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Organo-Catalyzed Regio- and Geometry-Specific Construction of β-Hydroxyl-α-Vinyl Carboxylic Esters: Substrate Scope, Mechanistic Insights and Applications

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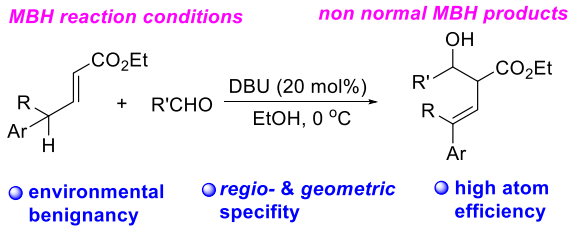
Supporting Information Placeholder



ABSTRACT: A green protocol has been developed for the synthesis of β-hydroxyl-α-vinyl carboxylic esters using aldehydes and α,β-unsaturated esters bearing an activated γ proton as starting materials under Morita-Baylis-Hillman (MBH) reaction conditions. Diverse β-hydroxyl-α-vinyl carboxylic esters have been synthesized regio-specifically in moderate to good yields with only E geometric selectivity. Other remarkable features include atom efficiency, environmental benignancy and mild reaction conditions. Furthermore, the reaction products could be readily converted into tetrahydrofuran, dihydrofuran and furan derivatives.

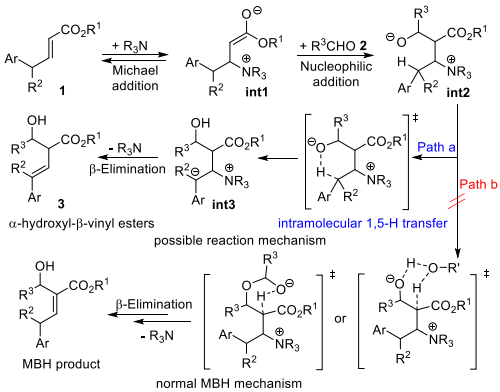
■ INTRODUCTION

β-Hydroxyl-α-vinyl carboxylic esters, a kind of highly functionalized compounds, contain several important structural motifs including homoallylic alcohols, β,γ-unsaturated esters and β-hydroxy esters. Thus, β-hydroxyl-α-vinyl carboxylic esters are versatile building blocks in organic synthesis, and their applications have been well documented in total synthesis as well as in medicinal chemistry.[1-7] In contrast to their wide use in synthesis, few methods[8-27] are available to prepare this kind of compounds, mainly including allylation of aldehydes with γ-(alkoxycarbonyl)-substituted allyl metal reagents[8-18] and deconjugative aldol condensation of aldehydes or ketones with crotyl derivatives[19-24]. Unfortunately, those processes often suffer from some drawbacks such as harsh reaction conditions, poor regioselectivity, and use of stoichiometric metal catalysts or highly toxic reagents. Therefore, new facile and regioselective synthetic approaches are still in great demand.

With this goal in mind, we hypothesized that under the condition of Morita-Baylis-Hillman (MBH) reaction[28], usually catalytic amounts of amine, α,β-unsaturated ester with an activated hydrogen in γ position might react with aldehyde to form a new type of compound, β-hydroxyl-α-vinyl carboxylic ester, instead of the common MBH product. The reaction involves reversible conjugate addition of the nucleophilic amine catalyst to Michael acceptor **1** to generate an β-ammonium enolate **int1**, nucleophilic attack of **int1** on the aldehyde **2** to form a second zwitter ionic intermediate **int2**, and then intramolecular 1,5-proton transfer[29] to produce **int3**, followed by β-elimination to give the final product **3** with liberation of the amine catalyst (Scheme 1).

This novel protocol not only inherits the merits of MBH reaction such as atom efficiency, environmental benignancy, mild reaction conditions, etc, but also earns some new advantages including the formation of two new stereogenic centers in one step, and the wide applications in the rapid construction of diverse structural frameworks, especially tetrahydrofuran, dihydrofuran and furan derivatives.

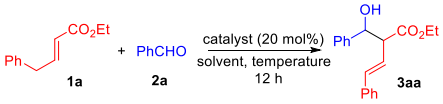
Scheme 1. Possible mechanism for the reaction of aldehydes and α,β-unsaturated esters with an activated γ proton under MBH condition

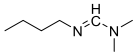


■ RESULTS AND DISCUSSION

To evaluate our hypothesis, commercially available ethyl *(E)*-4-phenyl-2-butenoate (**1a**) and benzaldehyde (**2a**) were chosen as the model substrates. Gratifyingly, when **1a** and **2a** were treated with 20 mol% DBU in EtOH at rt, the expected product *(E)*-ethyl-2-(hydroxy(phenyl)methyl)-4-phenylbut-3-enoate (**3aa**) was obtained regiospecifically as a pair of diastereoisomers (dr 1:1) in 48% yield (Table 1, entry 1). To improve the yield, a series of tertiary amines and tertiary phosphines were tested (Table 1, entries 2-8). Among these commonly used catalysts for MBH reaction, DBU was proved to be the most effective one, which may be ascribed to the fact that the β-ammonium enolate intermediate **int1** can gain the extra stability from the conjugation of two nitrogens in DBU[30]. The solvent investigation showed that non-protic solvents, such as MeCN, THF and 1,4-dioxane, resulted in lower yields (Table 1, entries 9-11) while protic solvents, such as MeOH and EtOH, led to higher yields (Table 1, entries 12-13). Considering cost as well as environmental benignancy, EtOH was chosen as the reaction solvent. After further screening on the catalyst loading (Table 1, entry 1[d,e]), the reaction temperature (Table 1, entries 13-15), and the addition sequence (Table 1, entry 16), the optimal reaction condition was determined to be DBU (20 mol%) in EtOH at 0 °C with certain addition sequence (Table 1, entry 16).

Table 1. Optimization of Reaction Conditions of 1a with 2a

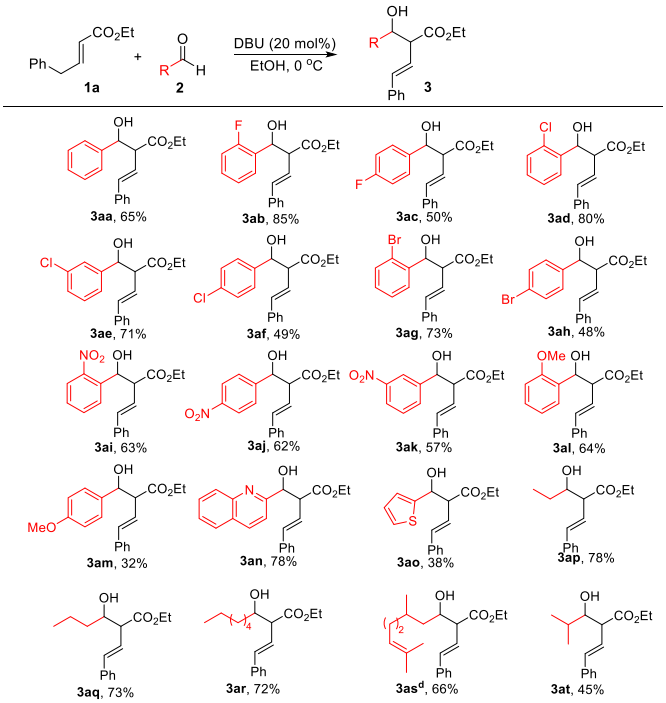


entry[a]	catalyst	Temp.	solvent	Yield (%)[b,c]
1	DBU[d,e]	rt	EtOH	48
2	DABCO	rt	EtOH	0
3	PPh_3	rt	EtOH	0
4	DBN	rt	EtOH	44
5		rt	EtOH	30
6		rt	EtOH	32
7		rt	EtOH	26
8	TMG	rt	EtOH	38
9	DBU	rt	CH_3CN	27
10	DBU	rt	1,4-dioxane	25
11	DBU	rt	THF	35
12	DBU	rt	MeOH	62
13	DBU	0 °C	EtOH	57
14	DBU	reflux	EtOH	19
15	DBU	-20 °C	EtOH	47
16[f]	DBU	0 °C	EtOH	65

[a]Unless otherwise noted, all reactions were carried out as follows: **2a** (1 mmol) and catalyst (20 mol %) were added successively to the solution of **1a** (1mmol) in solvent (2 mL), then the reaction mixture was stirred for 12 h; [b]Isolated yield; [c]dr = 1:1; [d]10 mol % of DBU was employed and the isolated yield is 41 %; [e]100 mol % of DBU was employed and the isolated yield is 50 %; [f]**1a** (1mmol), DBU (20 mol%), **2a** (1 mmol) and EtOH (2 mL) were added successively to a flask, then the reaction mixture was stirred at 0 °C for 12 h.

With the optimal condition in hand, we first explored the substrate scope of the method using different aldehydes, and the results are illustrated in Table 2. By treatment with DBU (20 mol%) in EtOH at 0 °C, *(E)*-4-phenyl-2-butenoate (**1a**) could react with various aromatic/hetero aromatic/polycyclic aromatic aldehydes, giving the corresponding *(E)*-β-hydroxyl-α-vinyl carboxylic esters in moderate to good yields (**3aa**-**3ao**). Generally, aromatic aldehydes with substituents in *ortho* position led to better outcomes than those with substituents in *meta* or *para* position (**3ad**, 80% *vs* **3ae**-**3af**, 47-71%), indicating that the steric hindrance of the aryl ring has little effect on this reaction. Meanwhile, electron-deficient aromatic aldehydes resulted in higher yields than electron-rich ones (**3ac**, **3af**, **3ah**, **3aj**, 48-62% *vs* **3am**, 32%), which revealed the coupling reaction has great dependence on the electronic effect. Notably, the big difference between the yields of **3ab** and **3ac** further disclosed the crucial role of the electron-withdrawing inductive effect in the formation of β-hydroxyl-α-vinyl carboxylic esters. Moreover, the outcomes of *ortho*-halogenated products (**3ad**, **3ag**, and **3al**) and *para*-halogenated products (**3af**, **3ah**, and **3am**) were also in agreement with this disclosure. When using a mixture of THF and water (50:1 v/v) instead of EtOH as the solvent, the coupling of **1a** with aliphatic aldehydes also proceeded smoothly (**3ap**-**3at**). In contrast to the substituted aromatic aldehydes, the steric hindrance of the aliphatic aldehydes has a significant impact on this reaction (**3ap**-**3ar**, 72-78% *vs* **3as**-**3at**, 45-66%).

Table 2. The substrate scope of the aldehydes[a,b,c]

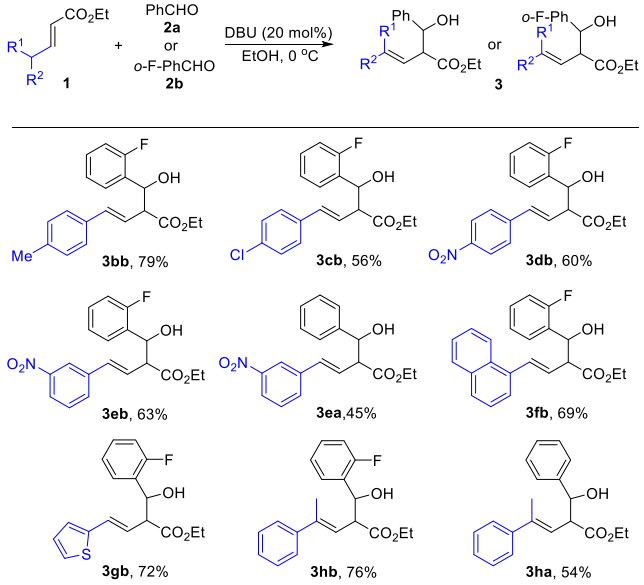


[a]For aromatic/hetero aromatic/polycyclic aromatic aldehydes (**2a**-**2q**), the reactions were carried out as follows: **1a** (1mmol), DBU (20 mol%), **2** (1 mmol) and EtOH (2 mL) were added successively to a flask, then the reaction mixture was stirred at 0 °C for 12 h; for

aliphatic aldehydes, the reactions were carried out as follows: **1a** (1mmol), DBU (20 mol%), **2** (1 mmol), THF (2 mL) and H_2O (27 uL) was added successively to a flask, then the reaction mixture was stirred at 0 °C for 12 h; [b] Isolated yield; [c] Except **3as**, all products were obtained as a pair of diastereoisomers and the dr value was approximately equal to 1:1; [d]The ratio of the four diastereomers was 2:1:1.3:1.7.

Next, we focused on the substrate scope in terms of various α,β-unsaturated esters containing an aryl-activated γ hydrogen. As shown in Table 3, *(E)*-4-aryl-2-butenoate **1** with electron-donating groups on the aryl ring was well tolerated under the optimal condition and furnished the expected product in good yields (**3bb**). Similarly, the electron-withdrawing groups such as chloro and nitro, were compatible with this catalytic system, affording the corresponding *(E)*-β-hydroxyl-α-vinyl carboxylic esters in moderate yields (**3cb**-**3ea**). The coupling of **1f** and **1g** with aldehyde **1b** also worked well, indicating our approach was applicable to polycyclic and hetero aromatic substrates (**3fb** and **3gb**). To further extend the generality of this reaction, *(E)*-ethyl 4-phenyl-2-pentenoate **1h** was employed and the results proved that α,β-unsaturated esters with an aryl substitute and an alkyl substitute in γ position were also suitable substrates for the transformation (**3ha** and **3hb**).

