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TMSOTf-Promoted Addition of Alkynes to Aldehydes: A Novel Synthesis of Chroman-4-ones

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A novel synthetic method to prepare chalcones **2** and chroman-4-ones **3** by TMSOTf-promoted addition of alkynes **1** to various aldehydes has been developed. The ratios of chalcones **2**, chroman-4-ones **3** and hydrated products **4** varied depending upon the substituents R (*n*Bu, phenyl, H and TMS) on the alkynes **1**. We also describe the transformation of the chalcones **2** to the corresponding chroman-4-ones **3** under basic conditions.

Introduction

Flavanones with chroman-4-ones as structural scaffolds, obtained mainly from nature, have received considerable attention due to their favourable pharmacological properties, such as antioxidant, antitumour and antibacterial activities.[1] A number of strategies for the synthesis of flavanones have been reported.[2,3] In general, these involve the condensation of acetophenones and benzaldehydes followed by cyclization of the resulting chalcone derivatives.[4] Recently, new types of synthetic protocols, such as the Heck reaction,[5] benzoin condensation,[6] conjugate addition/decarboxylation[7] and halo-arylation,[8] have been utilized for the synthesis of substituted flavonoids. Our group has focused on the Prins-type cyclization reactions of various alkenes with aldehydes in the presence of Lewis acids.[9] During the course of this research we developed a new approach to the synthesis of tetrahydrofuran starting from but-3-yn-1-ol using this methodology.[10] In this case, the reaction between aldehyde and alcohol generates an oxocarbenium ion, which then undergoes cyclization to afford the desired tetrahydrofuran with great selectivity. Inspired by this result, we decided to apply this strategy to the synthesis of benzopyran derivatives by using alkynylphenol as a substrate. Unlike typical Prins-type cyclization reactions, we anticipated that the reaction would proceed by the electrophilic addition of alkynes to aldehydes to give the corresponding unsaturated ketone as a key intermediate. Only limited methods have been reported for such an addition reaction and these involve the use of expensive transition-metal catalysts, such as $Yb(OTf)_3$, SbF_5, $In(OTf)_3$ and $GaCl_3$, to activate aldehyde carbonyl groups and thereby the development of a convenient procedure for this type of reaction still remains a challenge.[11]

In this paper we report a novel method for the synthesis of chroman-4-ones from 2-ethynylphenol derivatives by an electrophilic addition reaction promoted by TMSOTf.

Results and Discussion

2-Ethynylphenol derivatives **1** were easily prepared from the Sonogashira coupling reaction of 2-iodophenol and alkynes.[12] Initially, we investigated the addition reaction of 2-(hex-1-ynyl)phenol (**1a**) to benzaldehyde under different reaction conditions (Table 1). With regard to the Lewis acids (TMSOTf, $SnCl_4$, TFA and InX_3), the reaction in the presence of TMSOTf gave chalcone **2a** and flavanone **3a** in good yields (entries 1–4). The use of 2.0 equiv. of TMSOTf in Et_2O increased the yield of **2a** to 99% (entry 2). It seems that a longer reaction time or a larger quantity of TMSOTf is not crucial to the result of this reaction. Interestingly, a mixture of **2a** and **3a** was generated under these conditions, which suggests that TMSOTf may promote the cyclization to afford the chromanone **3a** (entries 3 and 4). In addition, when we performed the reaction in CH_2Cl_2, we only obtained compound **2a** in 28% yield (entry 5).

Next, we tried the addition reaction of 2-(hex-1-ynyl)phenol (**1a**) to various aldehydes under the optimized reaction conditions. The results are summarized in Table 2. In most cases, the reaction of **1a** with aldehydes proceeded smoothly to afford the corresponding chalcones **2a** as the

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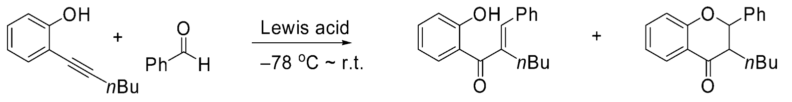
Table 1. Optimization of the electrophilic addition reaction.



1a **2a** **3a**

Entry	Solvent	Lewis acid (equiv.)	Time [h]	Yield [%][a]	
				2a	**3a**
1	Et$_2$O	TMSOTf (1.0)	30	89	–
2	Et$_2$O	TMSOTf (2.0)	22	>99	–
3	Et$_2$O	TMSOTf (2.0)	47	39	49
4	Et$_2$O	TMSOTf (3.0)	16	64	33
5	CH$_2$Cl$_2$	TMSOTf (2.0)	15	28	–
6	Et$_2$O	SnCl$_4$ (2.0)	22	36	–
7	Et$_2$O	TFA (2.0)	22	n.r.[b]	–
8	Et$_2$O	InX$_3$ (2.0)[c]	22	n.r.[b]	–

[a] Isolated yield. [b] No reaction. [c] X = Cl, Br.

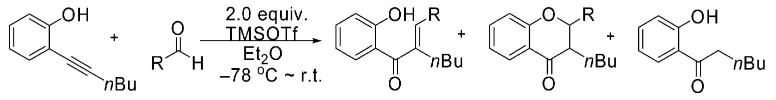
major products in high yields. In entries 1 and 7, chroman-4-one derivatives **3a** were observed as minor products. In addition to chalcones **2a**, ketones **4a**, generated from the hydration of **1a**, were also isolated in 20 and 37% yields (entries 2 and 6).

When we used 2-(phenylethynyl)phenol (**1b**) as the substrate, the results differed significantly from those of previous reactions in that the major products were chromanones **3b**, depending on the aldehydes used in the reactions (Table 3). Although the hydrated product **4b** was the major one when R was an ethyl group (entry 1), chalcones **2b** were obtained as the major products in good yields when R was isopropyl or cyclohexyl. However, with aromatic aldehydes we could obtain the chroman-4-ones **3b** (with *syn* only or *syn* dominant) as the major products except in the case of entry 6. Presumably, the nitro group on the aromatic ring renders the resulting unsaturated ketone a poor Michael acceptor.

We then turned our attention to the reaction of **1c** either having no substituent (R^1 = H) or a trimethylsilyl group (R^1 = TMS) on the terminal position of the alkyne (Table 4). In entries 1 and 5, chroman-4-ones **3c** were obtained as the major products in 64 and 45% yields, respectively. Only the hydrated product **4c** was obtained in 27% yield in entry 8. In general, the addition reactions of alkynes **1c** to aldehydes gave mixtures of chalcones **2c** and chroman-4-ones **3c** in moderate yields, except for entries 2 and 8. We believe that the low yields of **2c** and **3c** in entry 2 is a result of the steric hindrance of the large trimethylsilyl group.

Further transformation of the previously obtained 2′-hydroxychalcones **2** to chromanones **3** was executed by the known procedure.[3] The results are demonstrated in Table 5. In all cases, the chalcones **2** were treated with KOH in MeOH to generate the corresponding chroman-4-ones **3** in high yields although the *syn*/*anti* selectivity was relatively low.

Table 2. Addition of alkyne **1a** to various aldehydes.

