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Transition-Metal-Free Synthesis of 2-Substituted Methyl Benzo[*b*]furan-3-carboxylates

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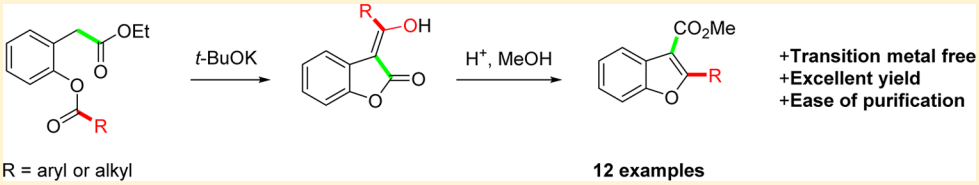
Supporting Information



ABSTRACT: A concise and highly efficient synthetic pathway was developed for 2-substituted methyl benzo[*b*]furan-3-carboxylates. This method provides convenient and cost-effective access for 2-substituted methyl benzo[*b*]furan-3-carboxylates without the use of a transition metal catalyst for synthesis. Furthermore, in most cases, this method gives excellent yields and conventional flash column chromatography is not needed for purification.

INTRODUCTION

The 2,3-disubstituted benzo[*b*]furan is a common structure found in numerous natural products. These compounds are known for their various biological activities,[1] and there is extensive interest in their synthesis (Figure 1).[2,3]

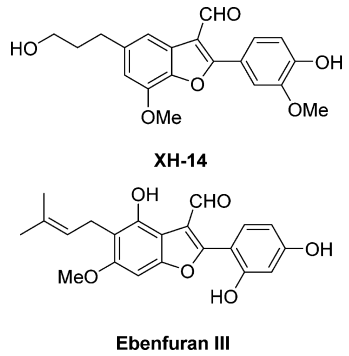
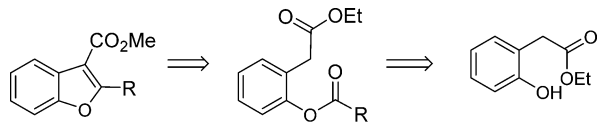


Figure 1. Representative examples of naturally occurring compounds containing 2,3-substituted benzo[*b*]furan structure.

Among the many strategies for the synthesis of the 2,3-disubstituted benzo[*b*]furan skeleton, the most common and widely used method is by transition metal catalyzed cyclization of 2-alkynylphenols.[4] Other popular methods employ Pd-catalyzed cross-coupling of *C*2-halogenated or stannylated benzo[*b*]furans with aryl boronic acids or aryl halides[5] or direct arylation of *C*2- or *C*3-substituted benzo[*b*]furans with aryl halides[6] utilizing C−H activation. Oxidative cross-coupling reactions at the *C*2 position of benzo[*b*]furan[7] and other methods[8] have also been reported recently. Although these methods give generally reasonable results, they require expensive transition metal catalysts for reactions and/or additional purification procedures. For the synthesis of indoles which are a nitrogen analogue of benzo[*b*]furan, the original or modified Madelung indole synthesis[9] can be used. However, these Madelung-type methods generally required harsh conditions and it could not be used to synthesize the analogous benzo[*b*]furans. To overcome these shortcomings of previous synthetic strategies, we focused on devising a more effective cyclization reaction for 2,3-disubstituted benzo[*b*]furans without transition metal catalysts. The retrosynthetic strategies focused on an affordable and highly effective synthetic approach for the desired product (Scheme 1).

Scheme 1. Retrosynthetic Analysis for 2-Substituted Methyl Benzo[*b*]furan-3-carboxylate



Herein is reported a simple approach toward the synthesis of 2,3-disubstituted benzo[*b*]furans without the use of transition metal catalysts. We believe this may be a more useful and cost-effective strategy for the synthesis of 2,3-disubstituted benzo[*b*]furans (Scheme 2).

RESULTS AND DISCUSSION

To investigate the scope of this synthetic strategy, substrates **2a**−**l** having various substituents were selected. The substituents encompass aryl groups containing the electron-withdrawing or -donating groups in different positions and aliphatic groups with an acidic α-proton. The starting material, ethyl 2-hydroxyphenylacetate (**1**), was obtained from a Fischer

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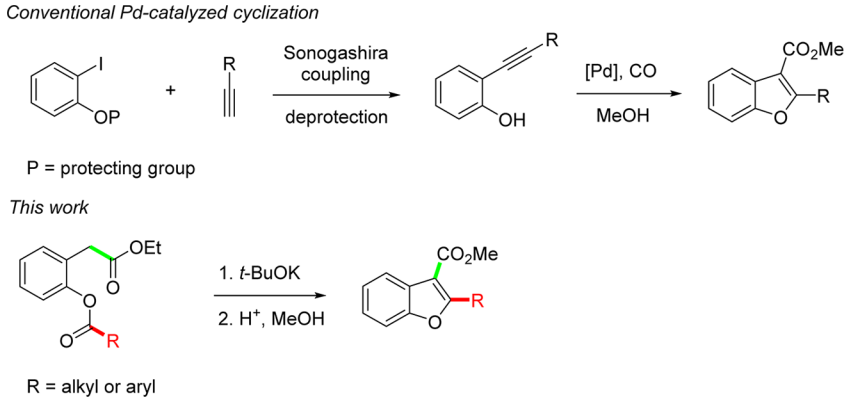
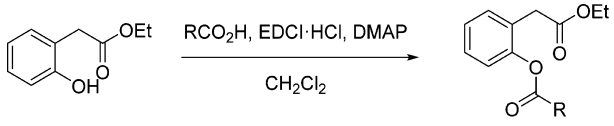
Scheme 2. Comparison Between Pd-Catalyzed Cyclization and This Work

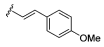


esterification reaction (90% yield) using commercially available 2-hydroxyphenylacetic acid, anhydrous ethanol, and concentrated sulfuric acid. The substrates **2a–l** were prepared using modified Steglich esterification[10] conditions which initially employed the DCC-mediated coupling reaction of an alcohol and a carboxylic acid catalyzed by DMAP (Table 1).

Table 1. Synthesis of Various Ethyl (2-Acyloxyphenyl)acetates



1 **2a-l**

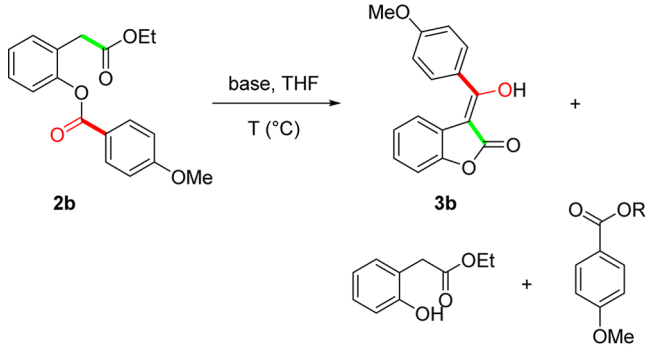
product	R	yield (%)[a]
2a	Ph	92
2b	*p*-MeOC$_6$H$_4$	93
2c	*m*-MeOC$_6$H$_4$	93
2d	*o*-MeOC$_6$H$_4$	97
2e	3,4-(MeO)$_2$C$_6$H$_3$	83
2f	*p*-FC$_6$H$_4$	96
2g	*p*-BrC$_6$H$_4$	91
2h	2-naphthyl	92
2i		79
2j	*i*-Bu	96
2k	cyclopropyl	96
2l	cyclohexyl	94

[a]Isolated yield.