Table 3. Substrate scope of the α,β-unsaturated ester[a,b,c]

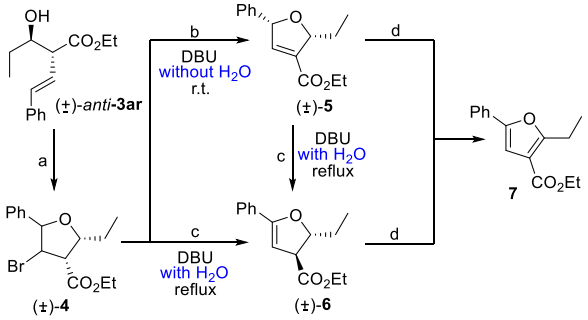


[a]All reactions were carried out as follows: **2** (1 mmol) and catalyst (20 mol %) were added successively to the solution of **1** (1mmol) in solvent (2 mL), then the reaction mixture was stirred for 12 h; [b] Isolated yield; [c] In all cases, the products were obtained as a pair of diastereoisomers and the dr value was approximately equal to 1:1.

It is noteworthy that the coupling reaction demonstrated excellent regio- and geometry-specificity, and only α-adducts with *(E)* configuration were attained, with no γ or *(Z)* isomers observed. All obtained *(E)*-β-hydroxyl-α-vinyl carboxylic esters consist of two diastereomers and the dr value was approximately 1:1. The structure of the products was firmly established by NMR experiments and single-crystal X-ray diffraction (XRD) analysis of two selected compounds **3ah** and **3ad** (see SI, Figure S1 and Table S1).

As mentioned above, β-hydroxyl-α-vinyl carboxylic esters are versatile building blocks in organic synthesis[1-7] due to their unique structural skeleton and densely functionalized nature. For example, this kind of compounds could be applied to the rapid construction of substituted tetrahydrofurans, dihydrofurans and furans with multiple functional groups, which are privileged frameworks in many bioactive natural products, pharmaceuticals and materials[31-32]. As shown in Scheme 2, bromotetrahydrofuran (±)-**4** could be easily installed from our product, (±)-*anti*-**3ap**, by the treatment with 2 equiv of NBS at rt (Scheme 2, a). When DBU was employed, the elimination reaction of (±)-**4** occurred and produced dihydrofuran in high yields. With or without the addition of H_2O, 2,3- or 2,5-dihydrofuran could be obtained respectively (Scheme 2, b and c). By oxidation of these dihydrofurans, tri-substituted furan **7** was also prepared successfully (Scheme 2, d).

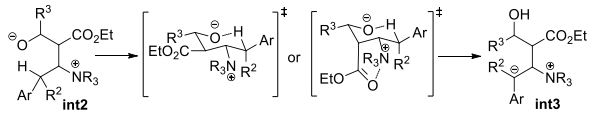
Scheme 2. Further applications of β-hydroxyl-α-vinyl carboxylic esters



(a) NBS (2 equiv)/DCM, rt, 92%; (b) DBU (1 equiv)/DCM, rt, 86%; (c) DBU (1 equiv)/H_2O (2 equiv)/DCM, reflux, 82% (from (±)-**4**) and 89% (from (±)-**5**); (d) DDQ (2 equiv)/toluene, reflux, 95% (from (±)-**5**) and 92% (from (±)-**6**).

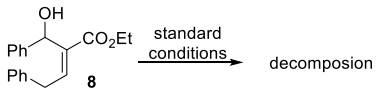
To gain some insight into the reaction mechanism, a series of experiments were conducted. In contrast to the commonly accepted mechanism for normal MBH reaction, which involves intermolecular six-membered proton transfer in the assistance of alcohol solvent[33-34] or a second molecular of aldehyde[35-36], there is a strong possibility that due to bearing an activated γ proton, the zwitter ionic intermediate **int2** may undergo intramolecular 1,5-proton transfer via a chair-like six-membered transition state to generate **int3**[29,37] (Scheme 1 and Scheme 3).

Scheme 3 Intramolecular 1,5-proton-transfer mechanism



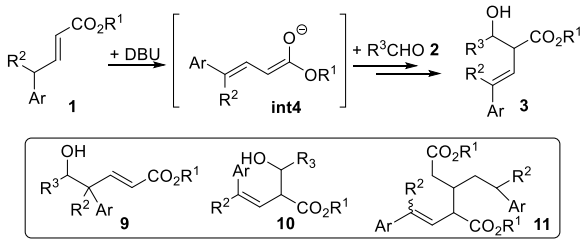
Throughout the entire reaction, no normal MBH product was observed[38], indicating that the activated proton in γ position in **int3** makes the direct intramolecular proton transfer much easier than intermolecular way. Furthermore, the decomposition of classic MBH compound **8** under the above-mentioned standard reaction conditions (Scheme 4, see SI, Figure S2) also illustrated that the formation of final β-hydroxyl-α-vinyl carboxylic esters is less likely through deconjugation of classic MBH products.

Scheme 4. Investigation of the plausible key intermediate



However, due to the basic nature of DBU, this reaction may occur via another possible mechanism as depicted in Scheme 5. DBU serves as a base to abstract γ proton, yielding the enolate intermediate **int4**, which then undergoes nucleophilic attack of aldehyde **2** to afford the desired product **3**. It should be noted that because of the lack of regio- and geometry-control, some side products such as γ adduct **9**, *(Z)* isomer **10** and dimmer **11**, might also generate, but in our case, none of them was observed. Actually, the coupling reaction of **1a** with benzaldehyde **2a** using other bases including *t*-BuOK, LDA, Hunig's base, 1,2,2,6,6-pentamethylpiperidine and 2,2,6,6-tetramethylpiperidine, didn't work well and the expected *(E)*-α-adduct was obtained in low (even zero) yields resulting from the mentioned side products (see SI, Table S2).

Scheme 5 Another possible mechanism and some plausible side products



In summary, we have developed a facile and efficient access to β-hydroxyl-α-vinyl carboxylic esters via DBU-catalyzed coupling reaction of aldehydes with α,β-unsaturated esters bearing an activated γ proton. Notable features of this approach include readily available starting material, green and inexpensive catalyst and solvent, mild conditions, convenient operations, good functional group compatibility, and excellent regio- and geometry-specificity. The approach should therefore have widespread applications in the synthesis of structurally diverse β-hydroxyl-α-vinyl carboxylic esters, which have been proved to be versatile building blocks in the fast installation of many important compounds, especially tetrahydrofuran, dihydrofuran and furan derivatives.

■ EXPERIMENTAL SECTION

General Considerations. NMR spectra were recorded at rt on Bruker Avance 400 MHz or 600 MHz spectrometers. The residual solvent signals were taken as the reference (0.00 ppm for ^{1}H NMR spectra and 77.0 ppm for ^{13}C NMR spectra in $CDCl_3$). Chemical shifts (δ) are reported in ppm, and coupling constants (J) are given in Hz. HRMS (ESI) spectra were recorded on a Waters Q-Tof premierTM mass spectrometer. All solvents were distilled under nitrogen atmosphere from the following drying agents immediately before use: toluene and DCM were distilled from CaH_2; EtOH was distilled from Mg powder; THF was distilled from Na. All reactions were carried out in flame or oven-dried glassware with magnetic stirring under argon atmosphere with freshly distilled dry solvents under anhydrous conditions unless otherwise indicated. Reactions were monitored by TLC on glass-backed plates coated with a 0.2 mm thickness of silica gel 60 F254; chromatograms were visualized by fluorescence quenching with UV light at 254 nm and then by staining with phosphomolybdic acid or sulfuric acid solution followed by heating. Flash column chromatography was performed with silica gel 300-400 mesh.

Preparation of substrates α,β-unsaturated esters.

Method A: Ethyl bromoacetate (30 mmol, 1.0 equiv) was added dropwisely to a solution of Ph_3P (30 mmol, 1.0 equiv) in toluene (100 mL). After stirring at rt overnight, the resulting white precipitate was filtered. The filter cake was dissolved in water. The resulting solution was slowly basified with NaOH solution (3 M) until pH 9, and then extracted with DCM (3 × 50 mL). The combined organic phase was washed successively with water (2 × 30 mL) and brine (1 × 30 mL), and then dried ($MgSO_4$) and filtered. The filtrate was concentrated *in vacuo* to give phosphorus salt, which was used in the next step without further purification. The corresponding aldehyde (20 mmol, 1.0 equiv) in DCM (10 mL) was added slowly to a solution of phosphorus salt (24 mmol, 1.2 equiv) in DCM (40 mL) at 0 °C. The resulting mixture was stirred at rt and monitored periodically by TLC. After completion, the reaction mixture was concentrated *in vacuo*, and then purified by flash column chromatography [silica gel, EtOAc/PE = 1:20] to give the α,β-unsaturated ester.

*Ethyl (E)-4-phenylbut-2-enoate (**1a**)*[39]*:* Yield: 91% (3.44 g, 18.1 mmol). Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.30 (t, J = 7.8 Hz, 2H), 7.22 (t, J = 6.6 Hz, 1H), 7.16 (d, J = 7.8 Hz, 2H), 7.09 (dt, J = 15.6, 7.2 Hz, 1H), 5.80 (d, J = 15.6 Hz, 1H), 4.16 (q, J = 7.2 Hz, 2H), 3.50 (d, J = 7.2 Hz, 2H), 1.29 – 1.22 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 166.3, 147.1, 137.6, 128.7, 128.6, 126.6, 122.3, 60.1, 38.2, 14.2.

*Ethyl (E)-4-(4-tolyl)but-2-enoate (**1b**)*[40]*:* Yield: 85% (3.47 g, 17.0 mmol). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.07 – 6.93 (m, 5H), 5.71 (dt, J = 15.2, 1.6 Hz, 1H), 4.08 (q, J = 6.8 Hz, 2H), 3.38 (dd, J = 6.8, 1.2 Hz, 2H), 2.24 (s, 3H), 1.18 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 147.5, 136.1, 134.6, 129.3, 128.6, 122.1, 60.1, 38.0, 20.9, 14.2.

*Ethyl (E)-4-(4-chlorophenyl)but-2-enoate (**1c**)*[41]*:* Yield: 93% (4.18 g, 18.6 mmol). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30 (d, J = 8.4 Hz, 2H), 7.12 (d, J =8.4 Hz, 2H), 7.10-1.03 (m, 1H), 5.81 (d, J = 15.6 Hz, 1H), 4.20 (q, J = 6.8 Hz, 2H), 3.50 (d, J = 6.4 Hz, 2H), 1.29 (t, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.2, 146.4, 136.1, 132.5, 130.1, 128.8, 122.7, 60.3, 37.7, 14.2.

*Ethyl (E)-4-(4-nitrophenyl)but-2-enoate (**1d**)*[42]*:* Yield: 83% (3.91 g, 16.6 mmol). Pale soild. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.18 (d, J = 9.0Hz, 2H), 7.50 (d, J = 8.4 Hz, 2H), 6.57 (d, J = 16.2 Hz, 1H), 6.51 (dt, J = 16.2, 6.6 Hz, 1H), 4.20 (q, J = 7.2 Hz, 2H), 3.30 (d, J = 6.6 Hz, 2H), 1.30 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.8, 146.9, 143.2, 131.4, 127.0, 126.7, 123.9, 61.0, 38.3, 14.1.

*Ethyl (E)-4-(3-nitrophenyl)but-2-enoate (**1e**)*[42]*:* Yield: 88% (4.14 g, 17.6 mmol). Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.12 (dt, J = 7.2, 1.8 Hz, 1H), 8.06 (s, 1H), 7.55 – 7.48 (m, 2H), 7.07 (dt, J = 15.6, 7.2 Hz, 1H), 5.84 (dt, J = 15.6, 1.2 Hz, 1H), 4.20 (q, J = 7.2 Hz, 2H), 3.64 (dd, J = 7.2, 1.2 Hz, 2H), 1.29 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 166.0, 145.0, 139.7, 135.0, 129.6, 123.7, 123.6, 121.9, 60.5, 37.9, 14.2.

*Ethyl (E)-4-phenylpent-2-enoate (**1h**)*[39]*:* Yield: 88% (3.60 g, 17.6 mmol). Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.32 (t, J = 7.2 Hz, 2H), 7.25 – 7.21 (m, 1H), 7.21 – 7.18 (m, 2H), 7.11 (dd, J = 15.6, 6.6 Hz, 1H), 5.80 (dd, J = 15.6, 1.2 Hz, 1H), 4.18 (q, J = 7.2 Hz, 2H), 3.61 (ddd, J = 13.8, 7.2, 1.2 Hz, 1H), 1.43 (d, J = 7.2 Hz, 3H), 1.27 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150

MHz, $CDCl_3$) δ 166.8, 152.6, 143.3, 128.7, 127.3, 126.7, 120.1, 60.3, 42.0, 20.3, 14.2.

Methord B: KF (20.25 mmol) was added to a solution of ethyl 4-bromocrotonate (6.8 mmol) in toluene/MeOH/H_2O (34 mL, V/V/V 4:4:1) and the solution was stirred for 20 min at rt. Then $Pd(OAc)_2$ (0.1125 mmol) and α-naphthalene boronic acid (4.5 mmol) were added. The resulting mixture was exhausted O_2 for 5 min and kept stirring at reflux under Ar atmosphere overnight. The reaction mixture was cooled to rt and EA (50 mL) were added. The organic layer was separated and washed successively with H_2O (2 × 15 mL), and brine (1 × 15 mL), then dried ($MgSO_4$) and filtered. The filtrate was concentrated *in vacuo* and the resulting residue was purified by column chromatography [silica gel, EtOAc–PE = 1:20] to give the expected product.