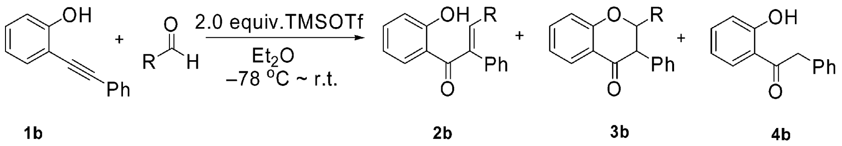


1a **2a** **3a** **4a**

Entry	R	Time [h]	Yield [%][a]		
			2a	**3a**	**4a**
1	ethyl	20	69	6 (*syn* only)	–
2	isopropyl	14	74	–	20
3	cyclohexyl	16	92	–	–
4	phenyl	22	>99	–	–
5	4-chlorophenyl	12	88	trace	–
6	4-nitrophenyl	14	61	–	37
7	4-tolyl	12	81	8 (*syn* only)	–
8	2-naphthyl	14	94	–	–

[a] Isolated yield.

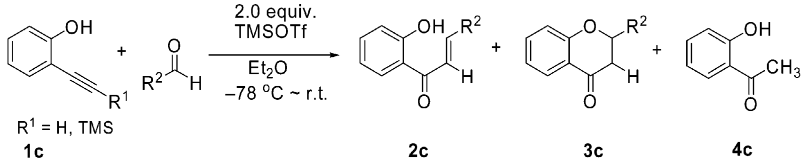
Table 3. Addition of alkyne **1b** to various aldehydes.



Entry	R	Time [h]	Yield [%)][a]		
			2b	**3b** (*syn*/*anti*)	**4b**
1	ethyl	6 d	6	–	60
2	isopropyl	65	53	–	33
3	cyclohexyl	29	68	12 (60:40)	11
4	phenyl	5	16	79 (*syn* only)	–
5	4-chlorophenyl	5	10	86 (*syn* only)	–
6	4-nitrophenyl	4 d	63	–	–
7	4-tolyl	12	38	61 (98:2)	–
8	2-naphthyl	6	29	44 (69:31)	–

[a] Isolated yield.

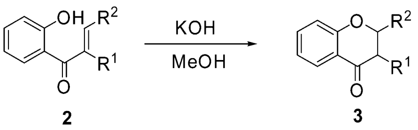
Table 4. Addition of alkyne **1c** to various aldehydes.



Entry	R^1	R^2	Time [h]	Yield [%][a]		
				2c	**3c**	**4c**
1	TMS	cyclohexyl	19	20	64	–
2	TMS	2-naphthyl	4	12	15	–
3	H	ethyl	3.5	15	37	–
4	H	isopropyl	4.5	15	52	–
5	H	cyclohexyl	4	14	45	5
6	H	phenyl	4	16	58	–
7	H	4-chlorophenyl	2.5	55	21	–
8	H	4-nitrophenyl	4	–	–	27
9	H	2-naphthyl	3	58	–	11

[a] Isolated yield.

Table 5. Cyclization of 2′-hydroxychalcone **2**.

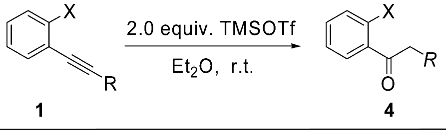


Entry	R^1	R^2	Time	Yield [%] [a](*syn*/*anti*)
1	H	phenyl	3 d	88
2	*n*Bu	phenyl	3 d	83 (64:36)
3	*n*Bu	cyclohexyl	2.5 h	95 (35:65)
4	*n*Bu	*n*-pentyl	2.0 h	99 (13:87)
5	Ph	cyclohexyl	1.5 h	75 (70:30)
6	Ph	4-nitrophenyl	2.0 h	80 (66:34)

[a] Isolated yield.

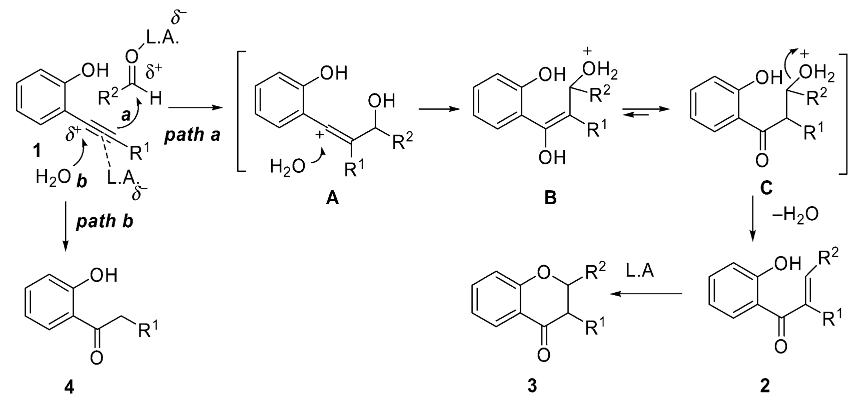
Although the conversion of alkynes to the corresponding ketones by Lewis acids is well documented,[13] we tested the hydration of alkynes under the same reaction conditions in the absence of an aldehyde to extend our method to an access to ketones from alkynes (Table 6). Whereas alkynes **1** with no phenolic hydroxy groups showed very low yields (entries 1 and 2), substrates containing a hydroxy group at

Table 6. Hydration of alkyne **1**.



Entry	X	R	Time [h]	Yield [%][a]
1	H	$–CH_2CH_2OH$	31	21
2	H	$–CH_2CH(CH_3)OH$	180	23
3	OH	TMS	23	62[b]
4	OH	H	4.5	46[b]
5	OH	*n*Bu	22	94
6	OMe	*n*Bu	90	51
7	OH	Phenyl	57	39

[a] Isolated yield. [b] Paraformaldehyde (1.2 equiv.) was added; R = H.

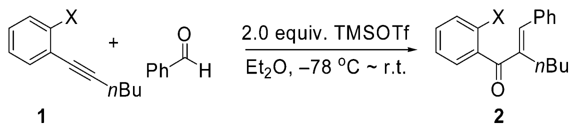


Scheme 1. Proposed mechanism for the addition reaction.

the *ortho* position led to yields as high as 94% (entries 3–5). In some cases, a longer reaction time was required to complete the reaction (entries 2 and 7).

In order to explore the effects of water and a hydroxy group in the alkyne on the addition reaction, we performed the addition of alkynes **1** to benzaldehyde in the presence of 4 Å MS under the same reaction conditions. The results are shown in Table 7. When molecular sieves (4 Å) were added to the reaction mixture, no reaction occurred (entry 2). However, the reaction of alkyne **1** containing a hydroxy group at the *ortho* position proceeded to give the resulting unsaturated ketone **2** in excellent yield regardless of the presence of molecular sieves (entries 3 and 4). From these experiments we can conclude that the presence of a hydroxy group as well as water in the reaction could play a critical role in the electrophilic addition of alkynes to aldehydes to form the coupled products.[14]

Table 7. Addition of alkynes **1c** to benzaldehyde in the presence of 4-Å molecular sieves (MS).



Entry	X	Time	Yield [%][a]	Additives
1	H	22 h	55	–
2	H	13 d	n.r.[b]	MS, 4 Å
3	OH	21 h	>99	–
4	OH	21 h	91	MS, 4 Å

[a] Isolated yield. [b] No reaction.

According to the above results, we propose the mechanism shown in Scheme 1. At first, the activated aldehyde catalyzed by TMSOTf reacts with the alkyne nucleophile to generate an unstable vinyl carbocation A (path a). This is rapidly attacked by water to give the 2′-hydroxychalcone **2** by tautomerization (B and C) and dehydration. On the other hand, the formation of the hydrated ketone **4** is explained by a different pathway, that is, the addition of water to the alkyne group activated by TMSOTf (path b).