In the early stage of study, we used acid chlorides for esterifications of the phenols. However, we found that the crude products were always contaminated with a small amount of impurities when acid chlorides were used for esterification and it rendered the purification very laborious. Thus, we decided to use DCC couplings of phenols and carboxylic acids for the acylation of the phenols, and it gave better results. However, to obtain pure products from the DCC coupling reaction mixtures, careful column chromatography procedures were required for the removal of dicyclohexylurea, which is an inevitable byproduct formed from DCC. For simple purification of products, we replaced DCC with 1-ethyl-3-(3-(dimethylamino)propyl)carbodiimide hydrochloride (EDCI·HCl). We found that the products from these modified conditions were sufficiently pure after filtration through a small plug of silica gel such that excellent yields were obtained and no additional purification procedures were required.

To investigate the optimum reaction conditions for base-mediated cyclization of substrate **2**, compound **2b** was selected and various bases and temperature conditions were tested. The result of the optimization for 3-(hydroxyl(4-methoxyphenyl)-methylene)benzo[*b*]furan-2(3*H*)-one is illustrated on Table 2. Under the conditions of entry 1, side products **1**, **4**, and **5** were isolated, purified, and confirmed by the NMR comparison of identical compounds independently prepared from other

Table 2. Optimization of Synthesis of (*Z*)-3-(Hydroxyl(4-methoxyphenyl)methylene)benzo[*b*]furan-2(3*H*)-one (3b)[a]



2b **3b** **1** **4**, R = Et **5**, R = H

			ratio of products (%)[b]			
entry	base	*T* (°C)	**3b**	**1**	**4**	**5**
1	*t*-BuOK[c]	0 to rt	70	15	5	10
2	*t*-BuOK[c]	−25 to 0	76	12	12	0
3	*t*-BuOK[c]	−78 to 0	100	0	0	0
4	NaH[d]	0 to rt	78	11	11	0
5	NaH[d]	−78 to 0	82	9	9	0
6	LiHMDS[c]	0 to rt	32	34	6	28
7	LiHMDS[c]	−78 to 0	73	13	7	7

[a]All reactions were carried out in 1.0 mmol scale of **2b** with 3 equiv of base in 3 mL of anhydrous THF. [b]Determined by integration of ^{1}H NMR. [c]Used 1.0 M solution in THF. [d]60% dispersion in mineral oil.

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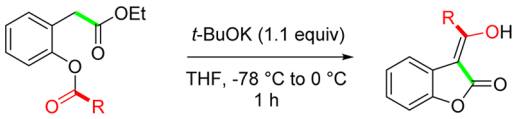
routes. To minimize the side products, further study focused on lowering the reaction temperature with potassium *tert*-butoxide and substituting potassium *tert*-butoxide with other bases (sodium hydride, lithium bis(trimethylsilyl)amide). Among these entries, entry 3 gave the best result. Under these conditions, NMR spectra revealed that the desired product **3b** was the sole product of the crude reaction mixture.

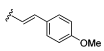
An early reaction optimization for 3-(hydroxyl(alkyl)-methylene)benzo[*b*]furan-2(3*H*)-one was conducted with an excess amount (3.0 equiv) of *t*-BuOK. However, additional investigations on the stoichiometry of the base revealed that a reduced amount of base has no detrimental effect. A slight excess amount (1.1 equiv) of *t*-BuOK gave comparable results with the original conditions.

Applying this standard condition to the substrates **2a−l**, gave excellent yields of 3-(hydroxyl(alkyl)methylene)benzo[*b*]furan-2(3*H*)-one products for all entries (Table 3).

Table 3. Synthesis of Various 3-(Hydroxyl(alkyl)methylene)benzo[*b*]furan-2(3*H*)-ones



2a-l **3a-l**

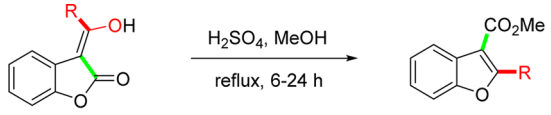
product	R	yield (%)[a]
3a	Ph	87
3b	*p*-MeOC$_6$H$_4$	89
3c	*m*-MeOC$_6$H$_4$	86
3d	*o*-MeOC$_6$H$_4$	77
3e	3,4-(MeO)$_2$C$_6$H$_3$	82
3f	*p*-FC$_6$H$_4$	66
3g	*p*-BrC$_6$H$_4$	85
3h	2-naphthyl	88
3i		76
3j	*i*-Bu	91
3k	cyclopropyl	88
3l	cyclohexyl	87

[a]Isolated yield.

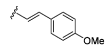
All products could be obtained as purified solids after recrystallization at low temperature (−20 °C). According to the NMR spectra of these products, they existed as enol tautomers almost exclusively and there was little detectable keto tautomer in each. To elucidate the structure of 3-(hydroxyl(alkyl)-methylene)benzo[*b*]furan-2(3*H*)-one more clearly, we analyzed the crystal structure of compound **3h** using a single crystal X-ray crystallography technique. (See Supporting Information for detailed X-ray crystallographic structure analysis for compound **3h**.)

The compounds **3a−l** were subjected to the methanolysis and dehydrative cyclization process in the presence of concentrated sulfuric acid to give methyl 2-substituted benzo[*b*]furan-3-carboxylates **6a−l** (Table 4). In the case of R = aryl, the reaction was completed within 6 h. If R = alkyl, the

Table 4. Synthesis of Various 2-Substituted Methyl Benzo[*b*]furan-3-carboxylates



3a-l **6a-l**

product	R	yield (%)[a]
6a	Ph	90
6b	*p*-MeOC$_6$H$_4$	92
6c	*m*-MeOC$_6$H$_4$	91
6d	*o*-MeOC$_6$H$_4$	90
6e	3,4-(MeO)$_2$C$_6$H$_3$	92
6f	*p*-FC$_6$H$_4$	90
6g	*p*-BrC$_6$H$_4$	91
6h	2-naphthyl	87
6i		89
6j	*i*-Bu	85
6k	cyclopropyl	87
6l	cyclohexyl	88

[a]Isolated yield.

reaction required a longer reaction time (12 h) for completion. In the case of **3i**, which has a conjugated system, it required the longest reaction time (24 h) among these entries.

This procedure proceeded very cleanly and gave excellent yields and satisfactory purities of products without additional purification procedures. After simple recrystallization of crude products, analytical grade products could be obtained easily. The products **6d** and **6j**, which are oily compounds at rt and therefore impossible to be recrystallized, were purified by column chromatography to obtain analytical grade samples.

A plausible reaction mechanism for the transformation from **2** to **6** was illustrated on Scheme 3. The proton abstraction from ester **2** gave hemiketal anion **7**. The hemiketal anion **7** transformed to *β*-ketoester **8**, whose phenolic residue attacked another ester group to give the 3-acylbenzo[*b*]furan-2(3*H*)-one **9**. The resulting 3-acylbenzo[*b*]furan-2(3*H*)-one **9** is immediately tautomerized to give tautomer **3** as a sole product. The enol **3** underwent methanolysis in the presence of methanol and concentrated sulfuric acid to give intermediate **10**. The phenolic oxygen next attacked the carbonyl group of ketone to give the hemiketal **11**. The hemiketal **11** was dehydrated spontaneously in the presence of concentrated sulfuric acid to give the desired 2-substituted methyl benzo[*b*]furan-3-carboxylate **6**.

