), 2852 (w), 1721 (m), 1672 (m), 1611 (m), 1571 (m), 1493 (m), 1439 (m), 1392 (m), 1345 (m), 1238 (s), 1200 (s), 1114 (s), 1069 (m), 1023 (m), 1010 (m), 948 (m), 881 (m), 835 (m), 807 (m), 770 (m), 681 (m), 622 (m), 574 (m) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 378 (28) [M<sup>+</sup>, <sup>79</sup>Br], 349 (18), 348 (100), 276 (7), 194 (16), 139 (14). HRMS (EI, 70 eV): calcd. for C<sub>17</sub>H<sub>15</sub>O<sub>5</sub>Br [M<sup>+</sup>, <sup>79</sup>Br] 378.00974; found 378.009529.

5-Ethyl 2-Methyl 4'-Bromo-3-hydroxy-4-methylbiphenyl-2,5-dicarboxylate (13k): Starting with 12d (0.557 g, 1.5 mmol) and 3j (0.453 g, 1.65 mmol), 13k was isolated after chromatography (silica gel, nheptane/EtOAc) as a pale-brownish oil (0.323 g, 55%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 1.30 (t, <sup>3</sup>J = 7.2 Hz, 3 H, CH<sub>3</sub>), 2.40 (s, 3 H, PhCH<sub>3</sub>), 3.47 (s, 3 H, OCH<sub>3</sub>), 4.30 (q, <sup>3</sup>*J* = 7.2 Hz, 2 H, OCH<sub>2</sub>), 7.00-7.05 (m, 3 H, CH<sub>Ar</sub>), 7.40-7.44 (m, 2 H, CH<sub>Ar</sub>), 10.99 (s, 1 H, OH) ppm.  $^{13}\mathrm{C}$  NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 11.7, 13.2 (CH<sub>3</sub>), 51.1 (OCH<sub>3</sub>), 60.4 (OCH<sub>2</sub>), 111.9, 120.1 (C<sub>Ar</sub>), 121.2 (CH<sub>Ar</sub>), 126.3 (C<sub>Ar</sub>), 128.8 (2 CH<sub>Ar</sub>), 129.8 (2 CH<sub>Ar</sub>), 134.6, 139.2, 140.2 (C<sub>Ar</sub>), 159.3 (COH), 166.3, 170.2 (CO) ppm. IR (neat):  $\tilde{v} = 3046$  (w), 2979 (w), 2952 (w), 2904 (w), 2873 (w), 1722 (m), 1665 (m), 1607 (m), 1567 (w), 1492 (w), 1437 (m), 1390 (m), 1367 (m), 1342 (m), 1305 (m), 1261 (s), 1230 (s), 1194 (s), 1157 (s), 1137 (m), 1071 (m), 1048 (s), 1009 (s), 933 (m), 918 (m), 889 (w), 828 (m), 782 (m), 742 (m), 724 (m), 665 (m), 618 (w), 588 (m), 557 (w) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 392 (47) [M<sup>+</sup>, <sup>79</sup>Br], 360 (100), 333 (30), 304 (15), 253 (55), 196 (12), 180 (9), 152 (38), 139 (10), 104 (8), 76 (11). HRMS (EI): calcd. for C<sub>18</sub>H<sub>17</sub>O<sub>5</sub>Br [M<sup>+</sup>, <sup>79</sup>Br] 392.02539; found 392.025473.