Conclusions

A novel synthetic method for the synthesis of chalcones **2** and chroman-4-ones **3** by TMSOTf-promoted addition of alkynes to aldehydes has been developed. The formation of chalcones **2**, chroman-4-ones **3** and hydrated products **4** depends upon the substituent (R = *n*-butyl, phenyl, H and TMS) on the alkyne **1**. We obtained chalcones **2a** as the major products in high yields from alkyne **1a** having an *n*-butyl at the terminal position, but the reactions of **1b** and **1c** afforded chroman-4-ones **2b** and **2c** as the major products in low-to-high yields. Finally, we successfully converted the chalcones **2** obtained to the corresponding chroman-4-ones **3** in high yields under basic conditions. Currently, further application of this strategy to the synthesis of natural products having the chroman-4-one core structure is in progress and will be reported in due course.

Experimental Section

General Remarks: All reactions were conducted by using oven-dried glassware under nitrogen (N_2). All commercially available reagents were purchased and used without further purification. Solvents Et_2O, CH_2Cl_2, and MeOH were dried and distilled according to usual protocols. Reactions were monitored by TLC analysis on silica gel plates with fluorescent indicator (60F-254) using a UV lamp and a $KMnO_4$ solution with heat as visualizing agents. Flash chromatography was carried out on silica gel (60, particle size 0.040–0.063 mm). The ^1H NMR spectra were measured with 400 MHz and the ^{13}C NMR spectra were measured with 100 MHz using $CDCl_3$. ^1H NMR chemical shifts are expressed in ppm (δ) downfield to $CHCl_3$ (δ = 7.26 ppm), ^{13}C NMR chemical shifts are expressed in ppm (δ) relative to the central $CDCl_3$ resonance (δ = 77.0 ppm). Coupling constants in the ^1H NMR spectra are in Hz. The following abbreviations are used to designate multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, quint = quintet, m = multiplet, br. = broad. High-resolution mass spectra (HRMS) were obtained by using the positive electrospray ionization and *m*/*z* values are reported in atomic mass units.

Representative Procedure for the Addition Reaction. (*E*)-2-Benzylidene-1-(2-hydroxyphenyl)hexan-1-one (2a, entry 4 in Table 2): TMSOTf (0.17 mL, 0.96 mmol) was added to a solution of 2-(hex-1-ynyl)phenol (**1a**) (84 mg, 0.48 mmol) and benzaldehyde (59 µL, 0.57 mmol) in freshly distilled diethyl ether (10 mL) under nitrogen at –78 °C. After the reaction mixture had been stirred at –78 °C for 3 h, it was warmed slowly to room temperature and stirred for 22 h until the reaction was complete (monitored by TLC). The solution was quenched with water (20 mL) and extracted with EtOAc (3 × 10 mL). The organic layer was washed with brine, dried with $MgSO_4$, filtered and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel (hexane/EtOAc = 20:1) to produce the unsaturated ketone **2a** (135 mg, >99%) as a colourless oil. ^1H NMR ($CDCl_3$, 400 MHz): δ = 12.00 (s, 1 H), 7.80 (dd, J = 8.0, 1.6 Hz, 1 H), 7.50–7.35 (m, 6 H), 7.06–6.89 (m, 2 H), 6.86 (s, 1 H), 2.75 (t, J = 7.8 Hz, 2 H), 1.54–1.36 (m, 4 H), 0.89 (t, J = 4.9 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 204.4, 163.2, 141.0, 137.1, 136.2, 135.4, 132.9, 129.1, 128.6, 128.3, 119.5, 118.6, 118.4, 30.8, 28.5, 22.9, 13.9 ppm. HRMS (EI): calcd. for $C_{19}H_{20}O_2$ $[M]^+$ 280.1463; found 280.1463.

(*E*)-1-(2-Hydroxyphenyl)-2-propylidenehexan-1-one (2a): Entry 1 in Table 2. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2a** (68 mg, 69%) as a light-yellow oil. ^1H NMR ($CDCl_3$, 400 MHz): δ = 12.03 (s, 1 H), 7.67–7.65 (m, 1 H), 7.44–7.40 (m, 1 H), 6.98–6.84 (m, 1 H), 6.88–6.84 (m, 1 H), 5.94 (m, 1 H), 2.47–2.45 (m, 2 H), 2.31–2.27 (m, 2 H), 1.38–1.34 (m, 4 H), 1.04 (t, J = 7.3 Hz, 3 H), 0.89 (t, J = 6.9 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 204.1, 162.9, 140.8, 135.7, 135.7, 132.8, 119.5, 118.3, 118.2, 30.7, 27.2, 22.8, 14.1, 14.0 ppm. HRMS (EI): calcd. for $C_{15}H_{20}O_2$ $[M]^+$ 232.1463, found 242.1461.

(*E*)-1-(2-Hydroxyphenyl)-2-(2-methylpropylidene)hexan-1-one (2a) and 1-(2-Hydroxyphenyl)hexan-1-one (4): Entry 2 in Table 2. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided **2a** (84 mg, 74%) as a light-yellow oil and **4a** (18 mg, 20%) also as a light-yellow oil. **2a:** ^1H NMR ($CDCl_3$, 400 MHz): δ = 11.99 (s, 1 H), 7.65 (d, J = 3.9 Hz, 1 H), 7.43–7.39 (m, 1 H), 6.98–6.93 (m, 1 H), 6.85–6.82 (m, 1 H), 5.75 (d, J = 4.9 Hz, 1 H), 2.94 (m, 1 H), 2.48 (t, J = 7.1 Hz, 2 H), 1.40–1.33 (m, 4 H), 1.06 (d, J = 6.6 Hz, 6 H), 0.89 (t, J = 6.4 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 207.0, 162.5, 136.2, 130.0, 119.3, 118.8, 118.5, 38.3, 31.5, 28.8, 24.2, 22.5, 14.0 ppm. HRMS (EI): calcd. for $C_{16}H_{22}O_2$ $[M]^+$ 246.1620, found 246.1621.

4a: ^1H NMR ($CDCl_3$, 400 MHz): δ = 12.41 (s, 1 H), 7.79–7.74 (m, 1 H), 7.47–7.43 (m, 1 H), 6.97 (d, J = 8.4 Hz, 1 H), 6.90–6.82 (m, 1 H), 2.97 (t, J = 7.4 Hz, 2 H), 1.78–1.70 (m, 2 H), 1.39–1.36 (m, 4 H), 0.92 (t, J = 6.7 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 206.9, 162.5, 136.1, 130.0, 119.3, 118.8, 118.5, 38.2, 31.4, 24.2, 22.5, 13.9 ppm.

(*E*)-2-(Cyclohexylmethylene)-1-(2-hydroxyphenyl)hexan-1-one (2a): Entry 3 in Table 2. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2a** (119 mg, 92%) as a light-yellow oil. ^1H NMR ($CDCl_3$, 400 MHz): δ = 11.99 (s, 1 H), 7.65 (dd, J = 8.0, 1.6 Hz, 1 H), 7.44 (t, J = 1.2 Hz, 1 H), 7.00–6.97 (m, 1 H), 6.86–6.82 (m, 1 H), 5.78 (d, J = 9.7 Hz, 1 H), 2.51–2.47 (m, 2 H), 1.75–1.73 (m, 5 H), 1.38–1.12 (m, 10 H), 0.90 (t, J = 7.1 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 204.4, 163.0, 146.5, 137.5, 135.7, 132.8, 119.6, 118.5, 118.2, 37.8, 32.9, 31.4, 27.6, 25.8, 25.6, 22.8, 13.9 ppm. HRMS (CI): calcd. for $C_{19}H_{27}O_2$ $[M + H]^+$ 287.2011, found 287.2011.