CONCLUSION

A new method for synthesizing 2-substituted methyl benzo-[*b*]furan-3-carboxylate derivatives has been developed using mild conditions without using any transition metal catalysts. The method is applicable to the preparation of various alkyl or aryl groups at the C2. Since our synthetic strategy allows simultaneous installation of a carbonyl substituent at C3 and an alkyl or aryl substituent at C2, it can be used to introduce other

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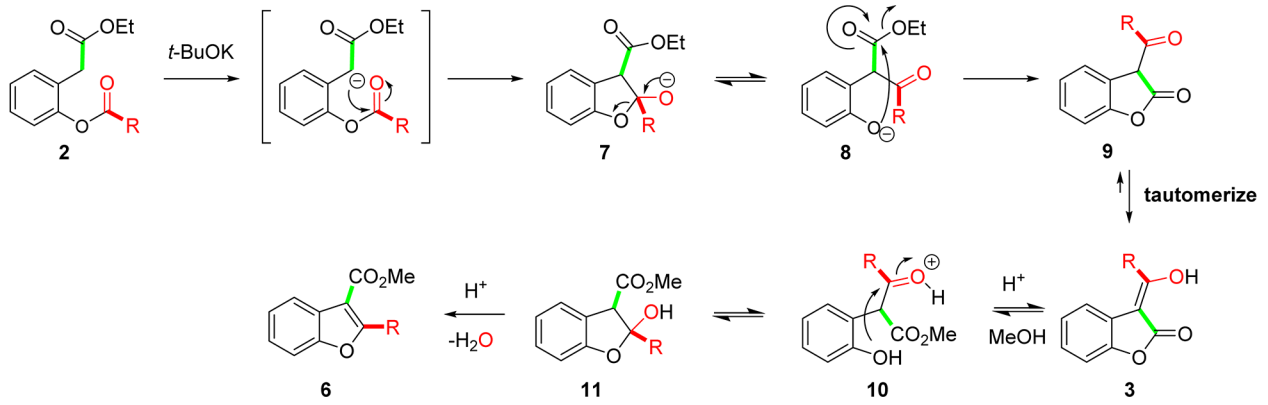
Scheme 3. Plausible Mechanism for the Sythesis of 2-Substituted Methyl Benzo[*b*]furan-3-carboxylates



moieties. The products were obtained from 2-hydroxyphenylacetic acid in four steps in very high overall yield. Moreover, in most cases, our strategy has no complicated purification procedure and does not need laborious column chromatography to obtain pure products.

EXPERIMENTAL SECTION

General Information. All reactions were conducted under an inert atmosphere unless otherwise stated. For air and moisture sensitive reactions, all glassware are dried in an convection oven and flame-dried. All solvents and reagents for reaction were purchased from the chemical supplier and used as received. Analytical thin layer chromatography (TLC) was carried out using commercial silica gel 60 TLC plates. NMR spectra were acquired from 400 and 500 MHz spectrometers, and chemical shifts were reported as parts per million (ppm) relative to the solvent residual peak ($CDCl_3$ = 7.26 ppm for ^1H NMR, 77.16 ppm for ^{13}C NMR). Coupling constants were reported in hertz (Hz). Multiplicities of NMR spectra are reported using the following general abbreviations: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broad. All melting point values are uncorrected. The high resolution mass spectra were obtained from an ESI+ quadrupole time-of-flight (Q-TOF) mass spectrometer.

Ethyl 2-Hydroxyphenylacetate (1). The mixture of 2-hydroxyphenylacetic acid (2.0 g, 13.1 mmol) and concentrated sulfuric acid (*ca.* 3 mL) in anhydrous ethanol (50 mL) was heated under reflux for 12 h. The resulting mixture was concentrated *in vacuo* and diluted with dichloromethane (20 mL). The organic layer was washed with water (10 mL × 3), dried over anhydrous $MgSO_4$, and concentrated under reduced pressure. The resulting residue was filtered through a small plug of silica gel with a mixture of EtOAc and *n*-hexane (1:2) to give the product as a low-melting white solid (2.13 g, 90%): ^1H NMR (400 MHz, $CDCl_3$) δ 7.67 (s, 1H), 7.21−7.14 (m, 1H), 7.12 (d, J = 7.4 Hz, 1H), 6.94−6.85 (m, 2H), 4.21 (q, J = 7.1 Hz, 2H), 3.69 (s, 2H), 1.30 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.0, 155.1, 131.0, 129.1, 120.8, 120.7, 117.3, 61.9, 37.7, 14.1. ^1H and ^{13}C NMR spectral data are consistent with previously reported values.[11]

Ethyl (2-Benzoyloxy)phenylacetate (2a). The mixture of ethyl 2-hydroxyphenylacetate (3.60 g, 20.0 mmol), benzoic acid (2.44 g, 20.0 mmol), and DMAP (0.489 g, 4.00 mmol) was suspended in anhydrous dichloromethane (100 mL). EDCI·HCl (4.21 g, 22.0 mmol) was added to this mixture and stirred for 12 h at rt. The reaction mixture was diluted with dichloromethane, and the organic layer was washed with 0.5 N aqueous HCl solution and water followed by a saturated aqueous sodium bicarbonate solution. The organic layer was dried over anhydrous $MgSO_4$, filtered, and concentrated *in vacuo*. The resulting residue was filtered through a small plug of silica gel with a mixture of EtOAc and *n*-hexane (1:2) to give the product as a colorless oil (5.16 g, 92%): ^1H NMR (400 MHz, $CDCl_3$) δ 8.24−8.17 (m, 2H), 7.64 (t, J = 7.4 Hz, 1H), 7.51 (t, J = 7.7 Hz, 2H), 7.36 (t, J = 7.7 Hz, 2H), 7.28−7.22 (m, 2H), 4.05 (q, J = 7.1 Hz, 2H), 3.63 (s, 2H), 1.11 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 164.6, 149.3, 133.7, 131.4, 130.2, 129.3, 128.7, 128.6, 126.8, 126.2, 122.7, 61.0, 36.6, 14.0. HRMS (ESI$^+$): calcd for $C_{17}H_{16}NaO_4^+$ [M + Na]$^+$, 307.0946; found, 307.0942. Anal. Calcd For $C_{17}H_{16}O_4$: C, 71.82; H, 5.67. Found: C, 71.83; H, 5.68.

Ethyl 2-(4-Methoxybenzoyloxy)phenylacetate (2b). The title compound **2b** (1.62 g, 93%) was obtained from **1** (1.00 g, 5.55 mmol) and *p*-anisic acid (0.842 g, 5.55 mmol) as a colorless oil using a procedure analogous to that described for the preparation of **2a**: ^1H NMR (400 MHz, $CDCl_3$) δ 8.20 (d, J = 8.9 Hz, 2H), 7.39 (dd, J = 13.3, 4.4 Hz, 2H), 7.30−7.24 (m, 2H), 7.03 (d, J = 8.9 Hz, 2H), 4.10 (q, J = 7.1 Hz, 2H), 3.90 (s, 3H), 3.67 (s, 2H), 1.17 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 164.3, 163.9, 149.4, 132.3, 131.3, 128.4, 126.9, 126.0, 122.7, 121.5, 113.9, 60.9, 55.5, 36.5, 14.0. HRMS (ESI$^+$): calcd for $C_{18}H_{18}NaO_5^+$ [M + Na]$^+$, 337.1052; found, 337.1046. Anal. Calcd for $C_{18}H_{18}O_5$: C, 68.78; H, 5.77. Found: C, 68.86; H, 5.73.

Ethyl 2-(3-Methoxybenzoyloxy)phenylacetate (2c). The title compound **2c** (1.62 g, 93%) was obtained from **1** (1.00 g, 5.55 mmol) and *m*-anisic acid (0.842 g, 5.55 mmol) as a colorless oil using a procedure analogous to that described for the preparation of **2a**: ^1H NMR (400 MHz, $CDCl_3$) δ 7.81 (d, J = 7.7 Hz, 1H), 7.74−7.69 (m, 1H), 7.45−7.34 (m, 3H), 7.28−7.23 (m, 2H), 7.22−7.16 (m, 1H), 4.07 (q, J = 7.1 Hz, 2H), 3.89 (s, 3H), 3.63 (s, 2H), 1.13 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 164.5, 159.7, 149.3, 131.3, 130.5, 129.6, 128.5, 126.8, 126.2, 122.6, 122.5, 120.2, 114.5, 61.0, 55.5, 36.5, 14.0. HRMS (ESI$^+$): m/z calcd for $C_{18}H_{18}NaO_5^+$ [M + Na]$^+$, 337.1052; found, 337.1046. Anal. Calcd for $C_{18}H_{18}O_5$: C, 68.78; H, 5.77. Found: C, 68.82; H, 5.74.