5-Ethyl 2-Methyl 4'-Bromo-4-ethyl-3-hydroxybiphenyl-2,5-dicarboxylate (131): Starting with 12d (0.557 g, 1.5 mmol) and 3n (0.476 g, 1.65 mmol), 131 was isolated after chromatography (silica gel, nheptane/EtOAc) as a pale-brownish oil (0.359 g, 59%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 1.18 (t, <sup>3</sup>J = 7.5 Hz, 3 H, CH<sub>3</sub>), 1.31 (t, <sup>3</sup>J = 7.2 Hz, 3 H, CH<sub>3</sub>), 2.88 (q,  ${}^{3}J$  = 7.4 Hz, 2 H, PhCH<sub>2</sub>), 3.47 (s, 3 H, OCH<sub>3</sub>), 4.30 (q,  ${}^{3}J$  = 7.2 Hz, 2 H, OCH<sub>2</sub>), 7.01–7.05 (m, 3 H, CH<sub>Ar</sub>), 7.40–7.44 (m, 2 H, CH<sub>Ar</sub>), 10.94 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.0, 13.2 (CH<sub>3</sub>), 19.6 (CH<sub>2</sub>), 51.1 (OCH<sub>3</sub>), 60.4 (OCH<sub>2</sub>), 112.1, 120.1 (C<sub>Ar</sub>), 121.2 (CH<sub>Ar</sub>), 128.8 (2 CH<sub>Ar</sub>), 129.8 (2 CH<sub>Ar</sub>), 131.8, 134.5, 139.4, 140.2 (C<sub>Ar</sub>), 159.0 (COH), 166.4, 170.2 (CO) ppm. IR (neat):  $\tilde{v} = 2972$  (w), 2954 (w), 2935 (w), 2875 (w), 2854 (w), 1723 (m), 1665 (m), 1605 (m), 1567 (w), 1490 (w), 1437 (m), 1387 (m), 1368 (m), 1347 (m), 1309 (m), 1282 (m), 1248 (s), 1222 (s), 1194 (m), 1158 (s), 1075 (s), 1029 (m), 1009 (m), 967 (m), 948 (m), 890 (w), 830 (m), 784 (m), 734 (m), 721 (m), 665 (m), 620 (w), 587 (m), 560 (w) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 406 (92) [M<sup>+</sup>, <sup>79</sup>Br], 376 (98), 348 (32), 331 (16), 302 (34), 275 (50), 249 (17), 221 (89), 194 (21), 165 (72), 152 (24), 128 (7), 82 (11). HRMS (EI): calcd. for  $C_{19}H_{19}O_5Br$  [M<sup>+</sup>, <sup>79</sup>Br] 406.04104; found 406.041136.



5-Ethyl 2-Methyl 4'-Bromo-4-hexyl-3-hydroxybiphenyl-2,5-dicarboxylate (13m): Starting with 12d (0.557 g, 1.5 mmol) and 3d (0.569 g, 1.65 mmol), 13m was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as a brownish oil (0.347 g, 50%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 0.67–0.75 (m, 6 H, 2 CH<sub>3</sub>), 1.16–1.20 (m, 6 H, 3 CH<sub>2</sub>), 1.40–1.46 (m, 2 H, CH<sub>2</sub>), 2.74 (t,  ${}^{3}J$  = 7.7 Hz, 2 H, CH<sub>2</sub>), 3.36 (s, 3 H, OCH<sub>3</sub>), 4.19 (q,  ${}^{3}J$  = 7.1 Hz, 2 H, OCH<sub>2</sub>), 6.90– 6.94 (m, 3 H, CH<sub>Ar</sub>), 7.29–7.34 (m, 2 H, CH<sub>Ar</sub>), 10.83 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 15.3, 15.5 (CH<sub>3</sub>), 23.9, 28.2, 31.0, 32.8, 32.9, (CH<sub>2</sub>), 53.3 (OCH<sub>3</sub>), 62.6 (OCH<sub>2</sub>), 114.2, 122.3 (CAr), 123.4 (CHAr), 131.0 (2 CHAr), 132.0 (2 CHAr), 133.0, 136.8, 141.5, 142.4 (C<sub>Ar</sub>), 161.3 (COH), 168.7, 172.4 (CO) ppm. IR (neat):  $\tilde{v} = 2953$  (w), 2926 (m), 2855 (w), 1934 (w), 1725 (m), 1667 (m), 1605 (w), 1566 (w), 1554 (w), 1492 (w), 1437 (m), 1388 (m), 1368 (m), 1347 (m), 1313 (w), 1248 (m), 1231 (m), 1195 (m), 1155 (m), 1099 (m), 1071 (m), 1010 (m), 953 (m), 920 (w), 843 (m), 785 (m), 720 (m), 673 (w), 663 (w), 628 (w), 588 (w) cm<sup>-1</sup>. GC-MS (EI, 70 eV): m/z (%) = 462 (42) [M<sup>+</sup>, <sup>79</sup>Br], 419 (10), 357 (100), 331 (42), 302 (13), 278 (17), 253 (26), 196 (19), 152 (17). HRMS (EI): calcd. for C<sub>23</sub>H<sub>27</sub>O<sub>5</sub>Br [M<sup>+</sup>, <sup>79</sup>Br] 462.10364; found 462.104001.