(*E*)-2-(4-Chlorobenzylidene)-1-(2-hydroxyphenyl)hexan-1-one (2a): Entry 5 in Table 2. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2a** (260 mg, 88%) as a light-yellow oil. ^1H NMR ($CDCl_3$, 400 MHz): δ = 11.94 (s, 1 H), 7.77 (dd, J = 7.9, 1.6 Hz, 1 H), 7.51–7.30 (m, 5 H), 7.26–6.90 (m, 2 H), 6.78 (s, 1 H), 2.70 (t, J = 7.8 Hz, 2 H), 1.52–1.34 (m, 4 H), 0.89 (t, J = 7.2 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 204.1, 163.2, 141.6, 136.3, 135.4, 134.2, 133.8, 132.7, 130.3, 128.8, 119.3, 118.6, 118.4, 30.6, 28.5, 22.9, 13.8 ppm. HRMS (EI): calcd. for $C_{19}H_{19}O_2Cl$ $[M]^+$ 314.1073; found 314.1074.

(*E*)-1-(2-Hydroxyphenyl)-2-(4-nitrobenzylidene)hexan-1-one (2a): Entry 6 in Table 2. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2a** (95 mg, 61%) as a light-yellow solid along with **4a** (34 mg, 37%).

2a: ^1H NMR ($CDCl_3$, 400 MHz): δ = 11.90 (s, 1 H), 8.25 (dd, J = 7.0, 1.7 Hz, 2 H), 7.78 (dd, J = 8.0, 1.6 Hz, 1 H), 7.53–7.50 (m, 3 H), 7.05–6.90 (m, 2 H), 6.82 (s, 1 H), 2.72–2.63 (m, 2 H), 1.52–1.33 (m, 4 H), 0.87 (t, J = 7.2 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 203.5, 163.3, 147.1, 144.2, 142.0, 136.7, 133.1, 132.6, 129.7, 123.8, 118.9, 118.8, 118.6, 30.5, 28.9, 22.8, 13.7 ppm. HRMS (EI): calcd. for $C_{19}H_{19}O_4N$ $[M]^+$ 325.1314; found 325.1314.

(*E*)-1-(2-Hydroxyphenyl)-2-(4-methylbenzylidene)hexan-1-one (2a) and 3-Butyl-2-(*p*-tolyl)chroman-4-one (3a): Entry 7 in Table 2. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2a** (209 mg, 81%) as a light-yellow oil and **3a** (17 mg, 8%) also as a yellow oil.

2a: ^1H NMR ($CDCl_3$, 400 MHz): δ = 12.00 (s, 1 H), 7.79 (dd, J = 8.0, 1.6 Hz, 1 H), 7.50 (m, 1 H), 7.30–7.22 (m, 4 H), 7.05 (dd, J = 8.3, 1.0 Hz, 1 H), 6.89 (t, J = 0.8 Hz, 1 H), 6.84 (s, 1 H), 2.75 (t, J = 7.8 Hz, 2 H), 2.40 (s, 3 H), 1.55–1.36 (m, 4 H), 0.91 (t, J = 7.2 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 204.4, 163.1, 140.2, 138.5, 137.5, 136.0, 132.9, 132.5, 129.3, 129.1, 119.5, 118.5, 118.3, 30.7, 28.5, 22.9, 21.3, 13.8 ppm. HRMS (EI): calcd. for $C_{20}H_{22}O_2$ $[M]^+$ 294.1620; found 294.1621.

3a: ^1H NMR ($CDCl_3$, 400 MHz): δ = 7.89 (dd, J = 7.8, 1.5 Hz, 1 H), 7.46 (m, 1 H), 7.34–6.96 (m, 6 H), 5.29 (d, J = 10.1 Hz, 1 H), 3.01–2.99 (m, 1 H), 2.37 (s, 3 H), 1.59–1.20 (m, 6 H), 0.80 (t, J = 6.8 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 194.4, 160.7, 138.7, 135.8, 135.0, 129.4, 127.2, 127.1, 121.3, 120.8, 117.9, 83.1, 51.7, 50.7, 28.7, 25.9, 22.8, 21.2, 13.8 ppm. HRMS (EI): calcd. for $C_{20}H_{22}O_2$ $[M]^+$ 294.1620; found 294.1620.

(*E*)-1-(2-Hydroxyphenyl)-2-(naphthalen-2-ylmethylene)hexan-1-one (2a): Entry 8 in Table 2. Purification by column chromatography (silica gel; EtOAc/Hex = 1:20) provided compound **2a** (143 mg, 94%) as a light-yellow oil. ^1H NMR ($CDCl_3$, 400 MHz): δ = 12.21 (s, 1 H), 7.97–7.88 (m, 5 H), 7.58–7.53 (m, 4 H), 7.16 (d, J = 8.4 Hz, 1 H), 7.06 (s, 1 H), 6.98 (t, J = 7.5 Hz, 1 H), 2.98–2.90 (m, 2 H), 1.70–1.47 (m, 4 H), 1.00 (t, J = 7.3 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 204.4, 163.3, 141.3, 137.4, 136.2, 133.2, 132.9, 128.8, 128.3, 127.8, 126.8, 126.6, 126.3, 119.6, 118.7, 118.5, 30.4, 28.7, 23.0, 14.0 ppm. HRMS (EI): calcd. for $C_{23}H_{22}O_2$ $[M]^+$ 330.1620; found 330.1620.

1-(2-Hydroxyphenyl)-2-phenylethanone (4b): Entry 1 in Table 3. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **4b** (66 mg, 60%) as a light-yellow oil along with **2b** (5 mg, 6%).

4b: ^1H NMR ($CDCl_3$, 400 MHz): δ = 12.29 (s, 1 H), 7.78 (dd, J = 8.0, 1.6 Hz, 1 H), 7.49 (m, 1 H), 7.39–7.29 (m, 5 H), 7.02 (dd, J = 8.3, 0.9 Hz, 1 H), 6.93–6.92 (m, 1 H), 4.3 (s, 2 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 203.9, 162.9, 136.6, 133.9, 130.4, 129.5, 128.8, 127.6, 119.0, 117.9, 45.1 ppm.

(*E*)-1-(2-Hydroxyphenyl)-4-methyl-2-phenylpent-2-en-1-one (2b): Entry 2 in Table 3. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2b** (37 mg, 53%) as a light-yellow oil along with **4b** (18 mg, 33%).

2b: ^1H NMR ($CDCl_3$, 400 MHz): δ = 12.04 (s, 1 H), 7.74 (dd, J = 8.0, 1.6 Hz, 1 H), 7.46–7.30 (m, 6 H), 6.99 (d, J = 8.2 Hz, 1 H), 6.85 (t, 1 H), 6.02 (d, J = 10.3 Hz, 1 H), 2.75–2.69 (m, 1 H), 1.09 (d, J = 6.6 Hz, 6 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 202.4, 163.4, 147.4, 137.5, 136.1, 135.9, 133.0, 129.0, 128.5, 127.8, 119.3, 118.5, 118.3, 52.1, 28.4, 22.6 ppm. HRMS (EI): calcd. for $C_{18}H_{18}O_2$ $[M]^+$ 266.1307; found 266.1308.