Ethyl 2-(2-Methoxybenzoyloxy)phenylacetate (2d). The title compound **2d** (1.93 g, 97%) was obtained from **1** (1.14 g, 6.30 mmol) and *o*-anisic acid (1.05 g, 6.43 mmol) as a pale yellow oil using a procedure analogous to that described for the preparation of **2a**: ^1H NMR (400 MHz, $CDCl_3$) δ 8.05 (dd, J = 7.6, 1.3 Hz, 1H), 7.56 (td, J = 8.2, 1.7 Hz, 1H), 7.40−7.33 (m, 2H), 7.30−7.22 (m, 2H), 7.06 (t, J = 7.9 Hz, 2H), 4.10 (q, J = 7.1 Hz, 2H), 3.94 (s, 3H), 3.70 (s, 2H), 1.16 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.9, 164.0, 159.8, 149.4, 134.4, 132.3, 131.2, 128.4, 126.8, 126.0, 122.9, 120.2, 118.9, 112.1, 60.9, 56.0, 36.3, 14.1. HRMS (ESI$^+$): m/z calcd for $C_{18}H_{18}NaO_5^+$ [M + Na]$^+$, 337.1052; found, 337.1047. Anal. Calcd for $C_{18}H_{18}O_5$: C, 68.78; H, 5.77. Found: C, 68.79; H, 5.76.

Ethyl 2-(3,4-Dimethoxybenzoyloxy)phenylacetate (2e). The title compound **2e** (1.57 g, 83%) was obtained from **1** (1.00 g, 5.55 mmol) and 3,4-dimethoxybenzoic acid (1.01 g, 5.55 mmol) as a white solid using a procedure analogous to that described for the preparation of **2a**: mp 76−77 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 7.87 (dd, J = 8.4, 1.6 Hz, 1H), 7.68 (d, J = 1.5 Hz, 1H), 7.36 (t, J = 7.3 Hz, 2H), 7.27−7.22 (m, 2H), 6.96 (d, J = 8.5 Hz, 1H), 4.06 (q, J = 7.1 Hz, 2H), 3.98−3.95 (overlapped s, 6H), 3.62 (s, 2H), 1.13 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.8, 164.4, 153.6, 149.4, 148.8, 131.4, 128.6, 126.9, 126.1, 124.5, 122.8, 121.7, 112.4, 110.4, 61.0, 56.2, 56.1, 36.6, 14.1. HRMS (ESI$^+$): m/z calcd for $C_{19}H_{20}NaO_6^+$ [M + Na]$^+$,

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367.1158; found, 367.1152. Anal. Calcd for $C_{19}H_{20}O_6$: C, 66.27; H, 5.85. Found: C, 66.27; H, 5.88.

Ethyl 2-(4-Fluorobenzoyloxy)phenylacetate (2f). The title compound **2f** (1.61 g, 96%) was obtained from **1** (1.00 g, 5.55 mmol) and 4-fluorobenzoic acid (0.777 g, 5.55 mmol) as a pale yellow oil using a procedure analogous to that described for the preparation of **2a**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26−8.17 (m, 2H), 7.35 (t, J = 7.9 Hz, 2H), 7.24 (t, J = 7.5 Hz, 2H), 7.17 (t, J = 8.6 Hz, 2H), 4.04 (q, J = 7.1 Hz, 2H), 3.61 (s, 2H), 1.11 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 166.3 (d, $^1J_{C-F}$ = 255.2 Hz), 163.7, 149.2, 132.9 (d, $^3J_{C-F}$ = 9.5 Hz) 131.5, 128.6, 126.8, 126.3, 125.6 (d, $^4J_{C-F}$ = 3.0 Hz), 122.6, 115.9 (d, $^2J_{C-F}$ = 22.1 Hz), 61.0, 36.6, 14.1. HRMS (ESI$^+$): m/z calcd for $C_{17}H_{15}FNaO_4^+$ [M + Na]$^+$, 325.0852; found, 325.0847. Anal. Calcd for $C_{17}H_{15}FO_4$: C, 67.54; H, 5.00. Found: C, 67.54; H, 5.05.

Ethyl 2-(4-Bromobenzoyloxy)phenylacetate (2g). The title compound **2g** (1.83 g, 91%) was obtained from **1** (1.00g, 5.55 mmol) and 4-bromobenzoic acid (1.11 g, 5.55 mmol) as a white solid using a procedure analogous to that described for the preparation of **2a**: mp 50−51 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 (d, J = 8.5 Hz, 2H), 7.64 (d, J = 8.5 Hz, 2H), 7.35 (t, J = 7.7 Hz, 2H), 7.24 (t, J = 8.5 Hz, 2H), 4.04 (q, J = 7.1 Hz, 2H), 3.60 (s, 2H), 1.11 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.6, 164.0, 149.1, 132.0, 131.7, 131.5, 129.0, 128.6, 128.3, 126.8, 126.4, 122.6, 61.1, 36.6, 14.1. HRMS (ESI$^+$): m/z calcd for $C_{17}H_{15}BrNaO_4^+$ [M + Na]$^+$, 385.0051; found, 385.0048. Anal. Calcd for $C_{17}H_{15}BrO_4$: C, 56.22; H, 4.16. Found: C, 56.23; H, 4.15.

Ethyl 2-(2-Naphthoyloxy)phenylacetate (2h). The title compound **2h** (1.71 g, 92%) was obtained from **1** (1.00 g, 5.55 mmol) and 2-naphthoic acid (0.955 g, 5.55 mmol) as a white solid using a procedure analogous to that described for the preparation of **2a**: mp 90−91 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.82 (s, 1H), 8.25−8.19 (m, 1H), 8.02 (d, J = 8.0 Hz, 1H), 7.95 (dd, J = 12.7, 8.4 Hz, 2H), 7.68−7.57 (m, 2H), 7.41 (t, J = 7.6 Hz, 2H), 7.35−7.25 (m, 2H), 4.08 (q, J = 7.1 Hz, 2H), 3.69 (s, 2H), 1.11 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.8, 164.8, 149.4, 135.9, 132.5, 132.0, 131.5, 129.5 128.8, 128.6, 128.5, 127.9, 126.9, 126.9, 126.5, 126.3, 125.5, 122.8, 61.0, 36.7, 14.1. HRMS (ESI$^+$): m/z calcd for $C_{21}H_{18}NaO_4^+$ [M + Na]$^+$, 357.1103; found, 357.1098. Anal. Calcd for $C_{21}H_{18}O_4$: C, 75.43; H, 5.43. Found: C, 75.43; H, 5.44.

Ethyl 2-(*trans*-4-Methoxycinnamoyloxy)phenylacetate (2i). The title compound **2i** (1.49 g, 79%) was obtained from **1** (1.00 g, 5.55 mmol) and *trans*-4-methoxycinnamic acid (0.989 g, 5.55 mmol) as a faint yellow solid using a procedure analogous to that described for the preparation of **2a**: mp 92−93 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, J = 15.9 Hz, 1H), 7.55 (d, J = 8.7 Hz, 2H), 7.34 (t, J = 7.7 Hz, 2H), 7.25−7.17 (m, 2H), 6.94 (d, J = 8.7 Hz, 2H), 6.50 (d, J = 15.9 Hz, 1H), 4.13 (q, J = 7.1 Hz, 2H), 3.86 (s, 3H), 3.61 (s, 2H), 1.20 (t, J = 7.1 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.0, 165.3, 161.9, 149.4, 146.6, 131.3, 130.2, 128.5, 127.0, 126.9, 126.1, 122.7, 114.6, 114.4, 61.1, 55.6, 36.6, 14.3. HRMS (ESI$^+$): m/z calcd for $C_{20}H_{20}NaO_5^+$ [M + Na]$^+$, 363.1208; found, 363.1204. Anal. Calcd for $C_{20}H_{20}O_5$: C, 70.58; H, 5.92. Found: C, 70.60; H, 5.89.