*Ethyl (E)-4-(naphthalen-1-yl)but-2-enoate (**1f**):* Yield: 73% (790 mg, 3.29 mmol). Pale oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.92 (d, J = 8.4 Hz, 1H), 7.87 (d, J = 7.2 Hz, 1H), 7.77 (d, J = 7.8 Hz, 1H), 7.53 – 7.47 (m, 2H), 7.42 (t, J = 7.2 Hz, 1H), 7.32 (d, J = 7.2 Hz, 1H), 7.25 (dt, J = 15.6, 6.6 Hz, 1H), 5.76 (dt, J = 15.6, 1.2 Hz, 1H), 4.14 (q, J = 7.2 Hz, 2H), 3.97 (dd, J = 7.2, 1.2 Hz, 2H), 1.24 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 166.5, 146.9, 133.9, 133.9, 131.8, 128.8, 127.6, 126.9, 126.2, 125.7, 125.6, 123.7, 122.7, 60.3, 35.6, 14.2; ESI-HRMS calcd for $C_{16}H_{16}NaO_2$ ([M+Na]$^+$) 263.1048, found 263.1053.

Methord C: $Pd(PPh_3)_4$ (0.2 mmol) was added to a solution of ethyl 4-bromocrotonate (4 mmol) in dioxane (36 mL) under argon atmosphere and the solution was stirred at rt for 10 min, and then boronic acid (8 mmol) and Na_2CO_3 (20 mmol) were added. The resulting reaction mixture was stirred at reflux. After about 1 h, the mixture was cooled to rt, and EA (50 mL) were added. The organic layer was separated and washed successively with H_2O (2 × 15 mL), and brine (1 × 15 mL), then dried ($MgSO_4$) and filtered. The filtrate was concentrated *in vacuo* and the resulting residue was purified by column chromatography [silica gel, EtOAc–PE = 1:20] to give the expected product.

*Ethyl (E)-4-(thiophen-2-yl)but-2-enoate (**1g**)*[43]*:* Yield: 78% (612 mg, 3.12 mmol). Yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.18 (dd, J = 5.4, 1.2 Hz, 1H), 7.08 (dt, J = 15.6, 0.6 Hz, 1H), 6.95 (dd, J = 5.4, 1.2 Hz, 1H), 6.86 – 6.81 (m, 1H), 5.88 (dt, J = 15.6, 1.8 Hz, 1H), 4.19 (q, J = 7.2 Hz, 2H), 3.71 (d, J = 7.2 Hz, 2H), 1.28 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 166.3, 145.9, 139.8, 127.1, 125.6, 124.3, 122.6, 60.3, 32.3, 14.2.

Preparation for β-hydroxyl-α-vinyl carboxylic esters

Method A: α,β-Unsaturated ester **1** (1 mmol), DBU (20 mol%), aromatic/hetero aromatic/polycyclic aromatic aldehyde **2** (1 mmol) and EtOH (2 mL) were added successively to a round-bottom flask. The resulting reaction mixture was stirred at 0 °C for 12 h and then concentrated *in vacuo*. The residue was purified by column chromatography [silica gel, EtOAc/PE 1:8 to 1:3] to give the expected product **3**.

Method B: α,β-Unsaturated ester **1** (1 mmol), DBU (20 mol%), aliphatic aldehyde **2** (1 mmol), THF (2 mL) and H_2O (27 uL) were added successively to a round-bottom flask. The resulting reaction mixture was stirred at 0 °C for 12 h and then concentrated *in vacuo*. The residue was purified by column chromatography [silica gel, EtOAc/PE 1:8 to 1:3] to give the expected product **3**.

*Ethyl (E)-2-(hydroxy(phenyl)methyl)-4-phenylbut-3-enoate (**3aa**):*

*(±)-syn-**3aa**:* Yield: 32% (95.0 mg, 0.31 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.37 – 7.34 (m, 4H), 7.33 – 7.28 (m, 4H), 7.26 (dt, J = 6.6, 1.8 Hz, 1H), 7.23 (dt, J = 7.8, 1.8 Hz, 1H), 6.46 (d, J = 15.6 Hz, 1H), 6.34 (dd, J = 15.6, 9.0 Hz, 1H), 5.02 (dd, J = 6.6, 3.0 Hz, 1H), 4.06 – 4.03 (m, 2H), 3.46 – 3.44 (t, J =9,6 Hz, 1H), 3.00 (d, J = 3 Hz, 1H), 1.11 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.5, 140.7, 136.5, 135.3, 128.5, 128.2, 127.9, 127.9, 126.5, 126.5, 123.1, 74.47, 61.0, 57.7, 14.0; ESI-HRMS calcd. for $C_{19}H_{20}NaO_3$ ([M+Na]$^+$) 319.1310, found 319.1312.

*(±)-anti-**3aa**:* Yield: 33% (97.7 mg, 0.34 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.41 – 7.18 (m, 10 H), 6.33 (d, J = 16.2 Hz, 1H), 6.09 (dd, J = 15.6, 9.0 Hz, 1H), 5.02 (dd, J = 7.8, 5.4 Hz, 1H), 4.23 – 4.17 (m, 2H), 3.56 (t, J = 9.0 Hz, 1H), 3.03 (d, J = 5.4 Hz, 1H), 1.25 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.0, 141.2, 136.5, 134.2, 128.5, 128.4, 128.0, 127.8, 126.5, 126.4, 123.5, 75.6, 61.2, 57.2, 14.1; ESI-HRMS calcd. for $C_{19}H_{20}NaO_3$ ([M+Na]$^+$) 319.1310, found 319.1310.

*Ethyl (E)-2-((2-fluorophenyl)(hydroxy)methyl)-4-phenylbut-3-enoate (**3ab**):*

*(±)-syn-**3ab**:* Yield: 42% (132.0 mg, 0.42 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47 (dt, J = 7.8, 1.2 Hz, 1H), 7.32 – 7.25 (m, 4H), 7.22 (m, 2H), 7.12 – 7.06 (m, 1H), 7.04 – 6.99 (m, 1H), 6.36 (d, J = 16.2 Hz, 1H), 6.30 (dd, J = 16.2, 9.0 Hz, 1H), 5.45 (t, J = 3.6 Hz, 1H), 4.18 – 4.11 (m, 2H), 3.57 (dd, J = 9.0, 4.8 Hz, 1H), 3.38 (d, J = 3.6 Hz, 1H), 1.20 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.0, 159.5 (d, $J_{C\text{-}F}$ = 244.5 Hz), 136.5, 135.5, 129.2 (d, $J_{C\text{-}F}$ = 7.5 Hz), 128.5, 128.4 (d, $J_{C\text{-}F}$ = 4.5 Hz), 127.7, 127.7 (d, $J_{C\text{-}F}$ = 10.5 Hz), 126.4, 124.0 (d, $J_{C\text{-}F}$ = 4.5 Hz), 122.2, 115.0 (d, $J_{C\text{-}F}$ = 22.5 Hz), 68.5 (d, $J_{C\text{-}F}$ = 1.5 Hz), 61.2, 55.1, 14.0; ESI-HRMS calcd. for $C_{19}H_{19}FNaO_3$ ([M+Na]$^+$) 337.1216, found 337.1217.

*(±)-anti-**3ab**:* Yield: 43% (135.3 mg, 0.43 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.46 (dt, J = 7.8, 1.8 Hz, 1H), 7.26 – 7.19 (m, 6H), 7.14 (dt, J = 7.2, 6.0 Hz, 1H), 6.98 (m, 1H), 6.37 (d, J = 16.2 Hz, 1H), 6.18 (dd, J = 16.2, 9.6 Hz, 1H), 5.35 (t, J = 7.2 Hz, 1H), 4.22 – 4.14 (m, 2H), 3.61 (t, J = 8.4 Hz, 1H), 3.25 (dd, J = 6.0, 1.8 Hz, 1H), 1.22 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.9, 159.9 (d, $J_{C\text{-}F}$ = 243.0 Hz), 136.5, 134.5, 129.4 (d, $J_{C\text{-}F}$ = 7.5 Hz), 128.5, 128.4 (d, $J_{C\text{-}F}$ = 13.5 Hz), 127.8, 127.8 (d, $J_{C\text{-}F}$ = 4.5 Hz), 126.4, 124.3 (d, $J_{C\text{-}F}$ = 4.5 Hz), 123.2, 115.3 (d, $J_{C\text{-}F}$ = 21.0 Hz), 69.7, 61.2, 56.6, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}FNaO_3$ ([M+Na]$^+$) 337.1216, found 337.1215.

*Ethyl (E)-2-((4-fluorophenyl)(hydroxy)methyl)-4-phenylbut-3-enoate (**3ac**):*

*(±)-syn-**3ac**:* Yield: 27% (85.0 mg, 0.27 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.36-7.30 (m, 6H), 7.27 – 7.24 (m, 1H), 7.01 (t, J = 8.4 Hz, 2H), 6.46 (d, J = 15.6 Hz, 1H), 6.31 (dd, J = 15.6, 9.6 Hz, 1H), 5.06 (dd, J = 6.0, 1.8 Hz, 1H), 4.12 – 4.04 (m, 2H), 3.41 (dd, J = 9.0, 6.0 Hz, 1H), 3.02 (t, J = 2.4 Hz,1H), 1.15 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.5, 162.4 (d, $J_{C\text{-}F}$ = 244.5 Hz), 136.4 (d, $J_{C\text{-}F}$ = 1.5 Hz), 136.3, 135.7, 128.6, 128.2 (d, $J_{C\text{-}F}$ = 9.0 Hz), 128.0, 126.5, 122.7, 115.1 (d, $J_{C\text{-}F}$ = 21.0 Hz), 73.8, 61.1, 57.8, 14.0; ESI-HRMS calcd. for $C_{19}H_{19}FNaO_3$ ([M+Na]$^+$) 337.1216, found 337.1206.

*(±)-anti-**3ac**:* Yield: 23% (72.3 mg, 0.23 mmol). Pale yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.32 – 7.28 (m, 2H), 7.27 –

7.20 (m, 5H), 7.02 – 6.97 (m, 2H), 6.31 (d, *J* = 15.6 Hz, 1H), 6.04 (dd, *J* = 15.6, 9.0 Hz, 1H), 4.99 (dd, *J* = 8.4, 5.4 Hz, 1H), 4.23 – 4.14 (m, 2H), 3.50 (t, *J* = 8.4 Hz, 1H), 3.16 (d, *J* = 5.4 Hz, 1H), 1.25 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.0, 162.4 (d, $J_{C\text{-}F}$ = 367.5 Hz), 137.0 (d, $J_{C\text{-}F}$ = 6.0 Hz), 136.4, 134.5, 128.5, 128.2 (d, $J_{C\text{-}F}$ = 13.5 Hz), 127.9, 126.3, 123.2, 115.2 (d, $J_{C\text{-}F}$ = 31.5 Hz), 74.9, 61.2, 57.3, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}FNaO_3$ ($[M+Na]^+$) 337.1216, found 337.1210.

*Ethyl (E)-2-((2-chlorophenyl)(hydroxy)methyl)-4-phenylbut-3-enoate (**3ad**):*

*(±)-syn-**3ad**:* Yield: 39% (129.2 mg, 0.39 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.52 (dd, *J* = 7.8, 1.8 Hz, 1H), 7.33 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.27 (d, *J* = 4.2 Hz, 4H), 7.22 – 7.15 (m, 3H), 6.30 (dd, *J* = 16.2, 9.0 Hz, 1H), 6.21 (d, *J* = 16.2 Hz, 1H), 5.60 (t, *J* = 2.4 Hz, 1H), 4.25 – 4.17 (m, 2H), 3.64 (dd, *J* = 9.0, 2.4 Hz, 1H), 3.57 (d, *J* = 2.4 Hz, 1H), 1.25 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.7, 137.8, 136.6, 135.5, 131.4, 129.2, 128.7, 128.7, 128.5, 127.7, 126.7, 126.4, 121.7, 70.7, 61.4, 53.3, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}ClNaO_3^+$ ($[M+Na]^+$) 353.0920, found 353.0919.

(±)-*anti-**3ad**:* Yield: 41% (135.6 mg, 0.41 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.52 (d, *J* = 7.2 Hz, 1H), 7.30 – 7.25 (m, 6H), 7.22 – 7.15 (m, 2H), 6.38 (d, *J* = 16.2 Hz, 1H), 6.27 (dd, *J* = 16.2, 9.0 Hz, 1H), 5.47 (t, *J* = 6.0 Hz, 1H), 4.17 – 4.11 (m, 2H), 3.64 (dd, *J* = 9.0, 7.2 Hz, 1H) 3.62 (d, *J* = 6.6 Hz, 1H), 1.19 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.0, 138.9, 136.5, 134.1, 132.3, 129.4, 128.9, 128.5, 127.7 (2C), 127.0, 126.4, 123.4, 72.0, 61.2, 56.1, 14.0; ESI-HRMS calcd. for $C_{19}H_{19}ClNaO_3^+$ ($[M+Na]^+$) 353.0920, found 353.0915.

*Ethyl (E)-2-((3-chlorophenyl)(hydroxy)methyl)-4-phenylbut-3-enoate (**3ae**):*

*(±)-syn-**3ae**:* Yield: 35% (115.6 mg, 0.35 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.39 – 7.19 (m, 9H), 6.45 (d, *J* = 16.2 Hz, 1H), 6.28 (dd, *J* = 16.2, 9.0 Hz, 1H), 5.04 (d, *J* = 6.0 Hz, 1H), 4.13 – 4.04 (m, 2H), 3.45 – 3.37 (m, 1H), 3.16 (s, 1H), 1.14 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.4, 142.8, 136.3, 135.7, 134.1, 129.5, 128.5, 128.0, 128.0, 126.7, 126.5, 124.6, 122.4, 73.7, 61.2, 57.5, 14.0; ESI-HRMS calcd. for $C_{19}H_{19}ClNaO_3^+$ ($[M+Na]^+$) 353.0920, found 353.0922.