(*E*)-3-Cyclohexyl-1-(2-hydroxyphenyl)-2-phenylprop-2-en-1-one (2b) and 2-Cyclohexyl-3-phenylchroman-4-one (3b): Entry 3 in Table 3. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2b** (112 mg, 68%), **3b-*syn*** (12 mg, 7%), **3b-*anti*** (8 mg, 5%) and **4b** (12 mg, 11%) as yellow oils.

2b: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 12.05 (s, 1 H), 7.74 (d, J = 8.0 Hz, 1 H), 7.40–7.30 (m, 6 H), 7.00 (dd, J = 8.3, 0.9 Hz, 1 H), 6.85 (t, 1 H), 6.06 (t, 1 H), 6.05 (d, J = 10.3 Hz, 1 H), 2.43–2.40 (m, 1 H), 1.77–1.61 (m, 5 H), 1.24–1.19 (m, 5 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 202.6, 163.4, 146.1, 137.8, 136.1, 136.0, 133.1, 129.0, 128.8, 128.5, 127.8, 125.8, 119.4, 118.5, 118.3, 38.0, 32.5, 25.7, 25.2 ppm. HRMS (EI): calcd. for $C_{21}H_{22}O_2$ $[M]^+$ 306.1620; found 306.1620.

3b-*syn*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 7.91–7.88 (m, 1 H), 7.54–7.01 (m, 8 H), 4.48 (dd, J = 9.8, 3.1 Hz, 1 H), 3.97 (d, J = 10.0 Hz, 1 H), 4.43 (m, 1 H), 1.75–1.15 (m, 10 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 192.7, 161.7, 136.0, 134.1, 131.6, 129.2, 128.9, 128.5, 128.1, 127.6, 121.1, 117.9, 85.7, 54.8, 38.9, 29.9, 28.0, 25.9, 25.4 ppm. HRMS (EI): calcd. for $C_{21}H_{22}O_2$ $[M]^+$ 306.1620; found 306.1620.

3b-*anti*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 7.91–7.88 (m, 1 H), 7.54–7.01 (m, 8 H), 4.30 (dd, J = 9.8, 3.1 Hz, 1 H), 3.80 (d, J = 3.2 Hz, 1 H), 4.43 (m, 1 H), 1.75–1.15 (m, 10 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 192.7, 161.7, 136.2, 134.1, 130.5, 129.0, 128.9, 128.5, 128.1, 127.5, 121.7, 117.9, 85.0, 54.1, 38.4, 29.5, 28.0, 26.3, 25.3 ppm. HRMS (EI): calcd. for $C_{21}H_{22}O_2$ $[M]^+$ 306.1620; found 306.1620.

(*E*)-1-(2-Hydroxyphenyl)-2,3-diphenylprop-2-en-1-one (2b) and 2,3-Diphenylchroman-4-one (3b): Entry 4 in Table 3. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2b** (26 mg, 16%) as a light-yellow solid and **3b** (123 mg, 79%) as a white solid.

2b: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 12.01 (s, 1 H), 7.86 (d, J = 8.0 Hz, 1 H), 7.49 (td, J = 7.7, 1.1 Hz, 1 H), 7.39–7.32 (m, 5 H), 7.27–7.21 (m, 3 H), 7.16–7.02 (m, 4 H), 6.86 (td, J = 7.6, 0.6 Hz, 1 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 202.4, 163.4, 139.5, 136.7, 136.4, 136.0, 134.5, 133.0, 130.0, 129.3, 129.0, 128.8, 128.3, 128.3, 119.2, 118.7, 118.4 ppm. HRMS (EI): calcd. for $C_{21}H_{16}O_2$ $[M]^+$ 300.1150; found 300.1152.

3b: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 8.01 (dd, J = 8.1, 1.7 Hz, 1 H), 7.74 (td, J = 8.5, 1.6 Hz, 1 H), 7.26–7.20 (m, 8 H), 7.12–7.08 (m, 2 H), 6.99 (dd, J = 7.4, 1.7 Hz, 2 H), 5.60 (d, J = 11.5 Hz, 1 H), 4.19 (d, J = 11.5 Hz, 1 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 192.6, 161.1, 137.7, 136.2, 134.8, 129.6, 128.5, 128.5, 128.3, 127.6, 127.4, 127.1, 121.7, 121.0, 118.1, 84.9, 59.6 ppm. HRMS (EI): calcd. for $C_{21}H_{16}O_2$ $[M]^+$ 300.1150; found 300.1153.

(*E*)-3-(4-Chlorophenyl)-1-(2-hydroxyphenyl)-2-phenylprop-2-en-1-one (2b) and 2-(4-Chlorophenyl)-3-phenylchroman-4-one (3b): Entry 5 in Table 3. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2b** (18 mg, 10%) as a yellow solid and **3b** (149 mg, 86%).

2b: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 11.96 (s, 1 H), 7.80 (d, J = 8.0 Hz, 1 H), 7.49–6.94 (m, 13 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 202.0, 163.5, 140.1, 136.5, 135.6, 134.9, 134.6, 133.0, 132.9, 131.2, 129.2, 129.1, 128.6, 128.5, 119.0, 118.7, 118.5 ppm. HRMS (EI): calcd. for $C_{21}H_{15}O_2Cl$ $[M]^+$ 334.0760; found 334.0760.

3b: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 8.01 (d, J = 7.8 Hz, 1 H), 7.55 (td, J = 8.2, 0.8 Hz, 1 H), 7.27–7.21 (m, 5 H), 7.16–7.07 (m, 4 H), 6.99–6.97 (m, 2 H), 5.55 (d, J = 11.7 Hz, 1 H), 4.12 (d, J = 11.7 Hz, 1 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 192.3, 160.9, 136.3, 134.5, 134.3, 129.7, 128.7, 128.5, 128.5, 127.7, 127.6, 121.9, 121.0, 118.0, 84.1, 59.7 ppm. HRMS (EI): calcd. for $C_{21}H_{15}O_2Cl$ $[M]^+$ 334.0760; found 334.0765.

(*E*)-1-(2-Hydroxyphenyl)-3-(4-nitrophenyl)-2-phenylprop-2-en-1-one (2b): Entry 6 in Table 3. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2b** (113 mg, 63%) as a light-yellow solid. ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 11.92 (s, 1 H), 8.05 (d, J = 10.0 Hz, 1 H), 7.79 (d, J = 8.0 Hz, 1 H), 7.49–6.87 (m, 12 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 201.5, 163.7, 147.2, 143.2, 141.4, 137.0, 134.8, 132.8, 132.3, 130.5, 129.3, 129.1, 129.0, 123.6, 119.0, 118.7 ppm. HRMS (EI): calcd. for $C_{21}H_{15}O_2Cl$ $[M]^+$ 345.1001; found 345.0996.

(*E*)-1-(2-Hydroxyphenyl)-2-phenyl-3-(*p*-tolyl)prop-2-en-1-one (2b) and 3-Phenyl-2-(*p*-tolyl)chroman-4-one (3b): Entry 7 in Table 3. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2b** (65 mg, 38%) as a white solid and a 98:2 mixture of **3b-*syn*** and **3b-*anti*** (105 mg, 61%).