Ethyl (2-Isovaleroyloxy)phenylacetate (2j). The title compound **2j** (1.41 g, 96%) was obtained from **1** (1.00 g, 5.55 mmol) and isovaleric acid (0.612 mL, 5.55 mmol) as a colorless oil using a procedure analogous to that described for the preparation of **2a**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34−7.27 (m, 2H), 7.20 (t, J = 7.5 Hz, 1H), 7.09 (d, J = 8.0 Hz, 1H), 4.13 (q, J = 7.1 Hz, 2H), 3.55 (s, 2H), 2.46 (d, J = 7.2 Hz, 2H), 2.25 (sep, J = 6.8 Hz, 1H), 1.23 (t, J = 7.1 Hz, 3H), 1.06 (d, J = 6.7 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.2, 170.8, 149.2, 131.4, 128.5, 126.7, 126.1, 122.6, 61.0, 43.2, 36.5, 25.8, 22.5, 14.2. HRMS (ESI$^+$): m/z calcd for $C_{15}H_{20}NaO_4^+$ [M + Na]$^+$, 287.1259; found, 287.1255. Anal. Calcd for $C_{15}H_{20}O_4$: C, 68.16; H, 7.63. Found: C, 68.10; H, 7.67.

Ethyl (2-Cyclopropanecarbonyloxy)phenylacetate (2k). The title compound **2k** (1.32 g, 96%) was obtained from **1** (1.00 g, 5.55 mmol) and cyclopropanecarboxylic acid (0.501 g, 5.82 mmol) as a colorless oil using a procedure analogous to that described for the preparation of **2a**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33−7.27 (m, 2H), 7.19 (td, J = 7.6, 1.1 Hz, 1H), 7.10 (d, J = 8.1 Hz, 1H), 4.14 (q, J = 7.1 Hz, 2H), 3.56 (s, 2H), 1.89−1.80 (m, 1H), 1.24 (t, J = 7.1 Hz, 3H), 1.21−1.16 (m, 2H), 1.06−1.00 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.0, 170.8, 149.2, 131.3, 128.5, 126.7, 126.1, 122.5, 61.0, 36.5, 14.2, 13.0, 9.2. HRMS (ESI$^+$): m/z calcd for $C_{14}H_{16}NaO_4^+$ [M + Na]$^+$, 271.0946; found, 271.0943. Anal. Calcd for $C_{14}H_{16}O_4$: C, 67.73; H, 6.50. Found: C, 67.73; H, 6.54.

Ethyl (2-Cyclohexanecarbonyloxy)phenylacetate (2l). The title compound **2l** (1.52 g, 94%) was obtained from **1** (1.00 g, 5.55 mmol) and cyclohexanecarboxylic acid (0.745 g, 5.61 mmol) as a colorless oil using a procedure analogous to that described for the preparation of **2a**. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33−7.27 (m, 2H), 7.23−7.16 (m, 1H), 7.07 (d, J = 8.1 Hz, 1H), 4.13 (q, J = 7.1 Hz, 2H), 3.54 (s, 2H), 2.57 (tt, J = 11.3, 3.6 Hz, 1H), 2.09 (dd, J = 13.1, 2.6 Hz, 2H), 1.87−1.79 (m, 2H), 1.73−1.66 (m, 1H), 1.59 (qd, J = 12.3, 3.1 Hz, 2H), 1.42−1.26 (m, 3H), 1.23 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.1, 170.8, 149.3, 131.3, 128.5, 126.7, 126.0, 122.5, 61.0, 43.3, 36.4, 29.0, 25.8, 25.5, 14.2. HRMS (ESI$^+$): m/z calcd for $C_{17}H_{22}NaO_4^+$ [M + Na]$^+$, 313.1416; found, 313.1413. Anal. Calcd for $C_{17}H_{22}O_4$: C, 70.32; H, 7.64. Found: C, 70.33; H, 7.65.

3-(Hydroxyl(phenyl)methylene)benzo[*b*]furan-2(3*H*)-one (3a). A solution of **2a** (1.00 g, 3.52 mmol) in anhydrous THF was cooled to −78 °C. A 1.0 M THF solution of *t*-BuOK (3.87 mL, 3.87 mmol) was added dropwise to this mixture. The reaction mixture was allowed to warm to 0 °C and stirred additionally for 1 h at the same temperature. The reaction mixture was quenched with 1 N aqueous HCl solution (5 mL) and diluted with dichloromethane. The aqueous layer was extracted with dichloromethane (10 mL × 3). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated *in vacuo*. The resulting crude residue was recrystallized with dichloromethane/*n*-hexane at −20 °C to give the product as a greenish yellow solid (0.731 g, 87%): mp 98−99 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.44 (br s, 1H), 7.82 (d, J = 7.3 Hz, 2H), 7.65−7.55 (m, 3H), 7.25−7.15 (m, 3H), 7.00 (t, J = 7.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.4, 172.1, 150.7, 133.0, 132.4, 128.9, 128.4, 127.2, 123.9, 122.3, 120.0, 111.0, 97.9. HRMS (ESI$^+$): m/z calcd for $C_{15}H_{10}NaO_3^+$ [M + Na]$^+$, 261.0528; found, 261.0523. Anal. Calcd for $C_{15}H_{10}O_3$: C, 75.62; H, 4.23. Found: C, 75.63; H, 4.25.

3-(Hydroxyl(4-methoxyphenyl)methylene)benzo[*b*]furan-2(3*H*)-one (3b). The title compound **3b** (0.758 g, 89%) was obtained from **2b** (1.00 g, 3.18 mmol) as a greenish yellow solid using a procedure analogous to that described for the preparation of **3a**: mp 134−135 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.50 (br s, 1H), 7.82 (d, J = 8.8 Hz, 2H), 7.32 (d, J = 7.7 Hz, 1H), 7.24−7.16 (m, 2H), 7.08−7.00 (m, 3H), 3.93 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.6, 172.3, 163.0, 150.5, 130.5, 126.8, 125.2, 123.8, 122.7, 119.8, 114.3, 111.0, 96.9, 55.7. HRMS (ESI$^+$): m/z calcd for $C_{16}H_{12}NaO_4^+$ [M + Na]$^+$, 291.0633; found, 291.0631. Anal. Calcd for $C_{16}H_{12}O_4$: C, 71.64; H, 4.51. Found: C, 71.67; H, 4.46.

3-(Hydroxyl(3-methoxyphenyl)methylene)benzofuran-2(3*H*)-one (3c). The title compound **3c** (0.734 g, 86%) was obtained from **2c** (1.00 g, 3.18 mmol) as a greenish yellow solid using a procedure analogous to that described for the preparation of **3a**: mp 104−105 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.43 (br s, 1H), 7.48 (t, J = 7.9 Hz, 1H), 7.40 (d, J = 7.6 Hz, 1H), 7.32−7.13 (m, 5H), 7.01 (td, J = 7.8, 1.3 Hz, 1H), 3.87 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.4, 171.9, 159.9, 150.7, 134.1, 130.1, 127.2, 123.9, 122.2, 120.7, 120.2, 118.5, 113.2, 111.1, 98.0, 55.7. HRMS (ESI$^+$): m/z calcd for $C_{16}H_{12}NaO_4^+$ [M + Na]$^+$, 291.0633; found, 291.0628. Anal. Calcd for $C_{16}H_{12}O_4$: C, 71.64; H, 4.51. Found: C, 71.62; H, 4.53.