*(±)-anti-**3ae**:* Yield: 36% (119.0 mg, 0.36 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.38 (s, 1H), 7.29 – 7.25 (m, 5H), 7.24 (d, *J* = 4.8 Hz, 2H), 7.19 (d, *J* = 3.0 Hz, 1H), 6.37 (d, *J* = 15.6 Hz, 1H), 6.09 (dd, *J* = 15.6, 9.0 Hz, 1H), 5.02 – 4.96 (m, 1H), 4.23 – 4.16 (m, 2H), 3.52 (t, *J* = 8.4 Hz, 1H), 3.23 (t, *J* = 4.2 Hz, 1H), 1.24 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.8, 143.3, 136.3, 134.7, 134.4, 129.6, 128.5, 128.1, 127.9, 126.6, 126.4, 124.8, 123.1, 74.9, 61.3, 56.9, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}ClNaO_3^+$ ($[M+Na]^+$) $C_{19}H_{19}ClNaO_3(M+Na)^+$ 353.0920, found: 353.0913.

*Ethyl (E)-2-((4-chlorophenyl)(hydroxy)methyl)-4-phenylbut-3-enoate (**3af**):*

*(±)-syn-**3af**:* Yield: 26% (86.3 mg, 0.26 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.36 – 7.22 (m, 9H), 6.44 (d, *J* = 16.2 Hz, 1H), 6.29 (dd, *J* = 16.2, 9.0 Hz, 1H), 5.06 (dd, *J* = 6.0, 2.4 Hz, 1H), 4.12 – 4.06 (m, 2H), 3.40 (dd, *J* = 9.6, 6.0 Hz, 1H), 3.11 (d, *J* = 2.4 Hz, 1H), 1.16 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.5, 139.2, 136.3, 135.7, 133.6, 128.6, 128.4, 128.0, 127.9, 126.5, 122.4, 73.7, 61.2, 57.5, 14.0; ESI-HRMS calcd. for $C_{19}H_{19}ClNaO_3^+$ ($[M+Na]^+$) 353.0920, found: 353.0918.

*(±)-anti-**3af**:* Yield: 23% (75.7 mg, 0.23 mmol). Pale yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.33 – 7.20 (m, 9H), 6.34 (d, *J* = 15.6 Hz, 1H), 6.06 (dd, *J* = 15.6, 9.0 Hz, 1H), 4.99 (dd, *J* = 8.4, 5.4 Hz, 1H), 4.24 – 4.15 (m, 2H), 3.50 (t, *J* = 8.4 Hz, 1H), 3.14 (t, *J* = 5.4 Hz, 1H), 1.26 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.9, 139.7, 136.3, 134.6, 133.7, 128.5, 128.5, 127.9, 127.9, 126.4, 123.1, 74.8, 61.3, 57.1, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}ClNaO_3^+$ ($[M+Na]^+$) 353.0920, found 353.0911.

*Ethyl (E)-2-((2-bromophenyl)(hydroxy)methyl)-4-phenylbut-3-enoate (**3ag**):*

*(±)-syn-**3ag**:* Yield: 36% (134.7 mg, 0.36 mmol). Pale solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.51 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.47 (dd, *J* = 7.8, 6.0 Hz, 1H), 7.29 (m, 5H), 7.21 (m,1H), 7.10 (dt, *J* = 7.8, 1.2 Hz, 1H), 6.38 (d, *J* = 16.2 Hz, 1H), 6.30 (dd, *J* = 15.6, 9.0 Hz, 1H), 5.43 (t, *J* = 6.6 Hz, 1H), 4.17 – 4.12 (m, 2H), 3.69 (d, *J* = 6.6 Hz, 1H), 3.65 (dd, *J* = 8.4, 6.6 Hz, 1H), 1.19 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.7, 139.3, 136.6, 135.6, 132.5, 129.1, 129.0, 128.5, 127.7, 127.2, 126.4, 121.5, 121.5, 72.8, 61.4, 53.2, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}BrNaO_3$ ($[M+Na]^+$) 397.0415, found 397.0412.

*(±)-anti-**3ag**:* Yield: 37% (138.8 mg, 0.37 mmol). Pale yellow solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.51 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.47 (dd, *J* = 7.8, 6.0 Hz, 1H), 7.29 (m, 5H), 7.21 (m,1H), 7.10 (dt, *J* = 7.8, 1.2 Hz, 1H), 6.38 (d, *J* = 16.2 Hz, 1H), 6.30 (dd, *J* = 15.6, 9.0 Hz, 1H), 5.43 (t, *J* = 6.6 Hz, 1H), 4.17 – 4.12 (m, 2H), 3.69 (d, *J* = 6.6 Hz, 1H), 3.65 (dd, *J* = 8.4, 6.6 Hz, 1H), 1.19 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.9, 140.5, 136.5, 134.2, 132.7, 129.2, 128.5, 128.0, 127.8, 127.6, 126.5, 123.4, 122.6, 74.2, 61.2, 56.0, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}BrNaO_3$ ($[M+Na]^+$) 397.0415, found 397.0410.

*Ethyl (E)-2-((4-bromophenyl)(hydroxy)methyl)-4-phenylbut-3-enoate (**3ah**):*

*(±)-syn-**3ah**:* Yield: 24% (90.0 mg, 0.24 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.45 (d, *J* = 8.4 Hz, 2H), 7.35 (d, *J* = 7.2 Hz, 2H), 7.31 (t, *J* = 7.2 Hz, 2H), 7.24 (m, 3H), 6.44 (d, *J* = 15.6 Hz, 1H), 6.29 (dd, *J* = 15.6, 9.0 Hz, 1H), 5.05 (dd, *J* = 5.4, 2.4 Hz, 1H), 4.13 – 4.05 (m, 2H), 3.40 (dd, *J* = 9.0, 5.4 Hz, 1H), 3.11 (dd, *J* = 5.4, 2.4 Hz, 1H), 1.17 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.6, 139.7, 136.3, 135.7, 131.4, 128.6, 128.2, 128.0, 126.5, 122.4, 121.7, 73.7, 61.2, 57.4, 14.0; ESI-HRMS calcd. for $C_{19}H_{19}BrNaO_3$ ($[M+Na]^+$) 397.0415, found 397.0410.

*(±)-anti-**3ah**:* Yield: 24% (89.6 mg, 0.24 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.45 (d, *J* = 8.4 Hz, 2H), 7.30 – 7.21 (m, 7H), 6.35 (d, *J* = 16.2 Hz, 1H), 6.07 (dd, *J* = 16.2, 9.0 Hz, 1H), 4.98 (dd, *J* = 7.8, 5.4 Hz, 1H), 4.24-4.16 (m, 2H), 3.50 (t, *J* = 7.8 Hz, 1H), 3.11 (d, *J* = 5.4 Hz, 1H), 1.25 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.9, 140.3, 136.3, 134.6, 131.5, 128.6, 128.2, 127.9, 126.4, 123.0, 121.8, 74.9, 61.3, 57.0, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}BrNaO_3$ ($[M+Na]^+$) 397.0415, found 397.0414.

*Ethyl (E)-2-(hydroxy(2-nitrophenyl)methyl)-4-phenylbut-3-enoate (**3ai**):*

*(±)-syn-**3ai**:* Yield: 30% (102.4 mg, 0.30 mmol). Pale yellow solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.97 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.78 (d, *J* = 7.8 Hz, 1H), 7.58 – 7.54 (m, 1H), 7.42 – 7.38 (m, 1H), 7.28-7.18 (m, 5H), 6.34 (dd, *J* = 15.6, 9.0 Hz, 1H),

6.24 (d, *J* = 15.6 Hz, 1H), 5.81 (d, *J* = 3.0 Hz, 1H), 4.24-4.14 (m, 2H), 3.85 (s, 1H), 3.71 (dd, *J* = 9.0, 3.0 Hz, 1H), 1.26 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.7, 147.5, 136.1, 136.1, 133.1, 129.7, 128.8, 128.6, 128.4, 127.9, 126.4, 124.5, 121.4, 69.5, 61.6, 54.4, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}NNaO_5$ ($[M+Na]^+$) 364.1161, found 364.1161.

*(±)-anti-**3ai**:* Yield: 33% (112.3 mg, 0.33 mmol). Pale yellow solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.90 (dd, *J* = 8.4, 1.2 Hz, 1H), 7.77 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.66 – 7.61 (m, 1H), 7.44 – 7.40 (m, 1H), 7.30- 7.27 (m, 4H), 7.23-7.20 (m, 1H), 6.41 (d, *J* =15.6 Hz, 1H), 6.25 (dd, *J* = 15.6, 9.0 Hz, 1H), 5.72 (t, *J* = 6.6 Hz, 1H), 4.14 (q, *J* = 7.2 Hz, 2H), 3.92 (d, *J* = 6.6 Hz, 1H), 3.67 (dd, *J* = 9.0, 6.6 Hz, 1H), 1.19 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.8, 148.1, 136.9, 136.2, 134.7, 133.4, 128.6, 128.6, 128.5, 127.9, 126.5, 124.6, 123.0, 70.8, 61.4, 56.1, 14.0; ESI-HRMS calcd. for $C_{19}H_{19}NNaO_5$ ($[M+Na]^+$) 364.1161, found 364.1158.

*Ethyl (E)-2-(hydroxy(4-nitrophenyl)methyl)-4-phenylbut-3-enoate (**3aj**):*

*(±)-syn-**3aj**:* Yield: 30% (102.1 mg, 0.30 mmol). Pale yellow solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.19 (d, *J* = 9.0 Hz, 2H), 7.53 (d, *J* = 8.4 Hz, 2H), 7.31 – 7.22 (m, 5H), 6.36 (d, *J* = 16.2 Hz, 1H), 6.10 (dd, *J* = 16.2, 9.0 Hz, 1H), 5.13 (dd, *J* = 7.2, 6.0 Hz, 1H), 4.23 – 4.17 (m, 2H), 3.52 (t, *J* = 9.0 Hz, 1H), 3.40 (d, *J* = 6.0 Hz, 1H), 1.25 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.6, 148.5, 147.6, 136.0, 135.3, 128.6, 128.2, 127.4, 126.4, 123.5, 122.4, 74.6, 61.6, 56.9, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}NNaO_5$ ($[M+Na]^+$) 364.1161, found 364.1163.

*(±)-anti-**3aj**:* Yield: 32% (108.7 mg, 0.32 mmol). Pale yellow solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.19 (d, *J* = 9.0 Hz, 2H), 7.53 (d, *J* = 8.4 Hz, 2H), 7.31 – 7.22 (m, 5H), 6.36 (d, *J* = 16.2 Hz, 1H), 6.10 (dd, *J* = 16.2, 9.0 Hz, 1H), 5.13 (dd, *J* = 7.2, 5.4 Hz, 1H), 4.23 – 4.17 (m, 2H), 3.52 (t, *J* = 7.2 Hz, 1H), 3.40 (d, *J* = 5.4 Hz, 1H), 1.25 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.6, 148.5, 147.6, 136.0, 135.3, 128.6, 128.2, 127.4, 126.4, 123.5, 122.4, 74.6, 61.5, 56.9, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}NNaO_5$ ($[M+Na]^+$) 364.1161, found 364.1168.

*Ethyl (E)-2-(hydroxy(3-nitrophenyl)methyl)-4-phenylbut-3-enoate (**3ak**):*

*(±)-syn-**3ak**:* Yield: 26% (88.8 mg, 0.26 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.26 (s, 1H), 8.12 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.71 (d, *J* = 7.2 Hz, 1H), 7.49 (t, *J* = 7.8 Hz, 1H), 7.34 – 7.28 (m, 4H), 7.24 (m, 1H), 6.43 (d, *J* = 16.2 Hz, 1H), 6.28 (dd, *J* = 16.2, 9.0 Hz, 1H), 5.23 (dd, *J* = 5.4, 3.0 Hz, 1H), 4.18 – 4.09 (m, 2H), 3.45 (dd, *J* = 9.0, 5.4 Hz, 1H), 3.42 (d, *J* = 3.0 Hz, 1H), 1.19 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.5, 148.2, 142.9, 136.4, 136.0, 132.6, 129.2, 128.6, 128.2, 126.5, 122.8, 121.5, 121.4, 73.2, 61.5, 57.1, 14.0; ESI-HRMS calcd. for $C_{19}H_{19}NNaO_5$ ($[M+Na]^+$) 364.1161, found 364.1162.

*(±)-anti-**3ak**:* Yield: 22% (75.1 mg, 0.22 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.25 (t, *J* = 1.8 Hz, 1H), 8.09 (ddd, *J* = 8.4, 2.4, 1.2 Hz, 1H), 7.65 (d, *J* = 7.8 Hz, 1H), 7.46 (t, *J* = 7.8 Hz, 1H), 7.29 – 7.20 (m, 5H), 6.34 (d, *J* = 16.2 Hz, 1H), 6.09 (dd, *J* = 16.2, 9.0 Hz, 1H), 5.13 (dd, *J* = 8.4, 5.4 Hz, 1H), 4.24 – 4.15 (m, 2H), 3.54 (t, *J* = 8.4 Hz, 1H), 3.47 (t, *J* = 5.4 Hz, 1H), 1.23 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.7, 148.2, 143.5, 136.0, 135.3, 132.7, 129.2, 128.6, 128.1, 126.4, 122.9, 122.4, 121.5, 74.5, 61.5, 57.0, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}NNaO_5$ ($[M+Na]^+$) 364.1161, found 364.1157.