2b: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 12.03 (s, 1 H), 7.87 (dd, J = 8.0, 1.6 Hz, 1 H), 7.49–6.87 (m, 13 H), 2.32 (s, 3 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 22.4, 163.4, 139.2, 138.6, 137.4, 136.4, 136.3, 133.0, 131.6, 130.1, 129.4, 129.1, 129.0, 127.2, 119.3, 118.7, 118.4, 21.3 ppm. HRMS (EI): calcd. for $C_{22}H_{18}O_2$ $[M]^+$ 314.1307; found 314.1302.

3b-*syn*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 8.07–8.05 (m, 1 H), 7.62–7.52 (m, 1 H), 7.22–7.07 (m, 10 H), 6.94 (d, J = 6.7 Hz, 1 H), 5.60 (d, J = 11.5 Hz, 1 H), 4.21 (d, J = 11.5 Hz, 1 H), 2.31 (s, 3 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 192.8, 161.2, 138.4, 136.3, 134.8, 133.8, 129.7, 129.1, 128.5, 127.7, 127.4, 127.1, 121.7, 121.0, 118.2, 84.7, 59.4, 21.2 ppm. HRMS (EI): calcd. for $C_{22}H_{18}O_2$ $[M]^+$ 314.1307; found 314.1309.

3b-*anti*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 8.07–8.05 (m, 1 H), 7.62–7.52 (m, 1 H), 7.22–7.07 (m, 10 H), 5.80 (d, J = 3.4 Hz, 1 H), 3.95 (d, J = 3.4 Hz, 1 H), 4.21 (d, J = 11.5 Hz, 1 H), 2.31 (s, 3 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 192.7, 161.8, 137.8, 136.5, 135.1, 133.3, 129.5, 128.9, 128.4, 128.0, 127.5, 126.1, 122.2, 121.0, 118.3, 82.4, 58.4, 21.2 ppm. HRMS (EI): calcd. for $C_{22}H_{18}O_2$ $[M]^+$ 314.1307; found 314.1309.

(*E*)-1-(2-Hydroxyphenyl)-3-(naphthalen-2-yl)-2-phenylprop-2-en-1-one (2b) and 2-(Naphthalen-2-yl)-3-phenylchroman-4-one (3b): Entry 8 in Table 3. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2b** (54 mg, 29%) as a light-yellow solid and a 69:31 mixture of **3b-*syn*** and **3b-*anti*** (80 mg, 44%) as solids.

2b: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 12.02 (s, 1 H), 8.12–6.85 (m, 17 H) ppm. HRMS (EI): calcd. for $C_{22}H_{18}O_2$ $[M]^+$ 350.1307; found 350.1305.

3b-*syn*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 8.07 (d, J = 8.1 Hz, 1 H), 7.79–6.96 (m, 15 H), 5.78 (d, J = 11.5 Hz, 1 H), 4.43 (d, J = 11.5 Hz, 1 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 192.6, 161.2, 136.3, 135.1, 134.9, 133.2, 132.9, 129.7, 128.6, 128.2, 128.1, 127.6, 126.4, 126.3, 124.4, 121.8, 118.2, 85.0, 59.4 ppm. HRMS (EI): calcd. for $C_{22}H_{18}O_2$ $[M]^+$ 350.1307; found 350.1306.

3b-*anti*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 8.07 (d, J = 8.1 Hz, 1 H), 7.79–6.96 (m, 15 H), 5.98 (d, J = 3.3 Hz, 1 H), 4.10 (d, J = 3.3 Hz, 1 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 192.6, 161.7, 136.5, 134.3, 133.2, 132.9, 129.4, 128.4, 128.3, 127.9, 127.7, 127.5, 126.2, 125.4, 123.8, 122.3, 121.1, 118.4, 82.5, 58.3 ppm. HRMS (EI): calcd. for $C_{22}H_{18}O_2$ $[M]^+$ 350.1307; found 350.1307.

2-Cyclohexylchroman-4-one (3c): Entry 1 in Table 4. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **3c** (78 mg, 64%) as a white solid along with **2c** (24 mg, 20%).

3c: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.85 (dd, J = 7.8, 1.4 Hz, 1 H) 7.46–7.42 (m, 1 H), 6.99–6.94 (m, 2 H), 4.20–4.16 (m, 1 H), 2.75–2.62 (m, 2 H), 2.01–1.97 (d, 1 H), 1.81–1.69 (m, 5 H), 1.28–1.13 (m, 5 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 193.1, 161.8, 135.8, 126.8, 121.0, 117.8, 81.9, 41.7, 40.2, 28.2, 28.1, 26.3, 25.9, 25.8 ppm.

(*E*)-1-(2-Hydroxyphenyl)-3-(naphthalen-2-yl)prop-2-en-1-one (2c) and 2-(Naphthalen-2-yl)chroman-4-one (3c): Entry 2 in Table 4. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2c** (18 mg, 12%) as a yellow solid and **3c** (22 mg, 15%) as a yellow oil.

2c: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 12.9 (s, 1 H), 8.09–8.04 (m, 2 H), 7.97 (d, J = 8.0 Hz, 1 H), 7.90–7.84 (m, 3 H), 7.81–7.73 (m, 2 H), 7.57–7.49 (m, 3 H), 7.06 (d, J = 8.3 Hz, 1 H), 6.97 (t, J = 7.5 Hz, 1 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 136.4, 134.5, 133.3, 132.0, 131.1, 129.7, 128.8, 128.7, 127.8, 127.6, 126.9, 123.6, 120.1, 120.1, 118.8, 118.6 ppm. HRMS (EI): calcd. for $C_{19}H_{14}O_2$ $[M]^+$ 274.0994; found 274.0996.

3c: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.99–7.08 (m, 11 H), 5.66 (dd, J = 13.2, 2.8 Hz, 1 H), 3.24–2.97 (m, 2 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 191.9, 161.5, 136.2, 136.0, 133.3, 133.1, 128.8, 128.1, 127.7, 127.1, 126.5, 125.4, 123.6, 121.7, 121.0, 118.2 ppm. HRMS (EI): calcd. for $C_{19}H_{14}O_2$ $[M]^+$ 274.0994; found 274.0994.

(*E*)-1-(2-Hydroxyphenyl)pent-2-en-1-one (2c) and 2-Ethylchroman-4-one (3c): Entry 3 in Table 4. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2c** (17 mg, 15%) as a light-yellow oil and **3c** (40 mg, 37%) as a light-yellow oil.

2c: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 12.74 (s, 1 H), 7.81 (d, J = 8.0 Hz, 1 H), 7.49–7.45 (m, 1 H), 7.28–6.98 (m, 3 H), 6.92–6.88 (m, 1 H), 2.38 (quint., J = 7.3 Hz, 2 H), 1.16 (t, J = 7.4 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 194.3, 163.5, 152.1, 136.2, 129.8, 122.9, 119.6, 118.7, 118.5, 26.0, 12.2 ppm. HRMS (EI): calcd. for $C_{11}H_{12}O_2$ $[M]^+$ 176.0837; found 176.0838.