3-(Hydroxyl(2-methoxyphenyl)methylene)benzofuran-2(3*H*)-one (3d). The title compound **3d** (0.658 g, 77%) was obtained from **2d** (1.00 g, 3.18 mmol) as a greenish yellow solid using a procedure analogous to that described for the preparation of **3a**: mp 145−146 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.06 (br s, 1H), 7.57 (t, J = 7.9 Hz, 1H), 7.51 (d, J = 7.4 Hz, 1H), 7.14 (m, 4H), 6.95 (t, J = 7.2 Hz, 1H), 6.60 (d, J = 7.7 Hz, 1H), 3.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.8, 169.6, 157.0, 150.7, 133.1, 129.9, 126.8, 123.8, 122.7, 122.0, 121.0, 120.2, 111.7, 110.7, 99.9, 55.8. HRMS (ESI$^+$): m/z calcd

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for $C_{16}H_{12}NaO_4^+$ $[M + Na]^+$, 291.0633; found, 291.0629. Anal. Calcd for $C_{16}H_{12}O_4$: C, 71.64; H, 4.51. Found: C, 71.65; H, 4.51.

3-(3,4-Dimethoxyphenyl(hydroxyl)methylene)benzofuran-2(3*H*)-one (3e). The title compound **3e** (0.711 g, 82%) was obtained from **2e** (1.00 g, 2.90 mmol) as a greenish yellow solid using a procedure analogous to that described for the preparation of **3a**: mp 142−143 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.51 (br s, 1H), 7.50 (dd, J = 8.3, 1.8 Hz, 1H), 7.39−7.31 (m, 2H), 7.23−7.15 (m, 2H), 7.05−6.99 (m, 2H), 4.00 (s, 3H), 3.93 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.6, 172.1, 152.6, 150.5, 149.1, 126.9, 125.2, 123.7, 122.6, 122.4, 119.9, 111.1, 110.9, 110.8, 96.9, 56.3, 56.2. HRMS (ESI$^+$): m/z calcd for $C_{17}H_{14}NaO_5^+$ $[M + Na]^+$, 321.0739; found, 321.0733. Anal. Calcd for $C_{17}H_{14}O_5$: C, 68.45; H, 4.73. Found: C, 68.44; H, 4.73.

3-(4-Fluorophenyl(hydroxyl)methylene)benzo[*b*]furan-2(3*H*)-one (3f). The title compound **3f** (0.798 g, 66%) was obtained from **2f** (1.44 g, 4.75 mmol) as a greenish yellow solid using a procedure analogous to that described for the preparation of **3a**: mp 122−123 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.42 (br s, 1H), 7.85 (dd, J = 8.4, 5.4 Hz, 2H), 7.30−7.16 (m, 5H), 7.02 (t, J = 7.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.3, 170.8, 165.0 (d, $^1J_{C-F}$ = 254.0 Hz) 150.7, 130.9 (d, $^3J_{C-F}$ = 9.0 Hz), 129.1 (d, $^4J_{C-F}$ = 3.4 Hz), 127.4, 124.0, 122.1, 119.8, 116.3 (d, $^2J_{C-F}$ = 22.1 Hz), 111.2, 97.9. HRMS (ESI$^+$): m/z calcd for $C_{15}H_9FNaO_3^+$ $[M + Na]^+$, 279.0433; found, 279.0429. Anal. Calcd for $C_{15}H_9FO_3$: C, 70.31; H, 3.54. Found: C, 70.12; H, 3.59.

3-(4-Bromophenyl(hydroxyl)methylene)benzo[*b*]furan-2(3*H*)-one (3g). The title compound **3g** (0.740 g, 85%) was obtained from **2g** (1.00 g, 2.75 mmol) as a bright yellow solid using a procedure analogous to that described for the preparation of **3a**: mp 149−150 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.38 (br s, 1H), 7.75−7.67 (m, 4H), 7.28−7.16 (m, 3H), 7.03 (t, J = 7.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.3, 170.5, 150.8, 132.3, 131.8, 130.0, 127.6, 127.0, 124.0, 121.9, 119.9, 111.3, 98.3. HRMS (ESI$^+$): m/z calcd for $C_{15}H_8BrNaO_3^+$ $[M - H + Na]^+$, 337.9555; found, 337.9550. Anal. Calcd for $C_{15}H_9BrO_3$: C, 56.81; H, 2.86. Found: C, 56.81; H, 2.86.

3-(Hydroxyl(2-naphthyl)methylene)benzo[*b*]furan-2(3*H*)-one (3h). The title compound **3h** (0.759 g, 88%) was obtained from **2h** (1.00 g, 2.99 mmol) as a greenish yellow solid using a procedure analogous to that described for the preparation of **3a**: mp 135−137 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.54 (s, 1H), 8.37 (s, 1H), 8.03 (d, J = 8.5 Hz, 1H), 7.96 (d, J = 8.3 Hz, 2H), 7.85 (dd, J = 8.5, 1.2 Hz, 1H), 7.69−7.59 (m, 2H), 7.27−7.19 (m, 3H), 7.02−6.95 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.5, 172.1, 150.8, 135.1, 132.6, 130.2, 129.4, 129.0, 128.9, 128.5, 128.1, 127.3, 127.2, 124.5, 123.9, 122.4, 120.0, 111.1, 98.1. HRMS (ESI$^+$): m/z calcd for $C_{19}H_{12}NaO_3^+$ $[M + Na]^+$, 311.0684; found, 311.0678. Anal. Calcd for $C_{19}H_{12}O_3$: C, 79.16; H, 4.20. Found: C, 79.17; H, 4.20.

3-(Hydroxyl((*E*)-4-methoxystyryl)methylene)benzo[*b*]furan-2(3*H*)-one (3i). The title compound **3i** (0.656 g, 76%) was obtained from **2i** (1.00 g, 2.94 mmol) as an orange solid using a procedure analogous to that described for the preparation of **3a**: mp 136−137 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.78 (s, 1H), 7.75 (d, J = 15.5 Hz, 1H), 7.56 (d, J = 8.6 Hz, 2H), 7.49−7.43 (m, 1H), 7.26−7.12 (m, 3H), 7.02 (d, J = 15.5 Hz, 1H), 6.94 (d, J = 8.6 Hz, 2H), 3.85 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.0, 167.1, 162.0, 150.7, 142.1, 130.3, 127.6, 126.4, 124.2, 123.0, 120.5, 115.2, 114.7, 111.1, 97.5, 55.6. HRMS (ESI$^+$): m/z calcd for $C_{18}H_{14}NaO_4^+$ $[M + Na]^+$, 317.0790; found, 317.0785. Anal. Calcd for $C_{18}H_{14}O_4$: C, 73.46; H, 4.80. Found: C, 73.45; H, 4.81.

3-(Hydroxyl(isobutyl)methylene)benzo[*b*]furan-2(3*H*)-one (3j). The title compound **3j** (0.749 g, 91%) was obtained from **2j** (1.00 g, 3.78 mmol) as an off-white solid using a procedure analogous to that described for the preparation of **3a**: mp 68−70 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.06 (br s, 1H), 7.34 (d, J = 7.2 Hz, 1H), 7.27−7.15 (m, 3H), 2.64 (d, J = 7.3 Hz, 2H), 2.26 (sep, J = 6.8 Hz, 1H), 1.11−1.05 (overlapped s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 178.1, 173.6, 150.5, 126.5, 124.2, 122.8, 120.1, 111.1, 98.4, 42.6, 27.1, 22.7. HRMS (ESI$^+$): m/z calcd for $C_{13}H_{14}NaO_3^+$ $[M + Na]^+$, 241.0841; found, 241.0834. Anal. Calcd for $C_{13}H_{14}O_3$: C, 71.54; H, 6.47. Found: C, 71.55; H, 6.48.