*Ethyl (E)-2-(hydroxy(2-methoxyphenyl)methyl)-4-phenylbut-3-enoate (**3al**):*

*(±)-syn-**3al**:* Yield: 33% (107.9 mg, 0.33 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.35 – 7.30 (m, 3H), 7.27 (t, *J* = 7.2 Hz, 2H), 7.21 (dd, *J* = 9.6, 7.2 Hz, 2H), 6.91 (t, *J* = 7.2 Hz, 1H), 6.87 (d, *J* = 8.4 Hz, 1H), 6.38 – 6.31 (m, 2H), 5.32 (s, 1H), 4.09 (q, *J* = 7.2 Hz, 2H), 3.85 (s, 3H), 3.68 (s, 1H), 3.51 (s, 1H), 1.17 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.2, 156.2, 136.8, 134.4, 128.6, 128.4, 128.1, 127.5, 126.3, 123.6, 120.5, 110.3, 71.2, 60.8, 55.3, 54.8, 14.0; ESI-HRMS calcd. for $C_{20}H_{22}NaO_4$ ($[M+Na]^+$) 349.1416, found 349.1416.

*(±)-anti-**3al**:* Yield: 31% (101.2 mg, 0.31 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.28 (dd, *J* = 7.2, 1.2 Hz, 1H), 7.26 - 7.25 (s, 2H), 7.24 (s, 2H), 7.24 -7.22 (m, 1H), 7.22 -7.18 (m, 1H), 6.92 (dt, *J* = 7.2, 1.2 Hz, 1H), 6.85 (d, *J* = 7.2 Hz, 1H), 6.30 (d, *J* = 15.6 Hz, 1H), 6.17 (dd, *J* = 15.6, 9.0 Hz, 1H), 5.21 (t, *J* = 7.8 Hz, 1H), 4.18 (dq, *J* = 7.2, 1.2 Hz, 2H), 3.85 (s, 3H), 3.72 (t, *J* = 7.8 Hz, 1H), 3.52 (d, *J* = 9.0 Hz, 1H), 1.24 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.1, 156.6, 136.8, 133.4, 128.9, 128.4, 127.9, 127.6, 126.3, 124.4, 120.7, 110.5, 72.7, 61.0, 56.2, 55.3, 14.2; ESI-HRMS calcd. for $C_{20}H_{22}NaO_4$ ($[M+Na]^+$) 349.1416, found 349.1409.

*Ethyl (E)-2-(hydroxy(4-methoxyphenyl)methyl)-4-phenylbut-3-enoate (**3am**):*

*(±)-syn-**3am**:* Yield: 17% (55.5 mg, 0.17 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.37 (d, *J* = 7.8 Hz, 2H), 7.31 (m, 4H), 7.26 (d, *J* = 1.2 Hz, 1H), 6.86 (d, *J* = 7.2 Hz, 2H), 6.49 (d, *J* = 16.2 Hz, 1H), 6.34 (dd, *J* = 16.2, 7.8 Hz, 1H), 5.02 (d, *J* = 7.2 Hz, 1H), 4.05-4.08 (m, 2H), 3.79 (s, 3H), 3.44 (t, *J* = 7.2 Hz, 1H), 2.87 (s, 1H), 1.13 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 172.5, 159.3, 136.5, 135.3, 132.9, 128.6, 127.9, 127.8, 126.5, 123.3, 113.7, 74.1, 61.0, 57.9, 55.3, 14.0; ESI-HRMS calcd. for $C_{20}H_{22}NaO_4$ ($[M+Na]^+$) 349.1416, found 349.1412.

*(±)-anti-**3am**:* Yield: 15% (48.4 mg, 0.15 mmol); Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.27-7.21 (m, 7H), 6.85 (d, *J* = 9.0 Hz, 2H), 6.34 (d, *J* = 15.6 Hz, 1H), 6.05 (dd, *J* = 15.6, 9.0 Hz, 1H), 4.98 (d, *J* = 8.4 Hz, 1H), 4.25-4.17 (m, 2H), 3.78 (s, 3H), 3.75 (s, 1H), 3.54 (t, *J* = 9.0 Hz, 1H), 1.27 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.1, 159.3, 136.6, 134.1, 133.4, 128.5, 127.7, 127.7, 126.4, 123.6, 113.8, 75.2, 61.1, 57.2, 55.2, 14.1; ESI-HRMS calcd. for $C_{20}H_{22}NaO_4$ ($[M+Na]^+$) 349.1416, found 349.1424.

*Ethyl (E)-2-(hydroxy(quinolin-2-yl)methyl)-4-phenylbut-3-enoate (**3an**):* Yield: 78% (271.0 mg, 0.78 mmol, dr = 1:1). ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.14 (d, *J* = 8.4 Hz, 1H), 8.09 (d, *J* = 8.4 Hz, 1H), 8.05 (dd, *J* = 15.0, 8.4 Hz, 2H), 7.80 (dd, *J* = 7.8, 4.2 Hz, 2H), 7.74-7.69 (m, 2H), 7.56-7.51 (m, 2H), 7.47 (d, *J* = 8.4 Hz, 1H), 7.35 (d, *J* = 8.4 Hz, 1H), 7.32-7.27 (m, 4H), 7.24-7.21 (m, 5H), 7.19 – 7.15 (m, 1H), 6.38 (dd, *J* = 16.2 Hz, 1H), 6.36 (d, *J* = 15.0 Hz, 1H), 6.33 (dd, *J* = 15.6, 9.0 Hz, 1H), 6.28 (d, *J* = 16.2 Hz, 1H), 5.43 (d, *J* = 4.2 Hz, 1H), 5.23 (d, *J* = 6.6 Hz, 1H), 4.98 (s, 1H), 4.89 (s, 1H), 4.23 – 4.15 (m, 4H), 3.75 (dd, *J* = 9.6, 4.8 Hz, 1H), 3.67 (dd, *J* = 9.0, 7.2 Hz, 1H), 1.25 (t, *J* = 7.2 Hz, 3H), 1.21 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.5, 172.2, 159.4, 159.3, 146.8, 146.7, 136.8, 136.7, 136.5, 136.3, 134.6, 134.4, 129.8, 129.8, 128.9, 128.9, 128.5, 128.4, 127.8, 127.7, 127.6, 127.6, 127.6, 127.6, 126.6, 126.5, 126.4, 126.4, 123.6, 122.9, 119.7, 118.8, 74.8, 74.2, 61.2, 61.0, 57.5, 56.1, 14.2, 14.1; ESI-HRMS calcd. for $C_{22}H_{21}NNaO_3$ ($[M+Na]^+$) 370.1419, found 370.1417.

*Ethyl (E)-2-(hydroxy(thiophen-2-yl)methyl)-4-phenylbut-3-enoate (**3ao**):*

*(±)-syn-**3ao**:* Yield: 18% (54.3 mg, 0.18 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.38 (d, J = 7.8 Hz, 2H), 7.32 (t, J = 7.8 Hz, 2H), 7.29 – 7.23 (m, 2H), 7.00 (d, J = 3.6 Hz, 1H), 6.95(dd, J = 4.8, 3.6 Hz, 1H), 6.57 (d, J = 15.6 Hz, 1H), 6.36 (dd, J = 15.6, 9.0 Hz, 1H), 5.36 (dd, J = 6.0, 3.0 Hz, 1H), 4.17 – 4.07 (m, 2H), 3.54 (dd, J = 9.0, 6.0 Hz, 1H), 3.15 (d, J = 3. 0 Hz, 1H), 1.19 (t, J = 7.2 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 172.3, 144.3, 136.4, 135.8, 128.6, 128.0, 126.6, 126.4, 125.1, 124.7, 122.6, 70.8, 61.2, 57.8, 14.0; ESI-HRMS calcd. for $C_{17}H_{18}$**S**NaO_3 ([M+Na]$^+$) 325.0874, found 325.0874.

*(±)-anti-**3ao**:* Yield: 19% (57.3 mg, 0.19 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.31-7.27 (m, 4H), 7.25 – 7.21 (m, 2H), 6.98 (d, J = 9.0 Hz, 1H), 6.93 (dd, J = 4.8, 3.6 Hz, 1H), 6.47 (d, J = 15.9 Hz, 1H), 6.14 (dd, J = 15.9, 9.0 Hz, 1H), 5.27 (t, J = 6.0 Hz, 1H), 4.26-4.17 (m, 2H), 3.63 (t, J = 9.0 Hz, 1H), 3.25 (d, J = 6.0 Hz, 1H), 1.27 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.7, 145.2, 136.4, 134.7, 128.5, 127.9, 126.6, 126.4, 125.2, 124.7, 123.0, 71.6, 61.3, 57.2, 14.1; ESI-HRMS calcd. for $C_{17}H_{18}$**S**NaO_3 ([M+Na]$^+$) 325.0874, found 325.0873.

*Ethyl 3-hydroxy-2-((E)-styryl)pentanoate (**3ap**):*

*(±)-syn-**3ap**:* Yield: 37% (92.1 mg, 0.37 mmol). Pale oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.38 (d, J = 7.2 Hz, 2H), 7.31 (t, J = 7.8 Hz, 2H), 7.27 – 7.22 (m, 1H), 6.55 (d, J = 15.6 Hz, 1H), 6.20 (dd, J = 15.6, 9.0 Hz, 1H), 4.25 – 4.15 (m, 2H), 3.86 (ddd, J = 10.8, 7.8, 3.0Hz, 1H) 3.25 (t, J = 9.0 Hz, 1H), 2.55 (dd, J = 6.6, 4.2 Hz, 1H), 1.69-1.62 (m, 1H), 1.47-1.40 (m, 1H), 1.28 (t, J = 7.2 Hz, 3H), 1.00 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.3, 136.5, 134.0, 128.6, 127.8, 126.4, 124.2, 74.0, 61.0, 55.9, 27.6, 14.2, 9.8; ESI-HRMS calcd. for $C_{15}H_{20}NaO_3$ ([M+Na]$^+$) 271.1310, found 271.1307.

*(±)-anti-**3ap**:* Yield: 41% (101.5 mg, 0.41 mmol). Pale oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.40 (d, J = 7.2 Hz, 2H), 7.32 (t, J = 7.2 Hz, 2H), 7.24 (d, J = 5.4 Hz, 1H), 6.56 (d, J = 16.2 Hz, 1H), 6.33 (dd, J = 16.2, 9.6 Hz, 1H), 4.23 – 4.15 (m, 2H), 3.92 (dt, J =7.8, 4.8 Hz, 1H), 3.22 (dd, J = 9.6, 4.2 Hz, 1H), 2.80 (d, J = 3.0 Hz, 1H), 1.57 – 1.47 (m, 2H), 1.28 (t, J = 7.2 Hz, 3H), 0.98 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.6, 136.5, 135.1, 128.6, 127.8, 126.4, 123.0, 73.2, 61.1, 54.7, 27.1, 14.1, 10.0; ESI-HRMS calcd. for $C_{15}H_{20}NaO_3$ ([M+Na]$^+$) 271.1310, found 271.1309.

*Ethyl 3-hydroxy-2-((E)-styryl)hexanoate (**3aq**):*

*(±)-syn-**3aq**:* Yield: 34% (89.2 mg, 0.34 mmol). Colorless oil. ^{1}H NMR (600 MHz，$CDCl_3$）δ 7.40 (d, J = 7.2 Hz, 2H), 7.31 (t, J = 7.2 Hz, 2H), 7.27-7.22 (m, 1H), 6.55 (d, J = 15.6 Hz, 1H), 6.3(dd, J = 15.6, 9.0 Hz, 1H), 4.23-4.15 (m, 2H), 4.01 (dt, J = 7.8, 4.2 Hz, 1H), 3.19 (dd, J = 9.0, 4.2 Hz, 1H), 2.79 (s, 1H), 1.56-1.47 (m, 2H)，1.43-1.35 (m, 2H), 1.28 (t, J = 7.2 Hz, 3H), 0.92 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.5, 136.5, 135.0, 128.5, 127.8, 126.4, 123.0, 71.5, 61.0, 55.1, 36.3, 18.8, 14.1, 13.9; ESI-HRMS calcd. for $C_{16}H_{22}NaO_3$ ([M+Na]$^+$) 285.1467, found 285.1466.

*(±)-anti-**3aq**:* Yield: 39% (102.0 mg, 0.39 mmol). Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.31 (d, J = 7.2 Hz, 2H), 7.24 (t, J = 7.2 Hz, 2H), 7.19 – 7.15 (m, 1H), 6.48 (d, J = 16.2 Hz, 1H), 6.13 (dd, J = 15.6, 9.0 Hz, 1H), 4.18 – 4.07 (m, 2H), 3.86 (dd, J = 13.8, 6.6 Hz, 1H), 3.16 (dd, J = 9.0, 1.8 Hz, 1H), 2.46 (d, J = 6.6 Hz, 1H), 1.53 – 1.43 (m, 2H), 1.38 – 1.27 (m, 2H), 1.23 – 1.17 (t, J = 7.2 Hz, 3H), 0.84 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.3, 136.6, 134.1, 128.6, 127.8, 126.4, 124.2, 72.5, 61.0, 56.3, 36.9, 18.7, 14.2, 13.9; ESI-HRMS calcd. for $C_{16}H_{22}NaO_3$ ([M+Na]$^+$) 285.1467, found 285.1458.