3c: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.87–7.85 (dd, J = 7.8, 1.3 Hz, 1 H), 7.47–7.43 (m, 1 H), 7.00–6.95 (m, 2 H), 4.36 (m, 1 H), 2.67 (d, J = 7.7 Hz, 2 H), 1.92–1.73 (m, 2 H), 1.06 (t, J = 7.40 Hz, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 192.6, 161.6, 135.9, 126.9, 121.1, 120.9, 117.9, 79.0, 42.5, 27.9, 9.3 ppm. HRMS (EI): calcd. for $C_{11}H_{12}O_2$ $[M]^+$ 176.0837; found 176.0837.

(*E*)-1-(2-Hydroxyphenyl)-4-methylpent-2-en-1-one (2c) and 2-Isopropylchroman-4-one (3c): Entry 4 in Table 4. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2c** (21 mg, 15%) as a light-yellow oil and **3c** (69 mg, 52%) also as a light-yellow oil.

2c: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 12.74 (s, 1 H), 7.83–7.81 (m, 1 H), 7.47–7.45 (m, 1 H), 7.16–7.15 (m, 1 H), 7.01–6.89 (m, 3 H), 2.62–2.60 (m, 1 H), 1.13 (d, J = 9.5 Hz, 6 H) ppm.

3c: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.87–7.85 (m, 1 H), 7.48–7.43 (m, 1 H), 7.26–6.93 (m, 2 H), 4.20–4.16 (m, 1 H), 2.70–2.62 (m, 2 H), 2.07–2.02 (m, 1 H), 1.08–1.05 (m, 6 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 193.0, 161.9, 135.9, 126.8, 121.0, 120.9, 117.9, 82.5, 40.0, 32.1, 17.8 ppm. HRMS (EI): calcd. for $C_{12}H_{14}O_2$ $[M]^+$ 190.0994; found 190.0994.

(*E*)-1-(2-Hydroxyphenyl)-3-phenylprop-2-en-1-one (2c) and 2-Phenylchroman-4-one (3c): Entry 6 in Table 4. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2c** (29 mg, 16%) as a yellow solid and **3c** (102 mg, 58%) also as a light-yellow oil.

2c: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 12.84 (s, 1 H), 7.95–7.91 (m, 2 H), 7.68–7.64 (m, 3 H), 7.52–7.49 (m, 2 H), 7.45–7.43 (m, 2 H), 7.04 (dd, J = 8.3, 0.9 Hz, 1 H), 6.95 (td, J = 8.1, 1.0 Hz, 1 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 193.7, 163.6, 145.5, 136.4, 134.6, 130.9, 129.6, 129.0, 128.7, 128.3, 128.1, 120.1, 120.0, 118.8, 118.6 ppm. HRMS (CI): calcd. for $C_{15}H_{12}O_2$ $[M + H]^+$ 225.0915; found 225.0916.

3c: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.95 (dd, J = 8.0, 1.7 Hz, 1 H), 7.51–7.39 (m, 6 H), 7.07–7.04 (m, 2 H), 5.50–5.46 (d, 1 H), 3.14–2.87 (m, 2 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 191.9, 161.5, 138.7, 136.2, 128.8, 128.3, 127.0, 126.5, 126.2, 121.6, 120.9, 118.1, 79.6, 44.6 ppm. HRMS (EI): calcd. for $C_{15}H_{12}O_2$ $[M]^+$ 224.0837; found 224.0837.

(*E*)-3-(4-Chlorophenyl)-1-(2-hydroxyphenyl)prop-2-en-1-one (2c) and 2-(4-Chlorophenyl)chroman-4-one (3c): Entry 7 in Table 4. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **2c** (89 mg, 55%) as a yellow solid and **3c** (33 mg, 21%) also as a yellow solid.

2c: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 12.77 (s, 1 H), 7.90–7.81 (m, 2 H), 7.62–7.56 (m, 3 H), 7.51–7.47 (m, 1 H), 7.38 (d, J = 8.4 Hz, 2 H), 7.0 (d, J = 8.3 Hz, 1 H), 6.94 (td, J = 7.5, 0.8 Hz, 1 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 193.4, 163.6, 143.9, 136.8, 136.5, 133.0, 129.8, 129.6, 129.3, 120.5, 119.9, 118.9, 118.6 ppm. HRMS (CI): calcd. for $C_{15}H_{11}O_2Cl$ $[M + H]^+$ 259.0526; found 259.0526.

3c: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.91 (dd, J = 8.1, 1.6 Hz, 1 H), 7.50–7.39 (m, 5 H), 7.06–6.99 (m, 2 H), 5.46–5.42 (m, 1 H), 3.05–2.83 (m, 2 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 191.4, 161.3, 137.3, 136.5, 134.5, 128.8, 127.5, 121.8, 120.9, 118.1, 79.1, 44.5 ppm. HRMS (EI): calcd. for $C_{15}H_{11}O_2Cl$ $[M]^+$ 258.0448; found 258.0447.

1-(2-Hydroxyphenyl)ethanone (4c): Entry 8 in Table 4. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided compound **4c** (entry 8 in Table 4, 19 mg, 27%) as a light-yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 12.31 (s, 1 H), 7.73 (dd, J = 8.0, 1.3 Hz, 1 H), 7.49–7.44 (m, 1 H), 6.97 (d, J = 8.4 Hz, 1 H), 6.92–6.88 (m, 1 H), 2.63 (s, 3 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 204.5, 162.3, 136.4, 130.7, 119.7, 118.9, 118.4, 26.6 ppm.

General Procedure for the Cyclization of Chalcones: KOH was added at room temperature to a solution of chalcone in MeOH until pH 14. The reaction mixture was quenched with 1 N HCl and diluted with dichloromethane. The organic solution was washed with water and the organic layer was dried with $MgSO_4$, filtered and concentrated.

3-Butyl-2-phenylchroman-4-one (3a): Entry 2 in Table 5. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided **3a-*syn*** (12 mg, 53%) as a light-yellow solid and **3a-*anti*** (8 mg, 30%) as a light-yellow oil.

3a-*syn*: ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.91–6.98 (m, 9 H), 5.33 (d, J = 10.0 Hz, 1 H), 3.04–3.02 (m, 1 H), 1.61 (t, J = 5.6 Hz, 2 H), 1.26–0.79 (m, 7 H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 194.3, 160.7, 138.0, 135.9, 129.0, 128.8, 127.3, 127.2, 121.4, 120.8, 117.9, 83.3, 50.9, 28.7, 25.9, 22.8, 13.8 ppm.

3a-*anti*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 7.91–6.98 (m, 9 H), 5.62 (d, J = 1.7 Hz, 1 H), 2.67–2.65 (m, 1 H), 1.61 (t, J = 5.6 Hz, 2 H), 1.26–0.79 (m, 7 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 195.9, 160.9, 137.3, 135.8, 128.5, 127.9, 127.6, 125.6, 121.7, 119.7, 117.8, 81.4, 51.8, 28.8, 23.3, 22.4, 13.7 ppm.

3-Butyl-2-cyclohexylchroman-4-one (3a): Entry 3 in Table 5. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided **3a-*syn*** (31 mg, 33%) as a light-yellow solid and **3a-*anti*** (57 mg, 62%) as a light-yellow oil.