5-Ethyl 2-Methyl 4'-Bromo-4-heptyl-3-hydroxybiphenyl-2,5-dicarboxylate (13n): Starting with 12d (0.557 g, 1.5 mmol) and 3o (0.592 g, 1.65 mmol), 13n was isolated after chromatography (silica gel, n-heptane/EtOAc) as a brownish oil (0.357 g, 50%). <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>):  $\delta$  = 0.78–0.83 (m, 6 H, 2 CH<sub>3</sub>), 1.28–1.33 (m, 8 H, 4 CH<sub>2</sub>), 1.35–1.39 (m, 2 H, CH<sub>2</sub>), 2.84 (t,  ${}^{3}J$  = 7.4 Hz, 2 H, CH<sub>2</sub>), 3.47 (s, 3 H, OCH<sub>3</sub>), 4.29 (q, <sup>3</sup>J = 7.1 Hz, 2 H, OCH<sub>2</sub>), 7.00-7.04 (m, 3 H, CH<sub>Ar</sub>), 7.40–7.44 (m, 2 H, CH<sub>Ar</sub>), 10.93 (s, 1 H, OH) ppm. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>):  $\delta$  = 13.1, 13.2 (CH<sub>3</sub>), 21.6, 26.3, 28.1, 28.7, 30.3, 30.8 (CH<sub>2</sub>), 51.7 (OCH<sub>3</sub>), 60.4 (OCH<sub>2</sub>), 112.0, 120.1 (C<sub>Ar</sub>), 121.2 (CH<sub>Ar</sub>), 128.8 (2 CH<sub>Ar</sub>), 129.8 (2 CH<sub>Ar</sub>), 130.7, 134.6, 139.3, 140.2 (C<sub>Ar</sub>), 159.1 (COH), 166.7, 170.2 (CO) ppm. IR (neat):  $\tilde{v} = 2972$  (w), 2954 (w), 2935 (w), 2875 (w), 2854 (w), 1723 (m), 1665 (m), 1605 (m), 1567 (w), 1490 (w), 1437 (m), 1387 (m), 1368 (m), 1347 (m), 1309 (m), 1282 (m), 1248 (s), 1222 (s), 1194 (m), 1158 (s), 1075 (s), 1029 (m), 1009 (m), 967 (m), 948 (m), 890 (w), 830 (m), 784 (m), 734 (m), 721 (m), 665 (m), 620 (w), 587 (m), 560 (w) cm<sup>-1</sup>. GC–MS (EI, 70 eV): m/z (%) = 476 (30) [M<sup>+</sup>, <sup>79</sup>Br], 416 (7), 373 (100), 333 (30), 292 (18), 253 (17), 196 (11), 152 (9). HRMS (EI): calcd. for C<sub>24</sub>H<sub>29</sub>O<sub>5</sub>Br [M<sup>+</sup>, <sup>79</sup>Br] 476.11929; found 476.119450.

**1-Hydroxy-3-methylanthraquinone (7):** A mixture of **6b** (0.102 g, 0.38 mmol) and concentrated sulfuric acid (4 mL) was stirred at 20 °C for 1 h. The solution was poured into ice water, and the mixture was extracted with diethyl ether. The combined organic layer was dried (Na<sub>2</sub>SO<sub>4</sub>) and filtered, and the filtrate was concentrated in vacuo. The residue was purified by chromatography (silica gel, heptanes/EtOAc, 20:1) to give 7 as a yellow solid (0.076 gm, 84%). M.p. 234–237 °C. <sup>1</sup>H NMR (250 MHz, CD<sub>3</sub>OD):  $\delta$  = 2.39 (s, 3 H, PhCH<sub>3</sub>), 6.95 (br. s, 1 H, OH), 7.39–7.42 (m, 2 H, CH<sub>Ar</sub>), 7.45 (m, 1 H, CH), 7.54 (t, <sup>3</sup>*J* = 7.3 Hz, 1 H, CH), 7.74 (d, <sup>3</sup>*J* = 7.3 Hz, 2 H, CH) ppm. <sup>13</sup>C NMR (75 MHz, CD<sub>3</sub>OD):  $\delta$  = 21.7 (CH<sub>3</sub>), 122.0, 123.5, 129.8, 130.4 (CH), 132.1 (C), 134.3 (CH), 139.8, 142.2 (C), 156.5 (COH), 169.3 (C=O) ppm. MS (EI, 70 eV): *m/z* (%) = 238 (57) [M]<sup>+</sup>, 237 (100), 179 (36).

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