3-(Cyclopropyl(hydroxyl)methylene)benzo[*b*]furan-2(3*H*)-one (3k). The title compound **3l** (0.716 g, 88%) was obtained from **2l** (1.00 g, 4.03 mmol) as a white solid using a procedure analogous to that described for the preparation of **3a**: mp 101−102 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.13 (s, 1H), 7.50−7.43 (m, 1H), 7.25−7.12 (m, 3H), 2.27−2.19 (m, 1H), 1.48−1.40 (m, 2H), 1.26−1.20 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 179.2, 173.4, 150.3, 126.0, 124.0, 123.3, 119.5, 111.0, 97.2, 14.5, 10.5. HRMS (ESI$^+$): m/z calcd for $C_{12}H_9NaO_3^+$ $[M - H + Na]^+$, 224.0449; found, 224.0447. Anal. Calcd for $C_{12}H_{10}O_3$: C, 71.28; H, 4.98. Found: C, 71.28; H, 4.98.

3-(Cyclohexyl(hydroxyl)methylene)benzo[*b*]furan-2(3*H*)-one (3l). The title compound **3k** (0.732 g, 87%) was obtained from **2k** (1.00 g, 3.44 mmol) as a white solid using a procedure analogous to that described for the preparation of **3a**: mp 100−101 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.13 (br s, 1H), 7.28 (d, J = 7.5 Hz, 1H), 7.25−7.13 (m, 3H), 2.88 (t, J = 11.8 Hz, 1H), 1.90 (d, J = 11.0 Hz, 4H), 1.78 (d, J = 12.4 Hz, 1H), 1.70−1.60 (m, 2H), 1.47−1.25 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 182.3, 174.0, 150.4, 126.3, 124.2, 122.7, 120.1, 111.1, 96.4, 42.6, 28.6, 26.0, 25.7. HRMS (ESI$^+$): m/z calcd for $C_{15}H_{16}NaO_3^+$ $[M + Na]^+$, 267.0997; found, 267.0992. Anal. Calcd for $C_{15}H_{16}O_3$: C, 73.75; H, 6.60. Found: C, 73.74; H, 6.62.

Methyl 2-Phenylbenzo[*b*]furan-3-carboxylate (6a). **3a** (0.500 g, 2.10 mmol) was suspended in anhydrous methanol (20 mL), and concentrated sulfuric acid (ca. 2 mL) was added carefully to this mixture. The reaction mixture was heated under reflux for 6 h. The reaction mixture was cooled and concentrated under reduced pressure. The resulting residue was diluted with dichloromethane (20 mL) and washed with saturated aqueous sodium bicarbonate solution (20 mL × 3). The organic layer was dried under anhydrous $MgSO_4$ and concentrated *in vacuo*. The resulting residue was recrystallized from *n*-hexane to give **6a** (0.478 g, 90%) as a white solid: mp 79−80 °C (lit. mp[4c,e] = 77−78 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.08−7.99 (m, 3H), 7.59−7.50 (m, 4H), 7.43−7.36 (m, 2H), 3.97 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.5, 160.9, 153.8, 130.3, 129.6, 129.5, 128.2, 127.0, 125.3, 124.1, 122.7, 111.2, 108.8, 51.7. HRMS (ESI$^+$): m/z calcd for $C_{16}H_{12}NaO_3^+$ $[M + Na]^+$, 275.0684; found, 275.0679. Anal. Calcd for $C_{16}H_{12}O_3$: C, 76.18; H, 4.79. Found: C, 76.15; H, 4.82. All spectral data are consistent with previously reported values.[4c,e]

Methyl 2-(4-Methoxyphenyl)benzo[*b*]furan-3-carboxylate (6b). The title compound **6b** (0.484 g. 92%) was obtained from **3b** (0.500 g, 1.86 mmol) as a white solid using a procedure analogous to that described for the preparation of **6a**: mp 80−81 °C (lit. mp[12] = 78−79 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09−8.00 (m, 3H), 7.54−7.49 (m, 1H), 7.37−7.32 (m, 2H), 7.02 (d, J = 8.9 Hz, 2H), 3.95 (s, 3H), 3.89 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 161.3, 161.3, 153.6, 131.3, 127.3, 125.0, 124.0, 122.7, 122.1, 113.7, 111.1, 107.6, 55.5, 51.7. HRMS (ESI$^+$): m/z calcd for $C_{17}H_{14}NaO_4^+$ $[M + Na]^+$, 305.0790; found, 305.0782. Anal. Calcd for $C_{17}H_{14}O_4$: C, 72.33; H, 5.00. Found: C, 72.40; H, 5.03. All spectral data are consistent with previously reported values.[4c,12]

Methyl 2-(3-Methoxyphenyl)benzo[*b*]furan-3-carboxylate (6c). The title compound **6c** (0.479 g, 91%) was obtained from **3c** (0.500 g, 1.86 mmol) as a white solid using a procedure analogous to that described for the preparation of **6a**: mp 79−80 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11−8.03 (m, 1H), 7.69−7.62 (m, 2H), 7.57−7.51 (m, 1H), 7.45−7.34 (m, 3H), 7.08−7.02 (m, 1H), 3.96 (s, 3H), 3.90 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.5, 160.5, 159.3, 153.7, 130.8, 129.3, 127.1, 125.4, 124.1, 122.8, 122.0, 116.5, 114.6, 111.2, 109.0, 55.5, 51.8. HRMS (ESI$^+$): m/z calcd for $C_{17}H_{14}NaO_4^+$ $[M + Na]^+$, 305.0790; found, 305.0785. Anal. Calcd for $C_{17}H_{14}O_4$: C, 72.33; H, 5.00. Found: C, 72.36; H, 5.02.

Methyl 2-(2-Methoxyphenyl)benzo[*b*]furan-3-carboxylate (6d). The title compound **6d** (0.473 g, 90%) was obtained from **3d** (0.500 g, 1.86 mmol) as a colorless film using a procedure analogous to that described for the preparation of **6a**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09−8.03 (m, 1H), 7.62−7.52 (m, 2H), 7.48 (td, J = 8.4, 1.6 Hz, 1H), 7.39−7.34 (m, 2H), 7.09 (t, J = 7.5 Hz, 1H), 7.03 (d, J = 8.4 Hz, 1H), 3.85−3.82 (overlapped s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.5, 158.2, 157.7, 154.3, 131.8, 131.4, 126.7, 125.0, 123.9, 122.1, 120.4, 119.4, 111.3, 111.2, 111.1, 55.7, 51.6. HRMS (ESI$^+$): m/z

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calcd for $C_{17}H_{14}NaO_4^+$ [M + Na]$^+$, 305.0790; found, 305.0784. Anal. Calcd for $C_{17}H_{14}O_4$: C, 72.33; H, 5.00. Found: C, 72.37; H, 5.04. All spectral data are consistent with previously reported values.[13]

Methyl 2-(3,4-Dimethoxyphenyl)benzo[*b*]furan-3-carboxylate (6e). The title compound **6e** (0.498 g, 92%) was obtained from **3e** (0.500 g, 1.73 mmol) as a white solid using a procedure analogous to that described for the preparation of **6a**: mp 89−90 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07−8.01 (m, 1H), 7.77−7.72 (m, 2H), 7.54−7.49 (m, 1H), 7.36−7.31 (m, 2H), 6.99−6.95 (m, 1H), 3.99 (s, 3H), 3.95 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 160.9, 153.5, 150.9, 148.4, 127.3, 125.1, 124.0, 123.1, 122.7, 122.1, 112.4, 111.0, 110.6, 107.8, 56.1, 56.1, 51.7. HRMS (ESI$^+$): *m*/*z* calcd for $C_{18}H_{16}NaO_5^+$ [M + Na]$^+$, 335.0895; found, 335.0889. Anal. Calcd For $C_{18}H_{16}O_5$: C, 69.22; H, 5.16. Found: C, 69.26; H, 5.16.