*Ethyl hydroxy-2-((E)-styryl)nonanoate (**3ar**):*

*(±)-syn-**3ar**:* Yield: 35% (106.3 mg, 0.35 mmol). Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.39 (d, J = 1.2 Hz, 2H), 7.30 (t, J = 1.2 Hz, 2H), 7.23 (m, 1H), 6.54 (d, J = 15.6 Hz, 1H), 6.34 (dd, J = 15.6, 9.6 Hz, 1H), 4.21 – 4.14 (m, 2H), 3.99 (dt, J = 8.4, 4.2 Hz, 1H), 3.19 (dd, J = 9.6, 4.2 Hz, 1H), 2.83 (s, 1H), 1.52 – 1.24 (m, 13H), 0.87 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.4, 136.5, 134.9, 128.4, 127.7, 126.4, 123.1, 71.7, 60.9, 55.1, 34.2, 31.7, 29.1, 25.5, 22.5, 14.0, 13.9; ESI-HRMS calcd. for $C_{19}H_{28}NaO_3$ ([M+Na]$^+$) 327.1936, found 327.1929.

*(±)-anti-**3ar**:* Yield: 37% (112.3 mg, 0.37 mmol). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (d, J = 7.2 Hz, 2H), 7.24 (t, J = 7.2 Hz, 2H), 7.17 (t, J = 7.2 Hz, 1H), 6.48 (d, J = 15.6 Hz, 1H), 6.26 (dd, J = 15.6, 9.6 Hz, 1H), 4.12 (dq, J = 7.2, 2.4 Hz, 2H), 3.91 (dt, J = 8.4, 4.4 Hz, 1H), 3.12 (dd, J = 9.6, 4.4 Hz, 1H), 2.69 (s, 1H), 1.60 – 1.26 (m, 13H), 0.80 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.2, 136.5, 134.0, 128.5, 127.7, 126.4, 124.2, 72.7, 60.9, 56.3, 34.7, 31.7, 29.1, 25.4, 22.5, 14.1, 14.0; ESI-HRMS calcd. for $C_{19}H_{28}NaO_3$ ([M+Na]$^+$) 327.1936, found 327.1930.

*Ethyl 3-hydroxy-5,9-dimethyl-2-((E)-styryl)dec-8-enoate (**3as**):*

Less polar isomers: Yield: 33% (113.0 mg, 0.33 mmol). dr = 1:2; Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, J = 7.6 Hz, 2H), 7.34 (t, J = 7.6 Hz, 2H), 7.27 (dt, J = 7.6, 2.0 Hz, 1H), 6.58 (d, J = 16.0 Hz, 1H), 6.36 (dd, J = 16.0, 1.2 Hz, 1H), 5.11 (tt, J = 9.6, 1.2 Hz, 1H), 4.22 (q, J = 7.2 Hz, 2H), 4.15 – 4.10 (m, 1H), 3.21 – 3.16 (m, 1H), 2.79 (br s, 0.33H), 2.68 (s, 0.67H), 2.10 – 1.93 (m, 2H), 1.72 – 1.67 (m, 3H), 1.66 – 1.56 (m, 4H), 1.47 – 1.36 (m, 2H), 1.31 (t, J = 7.2 Hz, 3H), 1.26 – 1.09 (m, 2H), 0.96 (d, J = 6.8 Hz, 1H), 0.94 (d, J = 6.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.5, 173.3, 136.6, 136.5, 135.1, 135.0, 131.2, 131.0, 128.5, 127.7, 126.4, 124.7, 124.7, 123.2, 122.9, 69.9, 69.6, 61.0, 60.9, 55.9, 55.1, 41.6, 41.6, 37.8, 36.4, 29.1, 28.7, 25.6, 25.4, 25.3, 20.2, 18.9, 17.5, 14.1; ESI-HRMS calcd. for $C_{22}H_{32}NaO_3$ ([M+Na]$^+$) 367.2249, found 367.2256.

More polar isomers: Yield: 33% (113.7 mg, 0.33 mmol). dr = 1:1.3. Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 (d, J = 7.2 Hz, 2H), 7.31 (t, J = 7.2 Hz, 2H), 7.26 – 7.22 (m, 1H), 6.55 (d, J = 15.6 Hz, 1H), 6.20 (ddd, J = 15.6, 9.2, 6.4 Hz, 1H), 5.10 – 5.07 (m, 1H), 4.24 – 4.15 (m, 2H), 4.02 (m, 1H), 3.20 (t, J = 8.4 Hz, 1H), 2.47 (br s, 0.43H), 2.42 (br s, 0.56H), 2.00 – 1.93 (m, 2H), 1.79 – 1.67 (m, 2H), 1.67 (s, 3H), 1.58 (s, 3H), 1.49 – 1.42 (m, 1H), 1.37 – 1.73 [m, 5H, including 1.28 (t, J = 7.2 Hz, 3H)], 0.93 (d, J = 6.4 Hz, 1.3H), 0.90 (d, J = 6.4 Hz, 1.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.2, 173.2, 136.6, 134.1, 134.1, 131.2, 131.1, 128.5, 127.8, 126.4, 124.7, 124.7, 124.3, 124.2, 71.1, 70.6, 60.9, 56.9, 56.6, 42.5, 42.1, 37.9, 36.0, 29.2, 28.8, 25.6, 25.5, 25.2, 20.4, 18.9, 17.6, 17.6, 14.1; ESI-HRMS calcd. for $C_{22}H_{32}NaO_3$ ([M+Na]$^+$) 367.2249, found 367.2255.

*Ethyl 3-hydroxy-4-methyl-2-((E)-styryl)pentanoate (**3at**):*

*(±)-syn-**3at**:* Yield: 25% (65.5 mg, 0.25 mmol). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (t, J = 7.6 Hz, 2H), 7.35 - 7.29 (m, 2H), 7.26 (t, J = 7.6 Hz, 1H), 6.59 (dd, J = 16.0, 8.4 Hz, 1H), 6.36 (dt, J = 16.0, 9.2 Hz, 1H), 4.22 – 4.17 (m, 2H), 3.72 - 3.69 (m, 1H), 3.38 (dd, J = 9.2, 4.4 Hz, 1H), 2.82 (s, 1H),

1.73 (q, *J* = 6.8 Hz, 1H), 1.28 (dd, *J* = 14.4, 7.2 Hz, 3H), 1.05 - 1.00 (m, 3H), 0.95 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.7, 136.7, 134.8, 128.6, 127.8, 126.5, 123.2, 76.7, 61.0, 52.8, 31.0, 19.2, 17.8, 14.1; ESI-HRMS calcd. for $C_{16}H_{22}NaO_3$ ([M+Na]$^+$) 285.1467, found 285.1471.

*(±)-anti-**3at**:* Yield: 20% (52.4 mg, 0.20 mmol). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 (d, *J* = 7.2 Hz, 2H), 7.31 (t, *J* = 7.2 Hz, 2H), 7.27 – 7.20 (t, *J* = 7.2 Hz, 1H), 6.56 (d, *J* = 16.0 Hz, 1H), 6.19 (dd, *J* = 16.0, 9.2 Hz, 1H), 4.21 – 4.16 (m, 2H), 3.75 (s, 1H), 3.37 (t, *J* = 8.4 Hz, 1H),2.54 (s, 1H), 1.81 – 1.76 (m, 1H), 1.30 – 1.25 (m, 3H), 1.00 (d, *J* = 6.8 Hz, 3H), 0.93 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.6, 136.6, 133.7, 128.6, 127.8, 126.4, 124.5, 77.2, 61.0, 53.8, 30.7, 19.9, 15.4, 14.2; ESI-HRMS calcd. for $C_{16}H_{22}NaO_3$ ([M+Na]$^+$) 285.1467, found 285.1473.

*Ethyl (E)-2-((2-fluorophenyl)(hydroxy)methyl)-4-(4-tolyl)but-3-enoate (**3bb**):*

*(±)-syn-**3bb**:* Yield: 40% (131.3 mg, 0.40 mmol). Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47 (t, *J* = 7.2 Hz, 1H), 7.26 – 7.18 (m, 3H), 7.09 (dd, *J* = 7.2, 4.2 Hz, 3H), 7.04 – 6.99 (m, 1H), 6.33 (d, *J* = 16.2 Hz, 1H), 6.25 (dd, *J* = 16.2, 9.0 Hz, 1H), 5.44 (t, *J* = 3.0 Hz,1H), 4.19 – 4.10 (m, 2H), 3.55 (dd, *J* = 9.0, 4.2 Hz, 1H), 3.35 (d, *J* = 3.0 Hz, 1H), 2.32 (s, 3H), 1.20 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.1, 159.5 (d, J_{C-F} = 244.2 Hz), 137.7, 135.4, 133.7, 129.2, 129.1, 128.5 (d, J_{C-F} = 4.0 Hz), 127.8 (d, J_{C-F} = 12.4 Hz), 126.3, 124.0 (d, J_{C-F} = 3.3 Hz), 121.1, 115.0 (d, J_{C-F} = 21.6 Hz), 68.5, 61.2, 55.2, 21.2, 14.0; ESI-HRMS calcd. for $C_{20}H_{21}FNaO_3$ ([M+Na]$^+$) 351.1372, found 351.1368.

*(±)-anti-**3bb**:* Yield: 39% (127.5 mg, 0.39 mmol). Pale yellow solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.45 (dt, *J* = 7.2, 1.2 Hz, 1H), 7.27 – 7.20 (m, 1H), 7.19 – 7.11 (m, 3H), 7.07 (d, *J* = 7.8 Hz, 2H), 7.01 – 6.93 (m, 1H), 6.33 (d, *J* = 15.6 Hz, 1H), 6.12 (dd, *J* = 15.6, 9.0 Hz, 1H), 5.34 (t, *J* = 6.6 Hz, 1H), 4.22 – 4.12 (m, 2H), 3.59 (t, *J* = 7.8 Hz, 1H), 3.26 (d, *J* = 6.6 Hz, 1H), 2.31 (s, 3H), 1.22 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.0, 159.7 (d, J_{C-F} = 244.2 Hz), 137.7, 134.3, 133.7, 129.4 (d, J_{C-F} = 8.3 Hz), 129.2, 128.5 (d, J_{C-F} = 13.2 Hz), 127.8 (d, J_{C-F} = 4.0 Hz), 126.3, 124.2 (d, J_{C-F} = 3.3 Hz), 122.1, 115.2 (d, J_{C-F} = 21.9 Hz), 69.8, 61.2, 56.6, 21.2, 14.1; ESI-HRMS calcd. for $C_{20}H_{21}FNaO_3$ ([M+Na]$^+$) 351.1372, found 351.1370.

*Ethyl (E)-4-(4-chlorophenyl)-2-((2-fluorophenyl)(hydroxy)methyl)but-3-enoate (**3cb**):*

*(±)-syn-**3cb**:* Yield: 28% (97.5 mg, 0.28 mmol). Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.45 (dt, *J* = 7.8, 1.8 Hz, 1H), 7.27 – 7.20 (m, 5H), 7.10 (dt, *J* = 7.2, 0.6 Hz, 1H), 7.02 (dd, *J* = 9.0, 0.6 Hz, 1H), 6.31-6.25 (m, 2H), 5.46 (d, *J* = 4.2 Hz, 1H), 4.20 – 4.13 (m, 2H), 3.58 – 3.54 (m, 1H), 3.33 (s, 1H), 1.21 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.9, 159.5 (d, J_{C-F} = 244.5 Hz), 135.0, 134.2, 133.5, 129.3 (d, J_{C-F} = 9.0 Hz), 128.7, 128.4 (d, J_{C-F} = 4.5 Hz), 127.7 (d, J_{C-F} = 13.5 Hz), 127.6, 124.1 (d, J_{C-F} = 3.0 Hz), 123.0, 115.1 (d, J_{C-F} = 22.5 Hz), 68.5, 61.3, 55.0, 14.0; ESI-HRMS calcd. for $C_{19}H_{18}ClFNaO_3$([M+Na]$^+$) 371.0826, found 371.0824.

*(±)-anti-**3cb**:* Yield: 28% (98.0 mg, 0.28 mmol). Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.45 (dt, *J* = 7.2, 1.2 Hz, 1H), 7.28 – 7.22 (m, 4H), 7.19 (d, *J* = 8.4 Hz, 1H), 7.17 – 7.13 (dd, *J* =7.2,0.6 Hz, 1H), 6.98 (dd, *J* = 9.6, 0.6 Hz, 1H), 6.31 (d, *J* = 15.6 Hz, 1H), 6.16 (ddd, *J* = 15.6, 9.0, 1.2 Hz, 1H), 5.34 (t, *J* = 6.6 Hz, 1H), 4.24 – 4.13 (m, 2H), 3.58 (t, *J* = 8.4 Hz, 1H), 3.24 (d, *J* = 6.6 Hz, 1H), 1.23 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.8, 159.8 (d, J_{C-F} = 243.0 Hz), 135.0, 133.5, 133.2, 129.5 (d, J_{C-F} = 7.5 Hz), 128.7, 128.4 (d, J_{C-F} = 13.5 Hz), 127.7 (d, J_{C-F} = 3.0 Hz), 127.6, 124.3 (d, J_{C-F} = 1.5 Hz), 123.9, 115.2 (d, J_{C-F} = 21.0 Hz), 69.7, 61.3, 56.6, 14.1; ESI-HRMS calcd. for $C_{19}H_{18}ClFNaO_3$([M+Na]$^+$) 371.0826, found 371.0822.