3a-*syn*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 7.83 (dd, J = 7.8, 1.7 Hz, 1 H), 7.45–7.43 (m, 1 H), 6.98–6.91 (m, 2 H), 4.11 (d, J = 3.0 Hz, 1 H), 2.65–2.64 (m, 1 H), 1.74–0.87 (m, 20 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 195.3, 159.6, 135.9, 126.9, 120.8, 120.4, 117.8, 85.0, 47.6, 38.3, 29.1, 28.9, 28.4, 26.2, 25.9, 25.7, 22.7, 13.9 ppm. HRMS (EI): calcd. for $C_{19}H_{26}O_2$ [M]$^+$ 286.1933; found 286.1932.

3a-*anti*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 7.84–6.82 (m, 1 H), 7.45–7.41 (m, 1 H), 6.97–6.90 (m, 2 H), 3.98 (d, J = 6.8 Hz, 1 H), 2.56 (m, 1 H), 1.83–0.85 (m, 20 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 196.4, 161.3, 135.6, 127.5, 121.1, 119.7, 117.4, 84.9, 47.1, 38.0, 30.0, 27.7, 26.3, 25.7, 25.5, 23.2, 13.9 ppm.

3-Butyl-2-pentylchroman-4-one (3a-*anti*): Entry 4 in Table 5. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided a 13:87 mixture of **3a-*syn*** and **3a-*anti*** (30 mg, 99%) as a light-yellow oil.

3a-*anti*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 7.87–7.84 (m, 1 H), 7.46 (m, 1 H), 7.00–6.92 (m, 2 H), 4.44–4.40 (m, 1 H), 2.47–2.45 (m, 1 H), 1.61–1.28 (m, 14 H), 0.89 (t, J = 8.3 Hz, 6 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 195.1, 159.6, 135.8, 127.0, 120.9, 117.9, 80.6, 50.4, 32.1, 31.5, 29.1, 28.9, 27.8, 25.0, 23.5, 22.7, 22.5, 14.0, 13.9 ppm. HRMS (EI): calcd. for $C_{18}H_{26}O_2$ [M]$^+$ 274.1933; found 274.1933.

2-(4-Nitrophenyl)-3-phenylchroman-4-one (3b): Entry 6 in Table 5. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided **3b-*syn*** (20 mg, 53%) as a light-yellow solid and **3b-*anti*** (10 mg, 27%) as a light-yellow oil.

3b-*syn*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 8.13–6.95 (m, 13 H), 5.67 (d, J = 11.9 Hz, 1 H), 4.10 (d, J = 11.9 Hz, 1 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 191.6, 160.7, 147.8, 144.8, 136.5, 133.9, 129.7, 128.9, 127.9, 126.8, 123.5, 118.0, 83.9, 59.9 ppm. HRMS (EI): calcd. for $C_{21}H_{15}NO_2$ [M]$^+$ 345.1001; found 345.0997.

3b-*anti*: ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 8.13–6.95 (m, 13 H), 5.92 (d, J = 3.4 Hz, 1 H), 3.97 (d, J = 3.5 Hz, 1 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 191.3, 160.9, 147.6, 144.1, 136.8, 132.4, 129.2, 128.7, 127.8, 126.4, 122.3, 118.2, 81.2, 58.0 ppm.

General Procedure for the Hydration of Alkynes: TMSOTf (2.0 equiv.) was added to a stirred solution of the alkyne in dry diethyl ether. The mixture was stirred at room temperature until the completion of the reaction. The reaction mixture was quenched with H_2O and diluted with diethyl ether. The organic solution was washed with water and brine, and the organic layer was dried with $MgSO_4$, filtered and concentrated. Purification by column chromatography provided the products.

4-Hydroxy-1-phenylbutan-1-one (4): Entry 1 in Table 6. Purification by column chromatography (silica gel, EtOAc/Hex = 1:2) provided the ketone **4** (51 mg, 21%) as a light-yellow oil. ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 7.99–7.27 (m, 5 H), 3.75 (t, J = 6.0 Hz, 2 H), 3.14 (t, J = 6.9 Hz, 2 H), 2.03 (quint., J = 6.6 Hz, 2 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 200.5, 136.8, 133.1, 128.6, 128.1, 127.6, 126.0, 62.3, 35.3, 26.8 ppm.

4-Hydroxy-1-phenylpentan-1-one (4): Entry 2 in Table 6. Purification by column chromatography (silica gel, EtOAc/Hex = 1:5) provided the ketone **4** (15 mg, 23%) as a light-yellow oil. ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 7.99–7.97 (d, J = 8.5 Hz, 2 H), 7.57–7.48 (m, 1 H), 7.46–7.44 (m, 2 H), 3.40–3.35 (m, 1 H), 3.10–3.05 (m, 2 H), 1.94–1.85 (m, 2 H), 1.63 (s, 1 H), 1.16 (d, J = 6.2 Hz, 3 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 200.4, 132.9, 128.5, 128.0, 74.1, 63.6, 34.3, 30.9, 19.8, 15.6 ppm.

1-(2-Methoxyphenyl)hexan-1-one (4): Entry 6 in Table 6. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided the ketone **4** (entry 6 in Table 6, 45 mg, 51%) as a light-yellow oil. ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 7.63 (dd, J = 7.6, 1.5 Hz, 1 H), 7.42 (td, J = 7.8, 1.6 Hz, 1 H), 7.02–6.93 (m, 2 H), 3.88 (s, 3 H), 2.94 (t, J = 7.4 Hz, 2 H), 1.70–1.63 (m, 2 H), 1.34–1.32 (m, 4 H), 0.89 (t, J = 6.4 Hz, 3 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 203.3, 158.3, 133.1, 130.1, 128.8, 120.6, 111.5, 55.4, 43.7, 31.6, 24.1, 22.5, 14.0 ppm.

(*E*)-2-Benzylidene-1-phenylhexan-1-one (2): Entry 1 in Table 7. TMSOTf (0.15 mL, 0.85 mmol) was added to a stirred solution of alkyne (67 mg, 0.43 mmol) and benzaldehyde (51 µL, 0.51 mmol) in dry diethyl ether (8 mL) at –78 °C. The mixture was warmed to room temperature slowly and stirred until completion of the reaction. The reaction mixture was quenched with H_2O and diluted with diethyl ether. The organic solution was washed with water and brine, and the organic layer was dried with $MgSO_4$, filtered and concentrated. Purification by column chromatography (silica gel, EtOAc/Hex = 1:20) provided the corresponding ketone **2** (35 mg, 55%) as a light-yellow oil. ^{1}H NMR (CDCl$_3$, 400 MHz): δ = 7.81–7.79 (m, 2 H), 7.58–7.54 (m, 1 H), 7.49–7.34 (m, 6 H), 7.06 (s, 1 H), 2.75 (t, J = 7.9 Hz, 2 H), 1.60–1.40 (m, 4 H), 0.93 (t, J = 7.3 Hz, 3 H) ppm. ^{13}C NMR (CDCl$_3$, 100 MHz): δ = 199.4, 142.4, 140.6, 138.7, 135.7, 131.9, 130.0, 129.2, 128.5, 128.4, 128.2, 30.9, 27.6, 23.0, 13.9 ppm.

Supporting Information (see also the footnote on the first page of this article): ^{1}H and ^{13}C NMR spectroscopic data of intermediates and products.

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[14] Although the reactions were carried out in freshly distilled diethyl ether, we were able to obtain the desired products in all cases. We assume that the water required for this reaction may come from moisture, glassware or the starting materials which might not have been completely dry.

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