Methyl 2-(4-Fluorophenyl)benzo[*b*]furan-3-carboxylate (6f). The title compound **6f** (0.475 g, 90%) was obtained from **3f** (0.500 g, 1.95 mmol) as a white solid using a procedure analogous to that described for the preparation of **6a**: mp 92−93 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11−8.03 (m, 3H), 7.56−7.50 (m, 1H), 7.40−7.33 (m, 2H), 7.19 (t, *J* = 8.7 Hz, 2H), 3.96 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.6, 164.0 (d, *J* = 251.5 Hz), 160.0, 153.8, 131.8 (d, *J* = 8.6 Hz), 127.0, 125.8 (d, *J* = 3.4 Hz), 125.5, 124.2, 122.9, 115.4 (d, *J* = 21.8 Hz), 111.2, 108.7, 51.8. HRMS (ESI$^+$): *m*/*z* calcd for $C_{16}H_{11}FNaO_3^+$ [M + Na]$^+$, 293.0590; found, 293.0584. Anal. Calcd for $C_{16}H_{11}FO_3$: C, 71.11; H, 4.10. Found: C, 71.18; H, 4.13.

Methyl 2-(4-Bromophenyl)benzo[*b*]furan-3-carboxylate (6g). The title compound **6g** (0.481 g, 91%) was obtained from **3g** (0.500 g, 1.58 mmol) as a white solid using a procedure analogous to that described for the preparation of **6a**: mp 101−102 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.08−8.02 (m, 1H), 7.94 (d, *J* = 8.5 Hz, 2H), 7.63 (d, *J* = 8.5 Hz, 2H), 7.56−7.51 (m, 1H), 7.41−7.34 (m, 2H), 3.96 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.5, 159.7, 153.8, 131.5, 131.1, 128.5, 127.0, 125.7, 125.0, 124.3, 122.9, 111.3, 109.3, 51.9. HRMS (ESI$^+$): *m*/*z* calcd for $C_{16}H_{11}BrNaO_3^+$ [M + Na]$^+$, 352.9789; found, 352.9783. Anal. Calcd for $C_{16}H_{11}BrO_3$: C, 58.03; H, 3.35. Found: C, 58.01; H, 3.35.

Methyl 2-(2-Naphthyl)benzo[*b*]furan-3-carboxylate (6h). The title compound **6h** (0.456 g, 87%) was obtained from **3h** (0.500 g, mmol) as a white solid using a procedure analogous to that described for the preparation of **6a**: mp 95−96 °C (lit. mp[4c] = 83−84 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.62 (s, 1H), 8.12−8.07 (m, 2H), 8.00−7.88 (m, 3H), 7.61−7.53 (m, 3H), 7.42−7.36 (m, 2H), 3.97 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.7, 160.9, 154.0, 134.1, 132.9, 130.0, 129.1, 127.8, 127.8, 127.6, 127.3, 127.0, 126.6, 126.2, 125.5, 124.2, 122.8, 111.3, 109.1, 51.8. HRMS (ESI$^+$): *m*/*z* calcd for $C_{20}H_{14}NaO_3^+$ [M + Na]$^+$, 325.0841; found, 325.0835. Anal. Calcd for $C_{20}H_{14}O_3$: C, 79.46; H, 4.67. Found: C, 79.45; H, 4.64. All spectral data are consistent with previously reported values.[4c]

Methyl (*E*)-2-(4-Methoxystyryl)benzo[*b*]furan-3-carboxylate (6i). The title compound **6i** (0.465 g, 89%) was obtained from **3i** (0.500 g, 1.70 mmol) as a greenish yellow solid using a procedure analogous to that described for the preparation of **6a** and a longer reaction time (24 h): mp 90−91 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03−7.94 (m, 1H), 7.77 (d, *J* = 16.3 Hz, 1H), 7.60−7.53 (m, 3H), 7.50−7.44 (m, 1H), 7.35−7.28 (m, 2H), 6.93 (d, *J* = 8.7 Hz, 2H), 4.00 (s, 3H), 3.85 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.9, 160.7, 160.5, 153.9, 135.5, 129.2, 128.9, 126.8, 125.4, 124.0, 122.3, 114.4, 113.4, 110.8, 108.0, 55.5, 51.7. HRMS (ESI$^+$): *m*/*z* calcd for $C_{19}H_{16}NaO_4^+$ [M + Na]$^+$, 331.0946; found, 331.0941. Anal. Calcd for $C_{19}H_{16}O_4$: C, 74.01; H, 5.23. Found: C, 74.04; H, 5.16.

Methyl 2-Isobutylbenzo[*b*]furan-3-carboxylate (6j). The title compound **6j** (0.453 g, 85%) was obtained from **3j** (0.500 g, 2.29 mmol) as a colorless oil using a procedure analogous to that described for the preparation of **6a** and a longer reaction time (12 h): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02−7.93 (m, 1H), 7.47−7.40 (m, 1H), 7.32−7.23 (m, 2H), 3.94 (s, 3H), 3.08 (d, *J* = 7.3 Hz, 2H), 2.23 (sep, *J* = 6.8 Hz, 1H), 1.00 (d, *J* = 6.7 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 165.0, 153.7, 126.1, 124.4, 123.8, 122.0, 110.9, 109.2, 51.4, 36.8, 28.4, 22.6. HRMS (ESI$^+$): *m*/*z* calcd for $C_{14}H_{16}NaO_3^+$ [M + Na]$^+$, 255.0997; found, 255.0992. Anal. Calcd for $C_{14}H_{16}O_3$: C, 72.39; H, 6.94. Found: C, 72.35; H, 6.99.

Methyl 2-Cyclopropylbenzo[*b*]furan-3-carboxylate (6k). The title compound **6k** (0.464 g, 87%) was obtained from **3k** (0.500 g, 2.47 mmol) as a white solid using a procedure analogous to that described for the preparation of **6a** and a longer reaction time (12 h): mp 61−62 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95−7.90 (m, 1H), 7.34 (d, *J* = 7.6 Hz, 1H), 7.30−7.20 (m, 2H), 3.96 (s, 3H), 3.10−3.02 (m, 1H), 1.31−1.26 (m, 2H), 1.20−1.15 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.0, 165.5, 152.8, 126.7, 124.1, 123.8, 121.4, 110.7, 108.3, 51.5, 9.8, 9.7. HRMS (ESI$^+$): *m*/*z* calcd for $C_{13}H_{12}NaO_3^+$ [M + Na]$^+$, 239.0684; found, 239.0679. Anal. Calcd for $C_{13}H_{12}O_3$: C, 72.21; H, 5.59. Found: C, 72.24; H, 5.57.

Methyl 2-Cyclohexylbenzo[*b*]furan-3-carboxylate (6l). The title compound **6l** (0.467 g, 88%) was obtained from **3l** (0.500 g, 2.05 mmol) as a white solid using a procedure analogous to that described for the preparation of **6a** and a longer reaction time (12 h): mp 57−58 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00−7.93 (m, 1H), 7.49−7.42 (m, 1H), 7.33−7.26 (m, 2H), 3.96 (s, 3H), 3.71 (tt, *J* = 12.0, 3.4 Hz, 1H), 1.97−1.84 (m, 4H), 1.82−1.67 (m, 3H), 1.51−1.26 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.3, 165.1, 153.6, 126.2, 124.3, 123.8, 122.0, 111.1, 107.1, 51.5, 37.4, 30.8, 26.3, 26.0. HRMS (ESI$^+$): *m*/*z* calcd for $C_{16}H_{18}NaO_3^+$ [M + Na]$^+$, 281.1154; found, 281.1149. Anal. Calcd for $C_{16}H_{18}O_3$: C, 74.40; H, 7.02. Found: C, 74.44; H, 7.11.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.5b01311.

Crystallography data of product **3h** (CCDC 1057072) (CIF)

^{1}H and ^{13}C NMR spectra of compounds (PDF)

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Notes

The authors declare no competing financial interest.

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