*Ethyl (E)-2-((2-fluorophenyl)(hydroxy)methyl)-4-(4-nitrophenyl)but-3-enoate (**3db**):*

*(±)-syn-**3db**:* Yield: 33% (118.5 mg, 0.33 mmol). Pale yellow solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.13 (d, *J* = 8.4 Hz, 2H), 7.47 – 7.43 (m, 1H), 7.41 (d, *J* = 9.0 Hz, 2H), 7.25 (m, 1H), 7.10 (t, *J* = 7.2 Hz, 1H), 7.04 (m, 1H), 6.50 (dd, *J* = 15.6, 9.0 Hz, 1H), 6.37 (d, *J* = 15.6 Hz, 1H), 5.52 (t, *J* = 3.0 Hz, 1H), 4.23 – 4.14 (m, 2H), 3.63 (dd, *J* = 9.6, 4.8 Hz, 1H), 3.37 (d, *J* = 3.0 Hz, 1H), 1.23 (t, *J* = 7.8 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.4, 159.3 (d, J_{C-F} = 244.5 Hz), 147.0, 142.9, 133.2, 129.4 (d, J_{C-F} = 9.0 Hz), 128.2 (d, J_{C-F} = 4.5 Hz), 127.6 (d, J_{C-F} = 13.5 Hz), 127.5, 126.9, 124.1 (d, J_{C-F} = 4.5 Hz), 123.9, 115.2 (d, J_{C-F} = 21.0 Hz), 68.6, 61.5, 54.9, 14.0; ESI-HRMS calcd. for $C_{19}H_{18}FNNaO_5$ ([M+Na]$^+$) 382.1067, found 382.1062.

*(±)-anti-**3db**:* Yield: 36% (130.0 mg, 0.36 mmol). Pale yellow solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.14 (d, *J* = 9.0 Hz, 2H), 7.47 (t, *J* = 7.2 Hz, 1H), 7.40 (d, *J* = 9.0 Hz, 2H), 7.28 – 7.24 (m, 1H), 7.17 (t, *J* = 7.2 Hz, 1H), 6.98 (t, *J* =9.0 Hz, 1H), 6.42 (d, *J* = 15.6 Hz, 1H), 6.37 (dd, *J* = 15.6, 8.4 Hz, 1H), 5.38 (d, *J* = 7.2 Hz, 1H), 4.25 – 4.15 (m, 2H), 3.63 (t, *J* = 8.4 Hz, 1H), 3.24 (s, 1H), 1.24 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.3, 159.7 (d, J_{C-F} = 244.0 Hz), 147.1, 142.8, 132.4, 129.6 (d, J_{C-F} = 8.2 Hz), 128.2, 128.1 (d, J_{C-F} = 13.0 Hz), 127.6 (d, J_{C-F} = 4.00 Hz), 127.0, 124.4 (d, J_{C-F} = 3.3 Hz), 123.9, 115.3 (d, J_{C-F} = 21.8 Hz), 69.6, 61.5, 56.7, 14.1; ESI-HRMS calcd. for $C_{19}H_{18}FNNaO_5$ ([M+Na]$^+$) 382.1067, found 382.1065.

*Ethyl (E)-2-((2-fluorophenyl)(hydroxy)methyl)-4-(3-nitrophenyl)but-3-enoate (**3eb**):*

*(±)-syn-**3eb**:* Yield: 32% (114.7 mg, 0.32 mmol). Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.13 (s, 1H), 8.09 - 8.05 (m, 1H), 7.59 (d, *J* = 7.2 Hz, 1H), 7.46 (q, *J* = 8.4 Hz, 2H), 7.27 - 7.21 (m, 1H), 7.11 (t, *J* = 7.2 Hz, 1H), 7.06 – 7.02 (m, 1H), 6.46 (dd, *J* = 16.2, 9.0 Hz, 1H), 6.36 (d, *J* = 16.2 Hz, 1H), 5.52 (s, 1H), 4.24 – 4.15 (m, 2H), 3.62 (dd, *J* = 9.0, 4.2 Hz, 1H), 3.34 (d, *J* = 1.2 Hz, 1H), 1.24 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.6, 159.4 (d, J_{C-F} = 244.5 Hz), 148.6, 138.3, 133.0, 132.1, 129.4, 129.4 (d, J_{C-F} = 9.0 Hz), 128.2 (d, J_{C-F} = 4.5 Hz), 127.6 (d, J_{C-F} = 12.0 Hz), 125.8, 124.1 (d, J_{C-F} = 3.0 Hz), 122.3, 121.1, 115.2 (d, J_{C-F} = 21.0 Hz), 68.6, 61.5, 54.8, 14.0; ESI-HRMS calcd. for $C_{19}H_{18}FNNaO_5$ ([M+Na]$^+$) 382.1067, found 382.1062.

*(±)-anti-**3eb**:* Yield: 31% (111.1 mg, 0.31 mmol). Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.10 (s, 1H), 8.07 (d, *J* = 9.0 Hz, 1H), 7.58 (d, *J* = 7.2 Hz, 1H), 7.50 – 7.43 (m, 2H), 7.28 – 7.23 (m, 1H), 7.17 (t, *J* = 7.2 Hz, 1H), 6.99 (t, *J* = 9.0 Hz, 1H), 6.41 (d, *J* = 16.2 Hz, 1H), 6.33 (dd, *J* = 16.2, 9.0 Hz, 1H), 5.37 (t, *J* = 6.0 Hz, 1H), 4.24 – 4.17 (m, 2H), 3.63 (t, *J* = 6.0 Hz, 1H), 3.29 (d, *J* = 6.0 Hz, 1H), 1.24 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.4, 159.7 (d, J_{C-F} = 243.0 Hz), 148.6, 138.2, 132.1, 132.1, 129.6 (d, J_{C-F} = 7.5 Hz), 129.4, 128.2 (d, J_{C-F} = 13.5 Hz), 127.7 (d, J_{C-F} = 4.5 Hz), 126.7, 124.4 (d, J_{C-F} = 1.5 Hz), 122.4, 121.1, 115.3 (d, J_{C-F} = 22.5 Hz), 69.6, 61.5, 56.5, 14.1; ESI-HRMS calcd. for $C_{19}H_{18}FNNaO_5$ ([M+Na]$^+$) 382.1067, found 382.1062.

*Ethyl (E)-2-(hydroxy(phenyl)methyl)-4-(3-nitrophenyl)but-3-enoate (**3ea**):*

*(±)-syn-**3ea**:* Yield: 24% (81.4 mg, 0.24 mmol). Pale yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.17 (s, 1H), 8.07 (dd, J = 8.4, 1.2 Hz, 1H), 7.63 (d, J = 7.8 Hz, 1H), 7.46 (t, J = 7.8 Hz, 1H), 7.34 (m, 4H), 7.28 (t, J =8.4 Hz, 1H), 6.50 (dd, J = 16.2, 8.4 Hz, 1H), 6.44 (d, J = 16.2 Hz, 1H), 5.16 (d, J = 6.0 Hz, 1H), 4.14 – 4.08 (m, 2H), 3.51 (dd, J = 8.4, 5.4 Hz, 1H), 3.02 (s, 1H), 1.16 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.2, 148.6, 140.6, 138.3, 132.7, 132.2, 129.4, 128.3, 128.0, 126.6, 126.3, 122.3, 121.1, 74.4, 61.3, 57.3, 14.0; ESI-HRMS calcd. for $C_{19}H_{19}NNaO_5$ ([M+Na]$^+$) 364.1161, found 364.1159.

*(±)-anti-**3ea**:* Yield: 21% (71.5 mg, 0.21 mmol). Pale oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.09 (s, 1H), 8.06 (d, J = 8.4 Hz, 1H), 7.53 (d, J = 7.8 Hz, 1H), 7.43 (t, J = 7.8 Hz, 1H), 7.38 – 7.32 (m, 4H), 7.29 (dt, J = 8.4, 4.2 Hz, 1H), 6.37 (d, J = 16.2 Hz, 1H), 6.23 (dd, J = 16.2, 9.0 Hz, 1H), 5.05 (dd, J = 8.4, 5.4 Hz, 1H), 4.26 – 4.19 (m, 2H), 3.60 (t, J = 8.4 Hz, 1H), 3.02 (d, J = 5.4 Hz, 1H), 1.27 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.5, 148.6, 140.9, 138.2, 132.1, 132.0, 129.4, 128.5, 128.2, 127.0, 126.4, 122.3, 121.0, 75.5, 61.4, 57.1, 14.1; ESI-HRMS calcd. for $C_{19}H_{19}NNaO_5$ ([M+Na]$^+$) 364.1161, found 364.1158.

*Ethyl (E)-2-((2-fluorophenyl)(hydroxy)methyl)-4-(naphthalen-1-yl)but-3-enoate (**3fb**):*

*(±)-syn-**3fb**:* Yield: 36% (131.2 mg, 0.36 mmol). Yellow solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.81 (d, J = 7.8 Hz, 1H), 7.75 (d, J = 8.4 Hz, 2H), 7.53 (t, J = 7.8 Hz, 1H), 7.49 (t, J = 7.2 Hz, 1H), 7.46-7.39 (m, 3H), 7.28-7.25 (m, 1H), 7.11 (t, J = 7.8 Hz, 1H), 7.07 (dd, J = 10.8, 8.4 Hz, 1H), 7.01 (d, J = 15.6 Hz, 1H), 6.29 (dd, J = 15.6, 9.6 Hz, 1H), 5.57 (d, J = 3.6 Hz, 1H), 4.23 (q, J = 7.2 Hz, 2H), 3.72 (dd, J = 9.6, 4.2 Hz, 1H), 3.47 (s, 1H), 1.28 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.3, 158.4 (d, $J_{C\text{-}F}$ = 244.5 Hz), 134.5, 133.4, 133.1, 131.0, 129.1 (d, $J_{C\text{-}F}$ = 9.0 Hz), 128.5 (d, $J_{C\text{-}F}$ = 4.5 Hz), 128.4, 128.1, 127.1 (d, $J_{C\text{-}F}$ = 12.0 Hz), 125.9, 125.7, 125.5, 125.3, 124.1 (d, $J_{C\text{-}F}$ = 3.0 Hz), 124.1, 123.8, 115.0 (d, $J_{C\text{-}F}$ = 21.00 Hz), 68.5, 61.4, 55.1, 14.1; ESI-HRMS calcd. for $C_{23}H_{21}FNaO_3$ ([M+Na]$^+$) 387.1372, found 387.1374.

*(±)-anti-**3fb**:* Yield: 33% (120.1 mg, 0.33 mmol). White solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.80 (d, J = 7.8 Hz, 1H), 7.73 (dd, J = 13.2, 7.8 Hz, 2H), 7.52 (dt, J = 7.2, 1.2 Hz, 1H), 7.46 - 7.38 (m, 4H), 7.28 – 7.24 (m, 1H), 7.18 (t, J = 7.2 Hz, 1H),7.03 (d, J = 15.6 Hz, 1H), 6.99 (d, J = 9.0 Hz, 1 H), 6.14 (ddd, J = 15.0, 9.0, 1.2 Hz, 1H), 5.43 (d, J = 7.8 Hz, 1H), 4.25 (q, J = 7.2 Hz, 2H), 3.75 (t, J = 9.0 Hz, 1H), 3.21 (s, 1H), 1.28 (t, J = 7.2Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.9, 160.0 (d, $J_{C\text{-}F}$ = 244.5 Hz), 134.4, 133.4, 132.3, 131.0, 129.5 (d, $J_{C\text{-}F}$ = 9.0 Hz), 128.5 (d, $J_{C\text{-}F}$ = 13.5 Hz), 128.4, 128.1, 128.0 (d, $J_{C\text{-}F}$ = 4.5 Hz), 126.3, 125.9, 125.7, 125.6, 124.4 (d, $J_{C\text{-}F}$ = 3.0 Hz), 124.1, 123.7, 115.4 (d, $J_{C\text{-}F}$ = 22.5 Hz), 69.8, 61.3, 57.3, 14.2; ESI-HRMS calcd. for $C_{23}H_{21}FNaO_3$ ([M+Na]$^+$) 387.1372, found 387.1369.

*Ethyl (E)-2-((2-fluorophenyl)(hydroxy)methyl)-4-(thiophen-2-yl)but-3-enoate (**3gb**):*

*(±)-syn-**3gb**:* Yield: 34% (108.8 mg, 0.34 mmol). Yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47 (t, J = 7.2 Hz, 1H), 7.25 - 7.21 (m, 1H), 7.13 (d, J = 4.8 Hz, 1H), 7.10 (t, J = 7.2 Hz, 1H), 7.03 - 6.99 (m, 1H), 6.91 (t, J = 4.8 Hz, 1H), 6.87 (d, J = 3.0 Hz, 1H), 6.48 (d, J = 15.6 Hz, 1H), 6.13 (dd, J = 15.6, 9.0 Hz, 1H), 5.43 (d, J = 4.2 Hz, 1H), 4.19 – 4.09 (m, 2H), 3.52 (dd, J = 9.0, 4.2 Hz, 1H), 3.35 (s, 1H), 1.20 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.8, 159.5 (d, $J_{C\text{-}F}$ = 243.0 Hz), 141.5, 129.2 (d, $J_{C\text{-}F}$ = 7.5 Hz), 128.5 (d, $J_{C\text{-}F}$ = 6.0 Hz), 128.4, 127.7 (d, $J_{C\text{-}F}$ = 12.0 Hz), 127.3, 125.9, 124.5, 124.1 (d, $J_{C\text{-}F}$ = 4.5 Hz), 121.7, 115.0 (d, $J_{C\text{-}F}$ = 21.0 Hz), 68.4 (d, $J_{C\text{-}F}$ = 1.5 Hz), 61.3, 55.0, 14.0; ESI-HRMS calcd. for $C_{17}H_{17}FNaO_3S$ ([M+Na]$^+$) 343.0780, found 343.0777.

*(±)-anti-**3gb**:* Yield: 38% (121.2 mg, 0.38 mmol). Yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.37 (t, J = 7.2 Hz, 1H), 7.21 – 7.13 (m, 1H), 7.12 – 7.03 (m, 2H), 6.91 J = 9.0 Hz, 1H), 6.83-6.78 (m, 2H), 6.42 (d, J = 15.6 Hz, 1H), 5.93 (dd, J = 15.6, 9.0 Hz, 1H), 5.24 (d, J = 6.6 Hz, 1H), 4.14 – 4.05 (m, 2H), 3.48 (t, J = 8.4 Hz, 1H), 3.26 (s, 1H), 1.14 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.7, 159.8 (d, $J_{C\text{-}F}$ = 244.5 Hz), 141.4, 129.4 (d, $J_{C\text{-}F}$ = 7.5 Hz), 128.4 (d, $J_{C\text{-}F}$ = 12.0 Hz), 127.7 (d, $J_{C\text{-}F}$ = 4.5 Hz), 127.4, 127.2, 125.9, 124.5, 124.2 (d, $J_{C\text{-}F}$ = 3.0 Hz), 122.6, 115.2 (d, $J_{C\text{-}F}$ = 22.5 Hz), 69.7, 61.2, 56.3, 14.0; ESI-HRMS calcd. for $C_{17}H_{17}FNaO_3S$ ([M+Na]$^+$) 343.0780, found 343.0786.

*Ethyl (E)-2-((2-fluorophenyl)(hydroxy)methyl)-4-phenylpent-3-enoate (**3hb**):*

*(±)-syn-**3hb**:* Yield: 38% (124.7 mg, 0.38 mmol). Pale yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.48 (t, J = 7.8 Hz, 1H), 7.28-7.26 (m, 4H), 7.23 – 7.21 (m, 2H), 7.09 (t, J = 7.8 Hz, 1H), 6.98 (t, J = 9.6 Hz,1H), 5.93 (d, J = 9.6 Hz, 1H), 5.53 (s, 1H), 4.19 – 4.13 (m, 2H), 3.83 (dd, J = 9.6, 3.6 Hz, 1H), 3.55 (s, 1H), 1.71 (s, 3H), 1.22 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.6, 159.4 (d, $J_{C\text{-}F}$ = 243.0 Hz), 143.1, 140.9, 128.9 (d, $J_{C\text{-}F}$ = 7.5 Hz), 128.4 (d, $J_{C\text{-}F}$ = 4.5 Hz), 128.1, 128.0 (d, $J_{C\text{-}F}$ = 12.0 Hz), 127.2, 125.8, 123.9 (d, $J_{C\text{-}F}$ = 3.0 Hz), 119.9, 114.8 (d, $J_{C\text{-}F}$ = 22.5 Hz), 68.5, 61.15, 50.6, 16.1, 14.0; ESI-HRMS calcd. for $C_{20}H_{21}FNaO_3$ ([M+Na]$^+$) 351.1372, found 351.1377.

*(±)-anti-**3hb**:* Yield: 38% (124.3 mg, 0.38 mmol). Pale yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.50 (t, J = 7.2 Hz, 1H), 7.29 – 7.19 (m, 6H), 7.14 (t, J = 7.2 Hz, 1H), 6.98 (t, J = 9.6 Hz, 1H), 5.74 (d, J = 9.6 Hz, 1H), 5.34 (t, J = 6.0 Hz,1H), 4.18 (d, J = 6.0 Hz, 2H), 3.85 (t, J = 9.6 Hz, 1H), 3.26 (d, J = 4.8 Hz, 1H), 1.80 (s, 3H), 1.24 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.3, 159.9 (d, $J_{C\text{-}F}$ = 244.5 Hz), 143.0, 134.0, 129.4 (d, $J_{C\text{-}F}$ = 9.0 Hz), 128.6 (d, $J_{C\text{-}F}$ = 12.0 Hz), 128.2, 128.0 (d, $J_{C\text{-}F}$ = 3.0 Hz), 127.2, 125.9, 124.2 (d, $J_{C\text{-}F}$ = 3.0 Hz), 121.0, 115.2 (d, $J_{C\text{-}F}$ = 21.0 Hz), 69.7, 61.1, 53.1, 16.2, 14.1; ESI-HRMS calcd. for $C_{20}H_{21}FNaO_3$ ([M+Na]$^+$) 351.1372, found 351.1378.

*Ethyl (E)-2-(hydroxy(phenyl)methyl)-4-phenylpent-3-enoate (**3ha**):*

*(±)-syn-**3ha**:* Yield: 25% (77.4 mg, 0.25 mmol). Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 – 7.20 (m, 10H), 5.96 (d, J = 9.6 Hz, 1H), 5.15 (d, J = 4.4 Hz, 1H), 4.10 (dt, J = 6.8, 1.2 Hz, 2H), 3.71 (ddd, J = 10.0, 5.2, 1.2 Hz, 1H), 3.11 (s, 1H), 1.81 (s, 3H), 1.16 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.1, 143.0, 140.9, 140.8, 128.2, 128.1, 127.7, 127.3, 126.4, 125.9, 120.7, 74.7, 61.0, 53.4, 16.3, 14.0; ESI-HRMS calcd. for $C_{20}H_{22}NaO_3$ ([M+Na]$^+$) 333.1467, found 333.1465.

*(±)-anti-**3ha**:* Yield: 29% (89.9 mg, 0.29 mmol). Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (d, J = 7.2 Hz, 2H), 7.31 (t, J = 7.2 Hz, 2H), 7.26 (d, J = 6.0 Hz, 3H), 7.21 (t, J = 7.6 Hz, 3H), 5.67 (d, J = 10.0 Hz, 1H), 4.99 (d, J = 8.4 Hz, 1H), 4.21 (q, J = 7.2 Hz, 2H), 3.76 (t, J = 9.6 Hz, 1H), 2.98 (s, 1H), 1.71 (s, 3H), 1.27 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.4, 143.1, 141.4, 140.0, 128.2, 128.1, 127.9, 127.2, 126.6, 125.9, 121.5, 75.6, 61.1, 54.0, 16.2, 14.2. ESI-HRMS calcd. for $C_{20}H_{22}NaO_3$ ([M+Na]$^+$) 333.1467, found 333.1464.

Preparation for tetrahydrofuran

*(±)-**4**:* A mixture of (±)-*anti*-**3ap** (310.3 mg, 1.25 mmol) and NBS (445 mg, 2.5 mmol) in DCM (13 mL) was stirred at rt under argon for 4 hours. The reaction mixture was concentrated *in vacuo* and the resulting residue was purified by column chromatography [silica gel, EtOAc/PE 1:10] to give the expected (±)-**4** (376 mg, 1.15 mmol), Yield: 92% (dr = 1:10). Major isomer: ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.46 (d, J = 7.8 Hz, 2H), 7.38 (t, J = 7.2 Hz, 2H), 7.34 (t, J = 7.2 Hz, 1H), 4.98 (d, J = 8.4 Hz, 1H), 4.35 (dt, J = 9.0, 1.8 Hz, 1H), 4.29 (m, 1H), 4.23 (q, J = 7.2 Hz, 2H), 3.22 – 3.17 (dt, J = 9.0,7.2 Hz, 1H), 1.80 (m, 1H), 1.30 (t, J = 7.2 Hz, 3H), 1.04 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.5, 137.9, 128.5, 126.5, 86.3, 82.7, 61.5, 59.7, 53.7, 52.5, 28.4, 14.1, 9.6; ESI-HRMS calcd. for $C_{15}H_{19}BrNaO_3$ ([M+Na]$^+$) 349.0415, found 349.0411.

Preparation for 2,5-dihydrofuran

*(±)-**5**:* A mixture of (±)-**4** (167 mg, 0.51 mmol) and DBU (77 μL, 0.51 mmol) in DCM (13 mL) was stirred at rt under argon atmosphere for 4 h. The reaction mixture was concentrated *in vacuo* and the resulting residue was purified by column chromatography [silica gel, EtOAc/PE 1:50] to give the expected ethyl *cis*-2-ethyl-5-phenyl-2,5-dihydrofuran-3-carboxylate (±)-**5** (108 mg, 0.44 mmol), Yield: 86%. Colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.33 (m, 5H), 6.78 (t, J = 1.8 Hz, 1H), 5.90 (dd, J = 6.0, 1.5 Hz, 1H), 5.35 – 5.22 (m, 1H), 4.22 (qd, J = 7.2, 1.8 Hz, 2H), 2.06–1.68 (m, 2H), 1.29 (t, J = 7.2 Hz, 3H), 1.00 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 162.9, 141.2, 140.5, 135.0, 128.7, 128.2, 126.4, 87.0, 86.4, 60.6, 27.4, 14.1, 9.0; ESI-HRMS calcd. for $C_{15}H_{18}O_3Na$ ([M+Na]$^+$) 269.1154, found 269.1148.

Preparation for 2,3-dihydrofuran

*(±)-**6**:*

Method A: A mixture of (±)-**4** (167 mg, 0.51 mmol), DBU (77 μL, 0.51 mmol) and H_2O (18.4 μL, 1.02 mmol) in DCM (13 mL) was stirred at reflux for 8 h. The reaction mixture was concentrated and the resulting residue was purified by column chromatography [silica gel, EtOAc/PE 1:50] to give the expected ethyl *trans*-2-ethyl-5-phenyl-2,3-dihydrofuran-3-carboxylate (±)-**6** (103 mg, 0.42 mmol), Yield: 82%.

Method B: A mixture of (±)-**5** (126 mg, 0.51 mmol), DBU (77 μL, 0.51 mmol) and H_2O (18.4 μL, 1.02 mmol) in DCM (13 mL) was stirred at reflux for 8 h. The reaction mixture was concentrated and the resulting residue was purified by column chromatography [silica gel, EtOAc/PE 1:50] to give the expected ethyl *trans*-2-ethyl-5-phenyl-2,3-dihydrofuran -3-carboxylate (±)-**6** (112 mg, 0.46 mmol), Yield: 89%.

Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (d, J = 6.8 Hz, 2H), 7.32 (d, J = 7.6 Hz, 3H), 5.33 (s, 1H), 4.93 (q, J = 12.5, 6.0 Hz, 1H), 4.19 (q, J = 6.8 Hz, 2H), 3.59 (d, J = 6.4 Hz, 1H), 169-1.86 (m, 2H), 1.28 (t, J = 7.2 Hz, 3H), 1.05 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.6, 137.9, 128.6, 128.5, 126.52 86.4, 82.8, 61.5, 59.7, 52.6, 28.4, 14.2, 9.6; ESI-HRMS calcd. for $C_{15}H_{19}O_3$ ([M+H]$^+$) 247.1329, found 247.1332.

Preparation for furan

*(±)-**7**:*

Method A: To a solution of (±)-**5** (123 mmol, 0.5 mmol) in toluene (1 mL) was added a solution of DDQ (136.2 mg, 0.6 mmol) in toluene (1 mL) dropwisely, and the mixture was stirred at reflux for 2 h. Upon completion as indicated by TLC, the mixture was poured into H_2O (5 mL), and separated. The aqueous layer was extracted with ethyl acetate (2 × 10 mL), and the combined organic layers were washed with brine (1 × 5 mL), then dried ($MgSO_4$) and filtered. The filtrate was concentrated *in vacuo* and the resulting residue was purified by flash column chromatography [silica gel, EtOAc/PE 1:50] to give the expected ethyl 2-ethyl-5-phenylfuran-3-carboxylate **7** (116 mg, 0.48 mmol), Yield: 95%.

Method B: To a solution of (±)-**6** (123 mmol, 0.5 mmol) in toluene (1 mL) was added a solution of DDQ (136.2 mg, 0.6 mmol) in toluene (1 mL) dropwisely, and the mixture was stirred at reflux for 2 h. Upon completion as indicated by TLC, the mixture was poured into H_2O (5 mL), and separated. The aqueous layer was extracted with ethyl acetate (2 × 10 mL), and the combined organic layers were washed with brine (1 × 5 mL), then dried ($MgSO_4$) and filtered. The filtrate was concentrated *in vacuo* and the resulting residue was purified by flash column chromatography [silica gel, EtOAc/PE 1:50] to give the expected ethyl 2-ethyl-5-phenylfuran-3-carboxylate **7** (112 mg, 0.46 mmol), Yield: 92%.

Colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.56 (d, J = 7.8 Hz, 2H), 7.29 (t, J = 7.8 Hz, 2H), 7.18 (t, J = 7.8 Hz, 1H), 6.80 (s, 1H), 4.23 (q, J = 7.2 Hz, 2H), 3.00 (q, J = 7.2 Hz, 2H), 1.29 (t, J = 7.2 Hz, 3H), 1.24 (t, J = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 163.9, 163.4, 151.6, 130.2, 128.7, 127.6, 123.6, 114.5, 105.5, 60.1, 21.3, 14.3, 12.3; ESI-HRMS calcd. for $C_{15}H_{16}NaO_3$ ([M+Na]$^+$) 267.0997, found 267.0994.

ASSOCIATED CONTENT

Supporting Information

X-Ray crystallography data and NMR spectra. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

Any additional relevant notes should be placed here.

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